1.1 Introduction

South Africa is a country with a low mean rainfall and as a result most of the natural vegetation is non-woody with a narrow broken belt of natural forest along the southern and eastern seabords. Following many years of investment and development, South Africa has become the third largest and oldest plantation resource in the Southern hemisphere. With a total area of over 1.5 million hectares consisting of both softwood and hardwood species the industry produces a range of products such as poles, sawn timber, wood chips, pulp and paper.

Forestry in South Africa follows the classic viewpoint of agriculture, ie choosing the desired crop species and growing it in an artificial man-made even-aged monoculture. The success of this approach is dependant on a number of factors such as markets (availability and distance); species selection (species site matching for maximum growth); improved sources of genetic material (seedlings or clones); site specific silviculture (site preparation, fertilisation, maintenance); managing risk (drought, disease, insects); harvesting (applying technologies) and sustainability (survivable ecological and economic system).

The introduction into South Africa of exotic forest tree species with much faster growth rates than indigenous species brought a major advantage to the timber industry and marked the first phase in domestication of forest species. Following several species introductions and trials conducted by various research organisations across the country over many years, our current commercial species fall into three main genera, *Eucalyptus*, *Acacia* and *Pinus*. From a whole suite of possibilities the list of species that have been commercialised through tree breeding programmes number less than 15.

1.1.1 Eucalypts

Many species of eucalpyt are fast growing and produce high value timber with particular qualities. Consequently forest product industries, particularly in the southern hemisphere have introduced and developed the technologies to support plantation forestry with eucalypts to serve as raw material for pulp, paper and solid wood markets. The origins of this industry go as far back as 1770 when Joseph Banks and Daniel Solander at Botany Bay made the first known collections of *E. gummifera*. In 1777 David Nelson, a member of Captain James Cook’s third expedition collected a specimen of *E. obliqua* at Bruny Island, southern Tasmania. It was from this collection that the French botanist Charles Louis L’Heritier de Brutelle described and illustrated a eucalyp for the first time.

*E. globulus* was the first of the eucalypts to become widely known outside Australia. The first account of introductions of *E. globulus* in the Cape Colony was in 1828. By 1865 in the report by the Colonial Botanist more than twenty one species of eucalypt had been
introduced into the Cape. In 1883 fourteen eucalypts were available from nurseries at Tokai and Worcester in the then Cape Colony for the purposes of fuel wood plantations. From 1881 the eucalypts spread rapidly from the Cape to other parts of the country with plantings recording impressive growth from the then Orange Free State, Natal, Transvaal and Lesotho. From the time of the Union in 1910 up to 1930 many species of eucalypt were tested in species trials. However, the information regarding seedlot origin, provenance and collection site details were inaccurate.5

Pioneers such as Fourcade and Hutchin recognised the importance of matching climatic conditions from different parts of the world with that of South Africa when using exotic species. ‘Climatic Fitness’, a term used by Hutchin, has a striking similarity with the view of Charles Darwin. This insight fits into the modern day framework of the genetic adaptation of species to different environmental conditions. Through time, species have evolved a genetic make-up, a *genotype* that would be suitable for planting on similar sites no matter how far apart.2 Since 1930 most seed was supplied by various state forestry departments and other organisations in Australia with the appropriate collection and site details well documented. This allowed for a more scientific approach to species testing in South Africa which laid a good foundation for tree breeding programmes in South Africa.5

In Australia, only about 60 eucalypts out of the full complement of species are classed as being economically important producers of timber, though many of the rest yield useful timber.3 Species trials have clearly identified the most important commercial eucalypts world wide, the bulk of which come from the subgenus *Symphomyrtus*6 (Table 1.1). Several species that were previously regarded as important have fallen into disfavour. This has been largely due to attack by pests and diseases or poor environmental adaptation, poor growth performance and poor wood properties.7 In South Africa this is particularly true of species that fall into the subgenus *Monocalyptus*. Species such as *E. fraxinoides*, *E. regnans*, *E. fastigata*, *E. oreades* and *E. elata* have poor survival in the summer rainfall regions due to attack by *Phythophthora*.8 The objectives of growing eucalypts have now polarised more definitely into growing short-rotation pulpwood for kraft9 and dissolving pulp. Some species are also suitable for longer-rotation management for solid wood.10

Eucalypt hybrids developed from the species listed in Table 1.1 have become a significant component of plantation forestry, particularly in the sub-tropics, tropics and to a lesser extent in the more temperate zones. Historically hybrid development has focused on F1 hybrids to capture heterosis. However, developing hybrids that combine complementary traits now appears to be of greater concern.5
Historically, *Eucalyptus grandis* has been the most important hardwood for the South African forestry industry. However, an increasing demand for hardwoods particularly for the pulp and paper industry, has led to the expansion of hardwoods into the colder sites where *E. grandis* does not survive. Typically cold tolerant eucalypts are suited to sites above 1200m asl, which are prone to frost and frequent snowfalls. The most common form of snow damage to trees is stem breakage, but trees can bend or be uprooted. Snow damaged plantations present a greater fire hazard and are prone to consequential damage through pest and/or disease attacks. Snow damage to trees is strongly dependent on the interaction of meteorological conditions, topography as well as species and stand characteristics. In the forestry areas in South Africa four major snow events have occurred in the past 30 years, on average a frequency of one event every 7.5 years. According to Gardner and Swain (1996) *E. grandis* and *Acacia mearnsii* are the most susceptible commercial hardwood species with *E. nitens* being the most resistant to snowfalls (Table 1.2).

Frost damage is equally severe in the Highveld of Mpumalanga and certain areas in KwaZulu Natal, especially in the valleys and drainage areas. Most frost damage occurs in winter, following planting, in the form of tip scorching and/or total scorching depending on the frequency and severity of the frost. Some species may be completely scorched and drop leaves but have the capacity to recover in the spring. This is typical of *E. macarthurii*, one of the most frost-tolerant species planted in South Africa. Table 1.3 refers to the relative frost-tolerance of certain commercial species.

Plantation forestry with eucalypts is sustainable and productivity can increase with effective risk management strategies such as species site matching, maintaining genetic diversity and reducing stress caused by negative impacts such as drought, frost, snow, pest and diseases.
### Chapter 1: Species Selection

<table>
<thead>
<tr>
<th>Species</th>
<th>Resistance rating</th>
<th>Percentage damage</th>
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<tbody>
<tr>
<td>E. nitens</td>
<td>Very tolerant</td>
<td>≤ 5</td>
</tr>
<tr>
<td>E. fraxinoides, E. fastigata</td>
<td>Tolerant</td>
<td>5 – 20</td>
</tr>
<tr>
<td>E. smithii, E. badjensis</td>
<td>Moderately Tolerant</td>
<td>20 – 35</td>
</tr>
<tr>
<td>E. macarthurii, E. benthamii, E. dunnii</td>
<td>Slightly Tolerant</td>
<td>35 – 50</td>
</tr>
<tr>
<td>E. grandis, A. mearnsii</td>
<td>Sensitive</td>
<td>50 – 100</td>
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</table>

**Table 1.2:** Levels of resistance to snow damage for various commercial hardwood species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Resistance rating</th>
</tr>
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<tbody>
<tr>
<td>E. macarthurii, E. benthamii</td>
<td>Very tolerant</td>
</tr>
<tr>
<td>E. nitens, E. badjensis, E. dorrigoensis</td>
<td>Tolerant</td>
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<tr>
<td>E. smithii, E. fraxinoides</td>
<td>Moderately Tolerant</td>
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<td>E. dunnii, E. saligna</td>
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<td>E. grandis, A. mearnsii</td>
<td>Sensitive</td>
</tr>
</tbody>
</table>

**Table 1.3:** Levels of resistance to frost damage for various commercial hardwood species.

1.1.2 **Acacias**

The first introductions of *Acacia mearnsii* (black wattle) into South Africa were done in 1864 by the Van der Plank brothers, with the first plantings established ten years later for firewood, shelterbelts and shade for livestock. The establishment of black wattle continued and in 1888 tests conducted on the bark concluded that the vegetable tannins in the bark were of a high quality and suitable for leather tanning. This led to the establishment of plantations to produce bark for the export market.

*Acacia mearnsii* is a very versatile and useful forest tree. Apart from the commercial value of its bark, the timber is used for firewood and building purposes, and products such as parquet flooring blocks, furniture, hardboard, rayon, charcoal, structural timber and fencing poles. In recent years more emphasis has been placed on the timber for pulp production for both local and external markets. Establishment programmes generally target the poorer site qualities for *Acacia mearnsii*. Being a legume this species will enhance soil fertility through nitrogen fixing.

1.1.3 **Pines**

According to Poynton (1977) the first commercial plantations consisted of *Pinus pinaster* and *Pinus pinea* and were established between 1825 and 1830 at Genendal.
Sir David Hutchins, Conservator of Forests for the Cape, introduced *Pinus patula* into South Africa in 1907 when a trial block was planted at Tokai plantation in the Western Cape Province. Further introductions were made in 1908 when several arboreums were established at plantations near Tzaneen, Belfast and Lothair in the Mpumalanga and Northern provinces. *P. patula* is the most important softwood species in commercial forestry in South Africa. Approximately 300,000ha is afforested with this species by the different forestry companies and it is grown for a variety of timber and pulp products.

The genus *Pinus* comprises approximately 100 taxonomically distinct species and many hybrids, varieties and cultivars. Their natural distribution includes most of the Northern Hemisphere and is almost entirely absent south of the equator. A few species have a more tropical distribution and cross the equator. Two species, *Pinus halepensis* and *Pinus pinaster*, are represented in Africa north of the Sahara.

*Pinus patula* belongs to the *Pinaceae* family and the genus *Pinus*. Two different varieties occur in *P. patula*, var. *patula* and var. *longipedunculata*. The species is placed in the section *Serotinae* subsection *Oocarpae*. Other species included in this subsection are *P. tecunumanii*, *P. oocarpa*, *P. greggii*, *P. muricata* and *P. pringlei*. The full taxonomic classification of *P. patula* is as follows (Table 1.4).

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<td>Family</td>
<td>Pinaceae</td>
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<td>Pinus</td>
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<tr>
<td>Sub-genus</td>
<td>Diploxylon (Hard pines)</td>
</tr>
<tr>
<td>Section</td>
<td>Serotinae (Closed-coned pines)</td>
</tr>
<tr>
<td>Sub-section</td>
<td>Oocarpae</td>
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<tr>
<td>Species</td>
<td><em>Pinus patula</em> Scheide et Deppe</td>
</tr>
<tr>
<td>Common name/s</td>
<td><em>Patula</em> pine, Mexican weeping pine, spreading-leafed pine</td>
</tr>
</tbody>
</table>

**Table 1.4:** The full taxonomic classification of *P. patula*.  

The wood of *P. patula* is yellowish-white in colour, has a moderate wood-density, is low in extractives and is suitable for a number of wood and paper products.

### 1.2 Species description

In its natural habitat *Eucalyptus nitens* occurs between 600 and 1,200m elevation in extensive populations in the Victorian Alps, eastern Victoria and southern New South Wales provinces of Australia. Two distinct populations are also found at Barrington Tops and Ebor in northern New South Wales, at altitudes of up to 1,600m, with overall latitude range from 30° to 38° South (Figure 1.1 and Photo 1.1). The mean maximum temperature of the hottest month ranges from 21-26°C and the mean minimum of the coldest month around –5 to 2°C. Frosts are frequent and severe, and snow is common. In South Africa this species ideally is suited to cooler sites in the summer rainfall regions of the country with a MAT not greater than 13.1°C to 15.0°C and MAP
should be above 810–899mm for optimum growth. \(^{21}\) *E. nitens* is classified as frost tolerant, but not as hardy as *E. macarthurii*, with good snow tolerance. *E. nitens* is susceptible to various forms of leafspot (*Mycosphaerella* spp) in its juvenile state. Diseases such as *Endothia* and *Botrysphaeria* appear following environmental stress such as drought, frost or hail. *E. nitens* in recent years has become susceptible to attacks from *Coryphodema tristis*, an indigenous cossid moth. \(^{22}\) *E. nitens* does not coppice well and the ability to coppice decreases with age. \(^{23}\) This species strips relatively easily and has good kraft pulping properties. \(^{24}\)

**Eucalyptus smithii** occurs naturally along the eastern edge of the tablelands of southeastern New South Wales and adjacent coastal escarpment and lowlands. Scattered populations are also found in the eastern Gippsland district of Victoria. The altitude varies from 50-1,150m with overall latitude range from 34° to 38° South (Figure 1.2 and Photo 1.2). The mean maximum temperature of the hottest month ranges from 23-28°C and mean minimum of the coldest month around –2 to 6°C. Frosts vary from few to frequent and snowfalls are light. \(^{4}\) *Eucalyptus smithii* is ideally suited to deep well drained soils on cool sites in the summer rainfall regions of South Africa with a MAT not greater than 15 –17°C \(^{25}\) and MAP should be above 819–936mm for optimum growth. \(^{21}\) *E. smithii* is classified as cold tolerant, and not frost hardy with moderate snow tolerance. *E. smithii* is susceptible to various forms of *Phythophthora*, particularly in the first two years of growth. In subsequent years *Botrysphaeria* will appear following environmental stresses such as drought, frost or hail. *E. smithii* will coppice well and is ideal for second rotation coppice crops. This species strips relatively easily during summer and has above average density and good pulp properties.

**Figure 1.1:** Natural distribution map of *Eucalyptus nitens*. \(^{2}\)
**Eucalyptus dunnii** has a restricted natural occurrence in north-eastern New South Wales extending into southeastern Queensland. The distribution covers approximately 250km from west of Coffs Harbour in New South Wales northwards to the McPherson range. The altitude varies from 300–750m with overall latitude range from 28° to 30° South (Figure 1.3 and Photo 1.3). The mean maximum temperature of the hottest month ranges from 27-30°C and mean minimum of the coldest month around 0 to 3°C. Frosts vary from 20-60 events every winter. 

**Eucalyptus dunnii** grows better than *E. grandis* on cooler sites and has better frost tolerance. It is ideally suited to sites in the summer rainfall regions of South Africa with a MAT of greater than 15.5°C and MAP should be between 822–925mm for optimum growth. 

*E. dunnii* is classified as mildly drought tolerant, susceptible to frost and snow damage. *E. dunnii* is susceptible to *Gonipterus scutellatus* (snout beetle) particularly at high altitudes (>1,300m asl) and during periods of stress such as drought. Following introduction *E. dunnii* has remained relatively disease free with a few recorded cases of *Botryosphaeria* which appear following environmental stresses such as drought, frost or hail. *E. dunnii* will coppice well, but is susceptible to wind damage. This species strips relatively easily and has above average density with a range of pulping properties suitable for both dissolving and kraft processes.
The natural occurrence of *E. macarthurii* is restricted to the central and southern tablelands of New South Wales, from the Blue Mountains to Goulburn. The altitude varies from 500–1,200m with overall latitude range from 33° to 35° South (Figure 1.4 and Photo 1.4). The mean maximum temperature of the hottest month ranges from 23-25°C and mean minimum of the coldest month around -1 to 2°C. Frosts are severe and frequent with regular light snowfalls. *Eucalyptus macarthurii* is the most frost tolerant species currently grown in South Africa and it is ideally suited to sites in the summer rainfall regions of the country with a MAT between 13.1°C and 16.0°C. The MAP should range from above 738 to 864mm for optimum growth. *E. macarthurii* is classified as cold tolerant, and the most frost hardy of all the commercial eucalypt species, but is susceptible to stem breakage following mild to heavy snowfalls. *E. macarthurii* is susceptible to various forms of *Phytophthora* particularly in the first two years following establishment and relatively disease free due to its thick bark. *E. macarthurii* will coppice well and is ideal for second rotation coppice crops. This species strips relatively easily during summer but with difficulty during winter. This species has above average density and the potential for suitable kraft pulp properties following selection and breeding.
The most widely planted eucalypt, *E. grandis* has a natural occurrence, which extends from Newcastle New South Wales to Bundaberg in Queensland. The altitude varies from 500–1,100m with overall latitude range from 25° to 33° South (Figure 1.5 and Photo 1.5). The mean maximum temperature of the hottest month ranges from 24-30°C and mean minimum of the coldest month around 3-8°C. *Eucalyptus grandis* grows in humid to sub-humid conditions with a low incidence of frost. This species is ideally suited to sites in the summer rainfall regions of South Africa with a MAT of greater than 17°C and the MAP should be greater than 900mm for optimum growth. *E. grandis* is classified as sub-tropical, and is not suitable for areas where frost and snow events occur. *E. grandis* is susceptible to various forms of diseases such as *Crysporthe austroafricana* particularly in the first two years following establishment and *Coniothyrium* spp which occur as lesions on the stem. *E. grandis* will coppice well and is ideal for second rotation coppice crops. This species strips easily throughout the year but is susceptible to drought which does negatively affect the stripping ability. This species has a lower density relative to all other commercial eucalypts, but has both good kraft and dissolving pulp properties.

Inter-specific *Eucalyptus hybrids* have been developed for any one of three reasons: to combine desired traits of two species; to exploit hybrid vigour (heterosis); or to increase the adaptability of a eucalypt species to areas which are marginal for the parent species. Some of the more popular hybrid combinations include *E. grandis x E. urophylla* (combining good growth with *Coniothyrium* tolerance), *E. grandis x E. camaldulensis* (combining good growth with drought tolerance) and *E. grandis x E. nitens* (combining good growth with cold tolerance and rooting ability).

*Acacia mearnsii* (black wattle) occurs naturally in southeastern Australia along the coastal lowlands of southern New South Wales and Victoria as well as eastern Tasmania. Over the natural range of the species the annual rainfall can vary from as low as 450mm to as high as 1,500mm. The altitude varies from 500–1,100 m with overall latitude range from 34° to 43° South (Figure 1.6 and Photo 1.6). The mean maximum temperature of the hottest month ranges from 25-28°C and mean minimum of the coldest month around 0-5°C. *Acacia mearnsii* grows in the cool to warm sub-humid humid climatic zones with a 1-10 per annum incidence of frost on the coastal but up to 40 on the tableland locations. This species is ideally suited to sites in the summer rainfall regions of South Africa with a MAT of between 16°C and 20°C and the MAP should be between...
760 and 858mm for optimum growth. This species is sensitive to frost, cold winds, hail and snow damage.

Pinus patula is indigenous to Mexico at altitudes of 1,500 to 3,100m and at latitudes 16°N to 24°N with mean annual precipitation of between 600 and 2,500mm. Figure 1.7 and Photo 1.7 show the natural distribution of this species in Mexico. Within its native range it attains a height of 35m and diameters of up to 80cm. P. patula is the most widely planted species in the Oocarpae subsection with an approximate 1.0 million hectares established worldwide. The broad growth requirements for this species in South Africa are MAT of <18°C and MAP of >700mm at high altitudes and >950mm at lower altitudes with well-drained soils. The greatest threat to P. patula
is *Fusarium circinatum* in the seedling stage followed by *Sirex noctilio,* *Sphaeropsis sapinea,* *Cinara cronarti,* *Rhizina undulata* and the bark beetle *Hylastes angustatus.* *P. patula* grows rapidly, captures the site quickly and is moderately resistant to drought and frost events. The good wood quality makes it suitable for a range of solid wood and pulp products.

Inter-specific *Pinus hybrids* have been developed for any one of three reasons: to combine desired traits of two species; to exploit hybrid vigour (heterosis); or to increase the adaptability of a pine species to areas which are marginal for the parent species. One of the more popular hybrid combinations includes *P. elliottii* x *P. caribae* (combining good form with good growth).

![Map of natural occurrence of *P. patula* in Mexico.](image)

**Figure 1.7:** Map of natural occurrence of *P. patula* in Mexico. Collections from different provenances in Mexico are indicated for the two varieties *patula* and *longipedunculata.*
1.3 Summary

<table>
<thead>
<tr>
<th>Species</th>
<th>Improved Genetic stock</th>
<th>Tolerance</th>
<th>Cold</th>
<th>Snow</th>
<th>Drought</th>
<th>Disease resistance</th>
<th>Insect tolerance</th>
<th>Flower and seed production</th>
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</tbody>
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Note: H = high; M = moderate; L = low; NA = not applicable

Table 1.5: An illustration of the relative expression of traits for the various commercial species.
<table>
<thead>
<tr>
<th>Species</th>
<th>Growth rate</th>
<th>Bark stripping</th>
<th>Defects form and forks</th>
<th>Density</th>
<th>Bark value</th>
<th>Solid</th>
<th>Kraft</th>
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<td>L</td>
<td>L</td>
</tr>
<tr>
<td>A. mearnsii</td>
<td>L</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>P. patula</td>
<td>H</td>
<td>NA</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>P. elliottii x caribaea</td>
<td>H</td>
<td>NA</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
</tbody>
</table>

Note: H = high; M = moderate; L = low; NA = not applicable

Table 1.6: Important characteristics of commercial value.
**Eucalyptus nitens**

- Juvenile leaves are discolorous, sessile and stems are square.
- Mature leaves are concolorous, petiolate and alternate.
- Bark is rough and persistent at the base.
- Buds are sessile, ovoid and usually occur as a 7-flowered umbel.
- Flowers are white and flower from Apr-Nov.
- Fruit are sessile, copular or barrel-shaped.

**Photo 1.1:** Characteristics of *E. nitens.*
Juvenile leaves are discolorous, sessile and lanceolate.

Mature leaves are narrow-lanceolate, discolorous, petiolate and alternate.

Bark is rough and persistent over most of the trunk.

Buds are pedicellate and usually occur as a 7-flowered umbel.

Flowers are white and flowering occurs from Feb-Oct.

Fruit are pedicellate and ovoid.

**Eucalyptus smithii**

**Photo 1.2:** Characteristics of *E. smithii.*
Mature leaves are petiolate, concolorous and moderately reticulate. Juvenile leaves are discolorous, sessile to shortly petiolate.

Bark is rough and persistent at the base and thin to fibrous above.

Buds are pedicellate, and usually occur as a 7-flowered umbel. Flowers are white and flowering occurs from Mar-Jun.

Fruit are pedicellate and obconical.

Photo 1.3: Characteristics of *E. dunnii*. 
**Eucalyptus macarthurii**

- Juvenile leaves are sessile, amplexicaul and slightly discolorous.
- Mature leaves are petiolate and narrow-lanceolate.
- Buds are sessile and usually occur as 7-flowered umbels.
- Flowers are white and flower from Jun-Nov.
- Fruit are sessile and obconical.

Bark is rough and persistent over most of the trunk.

**Photo 1.4:** Characteristics of *E. macarthurii.*
**Eucalyptus grandis**

- **Juvenile leaves are discolorous and petiolate.**
- **Mature leaves are discolorous, petiolate and alternate.**
- **Bark is rough and persistent at the base, but thin and flaking for the rest of the trunk.**
- **Buds are shortly pedicellate, and usually occur as a 8-flowered umbel.**
- **Flowers are white and flowering occurs from Mar-Aug.**
- **Fruit are pedicellate and obconical.**

*Photo 1.5: Characteristics of *E. grandis.*
**Acacia mearnsii**

Juvenile leaves are sprawling bipinnate with 4-8 opposite pairs of pinnae.

Mature leaves are bipinnate with 8-21 pairs of pinnae.

Typical stand of *A. mearnsii* with light canopies and bark that ranges from brownish to grey black in colour.

Flowers Oct-Dec

Creamy yellow flowers.

Protecting young seedlings from browsing.

Stripped wattle bark.

*Photo 1.6: Characteristics of *A. mearnsii*.*
Chapter 1: Species Selection

*Pinus patula*

- Needles are pale green to yellow-green with three to four needles per fascicle.
- Bark is roughly furrowed grey at the base to reddish grey into the crown.
- Ripe male strobili.
- Developing female conelets.
- Cones are conical and sessile.

*Photo 1.7:* Characteristics of *P. patula.*
1 Owen and Van Der Zel – 2000.
8 Clarke and Jones – 1998.
12 Sherry – 1971.
14 Dunlop – 2002.
19 Adapted from PERRY – 1991.
26 Gardner and Swain – 1996.
Rotation can be defined as the period in years between establishment of a stand of timber and the time when it is considered ready for final harvest. Rotation age is a function of species, site quality and final product. Species refers to the choice between hardwood and softwood in relation to silviculture zone, site quality and market. A ‘silviculture zone’ refers to areas of land delineated on the basis of climate. In general terms it is a rational classification of climate with regards to temperature.

Three main silviculture zones have been identified based on temperature and the degree of frost. The first of these is the subtropical zone which is characterised by MAT of 20.1-22ºC with virtually no frost. The warm temperate zone has a MAT of 16.1-20ºC with light frosts and the cool temperate zone has a MAT of 13.1-16ºC with moderate to severe frosts. A further distinction is made between the warm and cool temperate zones depending on latitude which has an effect on temperature at a specific altitude. For hardwoods the split between the cool and warm temperate zones is at 16ºC (ie 1,400m asl in Mpumalanga and 1,200m asl in KwaZulu Natal). For softwoods the split between the cool and warm temperate zones is at 17ºC (ie 1,200m asl in Mpumalanga and 1,000m asl in KwaZulu Natal).

Site quality refers to the tree growth capability of a site and is a rating of the productivity of a site in terms of roundwood production. The production capability of a site is a function of the climatic and edaphic factors that characterize the site. Site quality classes form a broad classification of site productivity that covers a range of sites from the poorest to the most productive. The rotation length of a forestry crop depends on many factors, but is often driven by market demands and in both Tables 2.1 and 2.2, the ideal situation is illustrated. Species are matched to silviculture zone and site quality. In general terms, as the mean annual temperature drops and site qualities deteriorate so in turn the rotation age increases at fixed stems per hectare.
### Table 2.1: Hardwood rotations.

<table>
<thead>
<tr>
<th>Silv Zone</th>
<th>MAT (deg C)</th>
<th>SQI</th>
<th>SQII</th>
<th>SQIII</th>
<th>SQIV</th>
<th>SQV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-tropical</td>
<td>20.1-22.0</td>
<td><em>E. hybrids</em></td>
<td>6 y</td>
<td><em>E. hybrids</em></td>
<td>7 y</td>
<td></td>
</tr>
<tr>
<td>Warm temperate</td>
<td>17.1-20.0</td>
<td><em>E. grandis</em></td>
<td>8-10 y</td>
<td><em>E. grandis</em></td>
<td>9-11 y</td>
<td><em>E. dunnii</em></td>
</tr>
<tr>
<td></td>
<td>16.1-17.0</td>
<td><em>E. smithii</em></td>
<td>9-11 y</td>
<td><em>E. smithii</em></td>
<td>10-12 y</td>
<td><em>E. dunnii</em></td>
</tr>
<tr>
<td>Cool temperate</td>
<td>15.1-16.0</td>
<td><em>E. nitens</em></td>
<td>10-12 y</td>
<td><em>E. nitens</em></td>
<td>11-13 y</td>
<td><em>E. macarthurii</em></td>
</tr>
<tr>
<td></td>
<td>13.1-15.0</td>
<td><em>P. ellxcar</em></td>
<td>14-15 y</td>
<td><em>P. ellxcar</em></td>
<td>15-17 y</td>
<td><em>P. ellxcar</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>P. elxcar</em></td>
<td>14-15 y</td>
<td><em>P. elxcar</em></td>
<td>15-17 y</td>
<td><em>P. elxcar</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>P. taeda</em></td>
<td>14-15 y</td>
<td><em>P. taeda</em></td>
<td>15-17 y</td>
<td><em>P. patula</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>P. patula</em></td>
<td>14-15 y</td>
<td><em>P. patula</em></td>
<td>15-17 y</td>
<td><em>P. patula</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>P. patula</em></td>
<td>14-15 y</td>
<td><em>P. patula</em></td>
<td>15-17 y</td>
<td><em>P. patula</em></td>
</tr>
</tbody>
</table>

### Table 2.2: Softwood rotations.

<table>
<thead>
<tr>
<th>Silv Zone</th>
<th>MAT (deg C)</th>
<th>SQI</th>
<th>SQII</th>
<th>SQIII</th>
<th>SQIV</th>
<th>SQV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-tropical</td>
<td>20.1-22.0</td>
<td><em>P. ellxcar</em></td>
<td>14-15 y</td>
<td><em>P. ellxcar</em></td>
<td>15-17 y</td>
<td><em>P. ellxcar</em></td>
</tr>
<tr>
<td>Warm temperate</td>
<td>17.1-20.0</td>
<td><em>P. elxcar</em></td>
<td>14-15 y</td>
<td><em>P. elxcar</em></td>
<td>15-17 y</td>
<td><em>P. elxcar</em></td>
</tr>
<tr>
<td></td>
<td>16.1-17.0</td>
<td><em>P. taeda</em></td>
<td>14-15 y</td>
<td><em>P. taeda</em></td>
<td>15-17 y</td>
<td><em>P. patula</em></td>
</tr>
<tr>
<td></td>
<td>15.1-16.0</td>
<td><em>P. patula</em></td>
<td>14-15 y</td>
<td><em>P. patula</em></td>
<td>15-17 y</td>
<td><em>P. patula</em></td>
</tr>
<tr>
<td></td>
<td>13.1-15.0</td>
<td><em>P. patula</em></td>
<td>14-15 y</td>
<td><em>P. patula</em></td>
<td>15-17 y</td>
<td><em>P. patula</em></td>
</tr>
</tbody>
</table>

Spacing or stocking density is dependent on the growth potential of the site, species and the product that will be produced (sawlogs or pulpwood). A rectangular espacement has become more popular with plants planted in rows with a fixed spacing between the plants within these rows. A wider spacing between rows favours silviculture and mechanical harvesting operations. Tables 3.1 and 3.2 reflect spacing for hardwood and softwood respectively.

Table 3.1: Hardwood spacing for pulp production.

<table>
<thead>
<tr>
<th>Silv Zone</th>
<th>MAT (deg C)</th>
<th>SQI</th>
<th>SQII</th>
<th>SQIII</th>
<th>SQIV</th>
<th>SQV</th>
</tr>
</thead>
</table>

Table 3.2: Softwood spacing for pulp production.

<table>
<thead>
<tr>
<th>Silv Zone</th>
<th>MAT (deg C)</th>
<th>SQI</th>
<th>SQII</th>
<th>SQIII</th>
<th>SQIV</th>
<th>SQV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool temperate</td>
<td>15.1-16.0</td>
<td>P. patula 1666spha</td>
<td>P. patula 1666spha</td>
<td>P. patula 1666spha</td>
<td>P. patula 1666spha</td>
<td>P. patula 1666spha</td>
</tr>
</tbody>
</table>
4.1 Introduction
The planting of seedlings or cuttings is the first step to establishing a plantation. Research and extended experience has resulted in good quality genetic material for commercial plantation forestry.

There are 4 main topics which will be discussed in this chapter:
- seedling and cutting orders;
- plant quality;
- plant transport; and
- transit nurseries.

This chapter also includes three tables which show the Sappi Plant Quality Index (PQI) specifications by species. These are intended as a guideline to understanding the quality of seedlings.

4.2 Seedlings and cuttings (plant) orders
Plants need to be ordered with sufficient lead-time to ensure that the nursery will be able to produce them. The ordering lead-time (Table 4.1) shows the minimum length of time required for plant production where the nursery produces the plants through the winter months. A shorter period is required when part or the complete production takes place through summer. These would generally be plants required for spring or early summer.

Plant orders and changes to orders are to be sent to the local nursery manager, who will in turn confirm the plant availability.
It is important that careful planning is carried out before ordering plants from the nursery. The plants have a 2-month window in which they remain within quality specifications, after which they will be discarded. For example, if one orders plants for October, they can be picked up in October (preferably), or during November. If they are not taken by November, the nursery will have to discard them. The plants will have to be produced again, and the lead-time will apply (Tables 4.2, 4.3, 4.4, 4.5) before the plants will be ready.

### 4.3 Plant quality

Sappi have developed a system called the Plant Quality Index (PQI), whereby the nursery measure certain parameters in randomly chosen plants on the beds and allocate scores. The minimum score a plant batch can attain is a PQI of 60, and the maximum is 100 (see Tables 4.2, 4.3, 4.4, 4.5 and Figures 4.1, 4.2, 4.3, 4.4, 4.5).

If a batch of plants does not attain the minimum score of 60, or if there is too much variability in the batch (variations amongst the plants > 10% - meaning a batch of plants are very uneven), they will either be discarded, or grown on further until they comply.

Old plants have been found to perform poorly when they are grown out in field trials, therefore it is important that plants are taken on time.

### 4.4 Plant transport

A rack type system is recommended to transport plants, and although costly, results in fewer deaths and less blanking. A specialised trailer such as that in Photo 4.1 can easily be made after consultation with your local nursery (for the different tray and seedling size parameters). This will ensure seedlings are transported in the best possible manner.

**Table 4.1: Ordering lead times.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Months lead time required to produce plants</th>
<th>Order for October needs to be placed by</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. greggii</em> (Northern)</td>
<td>10</td>
<td>January</td>
</tr>
<tr>
<td><em>P. greggii</em> (Southern) and <em>P. patula</em></td>
<td>9</td>
<td>February</td>
</tr>
<tr>
<td><em>P. elliottii, P. taeda, A. mearnsii, E. grandis, E. smithii, E. macarthurii and E. nitens</em></td>
<td>8</td>
<td>March</td>
</tr>
<tr>
<td><em>E. dunnii</em></td>
<td>7</td>
<td>April</td>
</tr>
<tr>
<td>Pine cuttings</td>
<td>10</td>
<td>January</td>
</tr>
<tr>
<td>Eucalypt cuttings</td>
<td>4</td>
<td>June</td>
</tr>
</tbody>
</table>

* These figures are based on the winter window for the nursery to produce plants. Shorter periods during other times of the year can be negotiated.
The distance between the racks should be > 35cm, as the tray is 10cm deep and the maximum height of plants (except wattle) is 25cm.

It is recommended that shade cloth be used to cover the plants, so they do not suffer excessive exposure to the sun or wind.

The best time to collect plants is early in the morning or late in the afternoon when it is cooler.

All empty trays are to be returned (where possible) whenever the truck comes back to collect the next load of plants. All trays are to be returned to the nursery of origin by 30 June (summer plantings) and 20 September (winter plantings) of each year.

4.5 Transit nurseries

**AVOID HOLDING PLANTS UNDER ANY CIRCUMSTANCES**

The condition that the plants are in when they are planted in the field is important. Plants should leave the nursery when they are in peak condition (PQI) for planting. Any further delays in planting after the plants have left the nursery can impact on plant quality.

- Plants should not be held for longer than one week after having been received from the nursery.
- Plants dispatched in liners should be planted immediately (the day they are taken or the following day at the latest). Plants dispatched in liners must **not** be transplanted into trays to be held.
The plants are given some fertilizer before being dispatched, and therefore plants can become oversized.

The nursery is well equipped to monitor and protect plants from diseases, whereas the grower might not be.

In order to hold plants, some recommendations are made below which will ensure that plants are kept in a similar condition to when they were received. This is broken into three sections, namely:

- where to store plants temporarily;
- watering; and
- diseases.

### 4.5.1 Where to store plants temporarily

- **DO NOT** put the plants you receive under the biggest and most shady tree in the garden:
  - the nursery grows these plants under ± 20% shade (hail net / plastic / both), and the plants are hardened off to survive under full light conditions;
  - by holding them under a big tree, you are reversing this phenomenon, and softening them off:
    - the plants will go out into full sunlight when they are planted, and if they are used to the shade, the sun will scorch them;
    - these shady areas often remain damp, which favours disease.

- **DO NOT** put the trays straight onto the ground, try to raise them:
  - that air prunes the roots, so you must have a layer of moving air under the trays;
  - when you water, there could be large puddles on the ground, and this will not only damage the sensitive root tips (by “drowning” them), but could also lead to diseases spreading from one area to another. Preferably, one needs to get the trays sufficiently high off the ground to get them out of the splash zone, as this is another way of transferring diseases.
  - Some ideas about elevating trays:
    - put them on top of other trays;
    - get some poles and lie them down next to each other, and put the trays on top of these;
    - get some cross-cut poles and put trays on top of these;
    - use bricks on the corners of trays to elevate the trays.

- When putting plants in full sun, they need far more attention because they dry out very quickly. If they haven’t been properly hardened off by the nursery, they can get scorched (this shouldn’t happen). However, rather put them in full sun than full shade.

- Try to choose a well-drained area so the water moves away quickly.

### 4.5.2 Watering

- This is critical to the survival of the plants.

- Water the plants well when they come off the truck:
  - they will have been watered well in the nursery before dispatch, but have had to endure:
    - travelling in the heat;
    - being wind-blown (some of the plants on the edges);
    - being jolted on dirt roads;
    - possibly being mishandled when loaded or off-loaded;
  - the watering will help them to settle and re-coup;
  - water the plants even if they arrive late in the afternoon / evening;
o as with all the watering, water well.

**From the day after the plants arrive, a strict watering regime needs to be adhered to.**

**Holding back water is another technique the nursery uses to harden off plants.**

**If you supply too much water, the plants will become dependent on this, and in the field when they don’t get it, they will die.**

**If it is raining, you do not need to water.**

**The same applies too if it is overcast. The plants are not transpiring as quickly, so they do not need water. Only if their heads are drooping must you water.**

**Water first thing in the morning (the earlier the better) if it is going to be hot.**

**Make sure the root plugs are saturated with water. The only way to check this is to pull a plant out and see how wet the bark is.**

**DO NOT just wait until the water runs out of the bottom of the tray - it can form channels through the bark - and not actually be wetting the entire plug.**

- if this happens (it is streaming out of the bottom, but the plug isn’t completely wet), water all the trays and come back again and again. The water will slowly filter throughout the whole plug.

**DO NOT re-water unless the plant tips are drooping and the plants are in danger of drying out and dying, or you are about to plant them out.**

**If you have to re-water (if it is very hot), make sure it happens before mid-day in order to give the leaves enough time to dry off before nightfall.**

**Before you water again, check the root plugs are dry. If not (if there is some water in the plug), rather do not water unless it is going to be hot.**

**In the nursery, depending on conditions, we can leave plants for 3-4 days without watering them. The only exception is if it is really hot (30°C plus), then we water them daily (first thing in the morning).**

**Make sure you check the edge plants are wet enough. They will be the first ones to dry out as they are exposed to more light as well as air movement.**

**It is not a good idea to base your watering on one or two samples that are pulled out. Make sure you take samples from the inside of a tray as well as the edges (due to drying out).**

**If the root plugs of the edge plants are still wet, there is a good chance you will not need to water, as the inner ones will be even wetter. It is preferable though to still test a couple of samples.**

**If the edge plants are rather dry, and the middle ones are wet on an overcast day, it is fine to only water the edges. This also applies to when you check the plants at midday. If the edge plants are drooping, but the middle ones still have moisture in their plugs, just water the edge ones.**

**If you are using a sprinkler system to water, make sure you alter its position every 15-20 minutes so as to get as much cover and variation as possible.**

**The plants must be completely wet before they get planted (even if it is in the late afternoon) - **water the plants well before they are planted.**

**Basic Rule:** Keep the leaves as dry as possible, and the medium wet (especially overnight).

### 4.5.3 Diseases

**Watering is a critical aspect as far as diseases are concerned. This is how we control diseases within the nursery. Obviously, if there is poor management of watering, or numerous days of overcast weather - and one has to water, then there are chemicals, which can be applied to reduce infestations. What must be borne in mind is that these**
normally occur during the active growing stages of the plants, and should not occur in delivered plants, as these should be hardened off - and hard plants are less susceptible to disease.

- However, if the notes on watering are not adhered to (or there are unfortunate weather patterns as described above), certain diseases may establish themselves.
- The best way to rid the plants of a disease is to get as much air flow through the leaves as possible:
  - This can be done by spreading the trays out (beware of outer plants drying out).
  - Soft plants are more susceptible to diseases than hard plants. When plants go soft, their leaves get big and soft, and this results in a dense leaf mass which means that air flow is impeded, and the leaves don’t dry out sufficiently. If there are disease spores around, they will multiply in these damp places and be able to spread to adjacent weak (and soft) plants.
  - Softness and hardness is not only a visible characteristic, but if one strokes a tray of plants with one’s hand, and they feel hard to the touch - then they are hard. If they are easily manipulated (and do not quickly stand up again), then they are soft.
  - However, beware of doing the above test (ie to check if they are hard or soft), as this is the best way of spreading disease spores from one tray to another. You would have picked up spores on your hands from diseased plants, and will transfer them to other healthy plants.
  - Once the trays have been separated (put them into rows), manually take out the dead plants:
    - these either have died from disease; or
    - are going to die, and will just be more material for the disease to live on.
  - Be careful not to touch too many of the healthy plants with the dead ones.
  - Put all dead matter in a plastic bag and discard away from the holding nursery (preferably burn it).
  - It might be an idea to wash your hands with water every 10-15 minutes to wash off accumulated spores.
- The most common disease you will encounter is *Botrytis* which looks very similar to bread mould.
- *Botrytis* is a nursery disease due to the unnatural keeping of plants so close to one another.
  - Do not plant seedlings or cuttings that have disease on them.
  - If there are plants that have spores on them, but are not dying, they will be fine in the field, as the plants stand alone and get a chance to dry off (wet leaves = disease).
- If one adheres to the watering and placement of plants described above, there should be no disease problems.
### Table 4.2: PQI specifications for *E. grandis*, *E. dunnii*, *E. smithii* and *E. nitens* seedlings.

<table>
<thead>
<tr>
<th>AGE</th>
<th>PLANT SIZE</th>
<th>SPECIFICATIONS</th>
<th>MIN. SCORE</th>
<th>MAX. SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter grown</td>
<td>Height Range</td>
<td>7-8 months</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Summer grown</td>
<td>6-7 months</td>
<td>5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10cm - 25cm</td>
<td>5</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Topping allowed?</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ht:RCD Ratio</td>
<td>&lt;90 - 130</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ROOT PLUG</th>
<th>SPECIFICATIONS</th>
<th>MIN. SCORE</th>
<th>MAX. SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plug Integrity</td>
<td>Root plug fully colonised with brown:white (30:70) root tips &gt; 2/3 of plug. Not root bound.</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Root Spiralling</td>
<td>No roots spiralling or spiralling &lt; 180° around root plug</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLANT HEALTH</th>
<th>SPECIFICATIONS</th>
<th>MIN. SCORE</th>
<th>MAX. SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf colour</td>
<td>Green or green red, not very red or yellow</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>No sign of disease</td>
<td>Yes</td>
<td>FAIL</td>
<td>15</td>
</tr>
</tbody>
</table>

NB. The minimum scores listed above do not add up to 60. This is an indication that if the seedlings scored as they have above, they would fail, and be unable to be dispatched. Root spiralling and disease are non-negotiables ie if greater than 10% of the seedlings measured in any batch fail a 0 score will be obtained. If any plants are diseased the batch will fail and will not be dispatched. NB These specifications refer to plants raised in Sappi 49 trays only.
## Table 4.3: PQI specifications for A. mearnsii, Northern P. greggii, Southern P. patula/P. greggii and P. elliottii/P. patula seedlings.

<table>
<thead>
<tr>
<th>A. mearnsii (Wattle)</th>
<th>Northern P. greggii</th>
<th>P. patula / P. greggii (Southern)</th>
<th>P. elliottii / P. taeda</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AGE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter grown</td>
<td>7-8 months</td>
<td>10-11 months</td>
<td>8-9 months</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Summer grown</td>
<td>6-7 months</td>
<td>9-10 months</td>
<td>7-8 months</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td><strong>HEIGHT RANGE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;100 - 120 cm</td>
<td>5</td>
<td>10</td>
<td>&lt;80 - 100 cm</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>&gt;100 - 200 cm</td>
<td>Colonised with white root tips along length of plug. Not root bound with brown root tips or white tips in only bottom 1/3</td>
<td>Colonised with white:brown (50:50) root tips &gt; 2/3 of plug. Not root bound with brown root tips or white tips in only bottom 1/3</td>
<td>Colonised with white:brown (50:50) root tips &gt; 2/3 of plug. Not root bound with brown root tips or white tips in only bottom 1/3</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td><strong>Topping allowed?</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>ROOT PLUG</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Plug Integrity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>FAIL 5</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td><strong>J-roots (*)</strong></td>
<td>Less than 8% seedlings with 'J-root' scores of 4 and 5</td>
<td>Less than 8% seedlings with 'J-root' scores of 4 and 5</td>
<td>Less than 8% seedlings with 'J-root' scores of 4 and 5</td>
</tr>
<tr>
<td></td>
<td>FAIL 10</td>
<td>FAIL 10</td>
<td>FAIL 10</td>
</tr>
<tr>
<td><strong>Rhizobium nodules</strong></td>
<td>Presence of Rhizobium nodules on roots</td>
<td>Grey to white fungus on root plug; bifurcating root tips</td>
<td>Grey to white fungus on root plug; bifurcating root tips</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td><strong>PLANT HEALTH</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Leaf colour</strong></td>
<td>Green to deep green</td>
<td>Deep green to green to light green</td>
<td>Deep green to green to light green</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td><strong>No sign of disease</strong></td>
<td>Yes</td>
<td>FAIL 5</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>100</td>
<td>60</td>
</tr>
</tbody>
</table>

NB. The minimum scores listed above do not add up to 60. This is an indication that if the seedlings scored as they have above, they would fail, and be unable to be dispatched.

Root spiralling, a fungal symbiosis and disease are non-negotiables ie if greater than 10% of seedlings measured fail a 0 score is obtained.

If any plants are diseased the batch will fail and will not be dispatched. NB These specifications refer to plants raised in Sappi 49 trays only.

## Eucalyptus Cuttings

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Summer</th>
<th>Winter</th>
<th>Height</th>
<th>Depth</th>
<th>Position</th>
<th>Root Plug</th>
<th>Root Tips</th>
<th>Plant Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>3-4 Months</td>
<td>3-4 Months</td>
<td>15cm - 30cm</td>
<td>2cm - 3cm</td>
<td>Center</td>
<td>Plug Integrity</td>
<td>Percentage white root tips</td>
<td>Acceptorable Unacceptable</td>
</tr>
<tr>
<td>Unigro 128</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>Root plug partially colonised (50% of medium falls off) or root plug colonised but not root bound.</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Unigro 98</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>Root plug not colonised, partially colonised, colonised but not root bound, root bound</td>
<td>5</td>
<td>15</td>
</tr>
</tbody>
</table>

**NB.** The minimum scores listed above do not add up to 60. This is an indication that if the Cuttings scored as they have above, they would fail, and be unable to be dispatched. Disease is a non-negotiable, ie no plants should show signs of disease. If signs of disease are evident then the batch will fail.

### Table 4.4: PQI specifications for Eucalyptus cuttings.
### Table 4.5: PQI specifications for PECH cuttings.

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Min. score</th>
<th>Max. score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AGE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter grown</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Summer grown</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td><strong>PLANT SIZE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height Range (cm)</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Stem D (mm)</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td><strong>ROOT PLUG</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plug Integrity</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Root Tips</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td><strong>PLANT HEALTH</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weeds</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Leaf colour</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>No sign of disease</td>
<td>FAIL</td>
<td>5</td>
</tr>
</tbody>
</table>

NB. The minimum scores listed above do not add up to 60. This is an indication that if the Cuttings scored as they have above, they would fail, and be unable to be dispatched. No cuttings should show signs of disease. Up to 10% of plants can score zero for root plug for plants produced in Unigro 98 trays.
Figure 4.1: *E. grandis* seedling – representative of a typical *Eucalyptus* seedling.

**Sturdiness Ratio**

Height = 175mm (from plug to apical bud)  
RCD = 2mm  
Height:RCD = 175÷2  
= 87.5  
(scores 10)
Figure 4.2: *A. mearnsii* (Black Wattle) seedling.
Figure 4.3: *P. patula* seedling – representative of a typical *Pinus* seedling.

**Sturdiness Ratio**

- Height = 180mm (from plug to apical bud)
- RCD = 2.5mm
- Height:RCD = 180/2.5 = 90
  (scores 20)
Figure 4.4: *Eucalyptus* cutting (in this case A380, a GU or *E. grandis* x *urophylla*).
Figure 4.5: PECH cutting (Pinus elliottii x caribaea cross).

1 Photos by J. Ballantyne.
Poor methods of land clearing can result in soil erosion and can significantly affect survival and growth, as well as the potential production of the site. Different methods of land clearing can be used.

5.1 Managing slash

The following reasons for slash management exist:

- to reduce the fire hazards in high-risk fire areas;
- heavy build up of material in high altitude sites (P. patula);
- to facilitate mechanical clearing and/or soil preparation; and
- where heavy slash will hinder re-establishment activities.

Slash is usually spread to facilitate re-establishment activities, in compartments where slash burning is not recommended due to such factors as steep slopes or erodible soils. Openings are usually cleared in heavy slash to facilitate pitting and planting, when slash cannot or should not be burned.

5.1.1 Stacking slash

Slash could be stacked in heaps or in short rows or in small blocks, but should not be stacked nearer than 5m from roads, open areas or fire breaks. Keep at least 20m away from possible fire hazards such as wattle jungles and overgrown riverine areas. The stacking of slash is a very expensive operation and not recommended, except when required to protect small areas such as Special Management Zones (wetland riparian areas, fire breaks or road verges), when burning a compartment.

Stacking slash to facilitate re-establishment:

- Leave 5m wide gates in the slash rows at 30m intervals.
- Do not stack slash rows within 5m from roads or fire breaks.
- The edge of the slash row should not be stacked closer than 1m from the pegged lines to facilitate soil preparation.
- The slash load should be evenly spread over the rows.
5.1.2 **Burning slash**

Burning slash could be required in the following cases:

- to reduce the fire hazard in high-risk areas; and
- to facilitate re-establishment activities in heavy slash.

No burning of slash is allowed during the following prohibition periods:

- Zululand Coast: 1 August to 30 September.
- Mpumalanga: 1 May to 31 October.
- Melmoth, Vryheid area: 1 June to 31 October.
- Kwazulu-Natal: 1 June to 31 October.

Burning restrictions, as gazetted in the National Veld and Forest Fire Act (Act No. 101 of 1998), are updated annually and should therefore be consulted to ensure that burning operations are conducted within the parameters as set out by this Act.

Special requirements could be required due to Special Management Zones (SMZs) in the compartment, erodible soils (sandy soils with low clay %), steep slopes (>30%) or other conditions that could result in a negative environmental impact.

Burning shall only be undertaken when the weather conditions are stable with a maximum Fire Danger Index (FDI) of 30 (relative humidity above 40% and temperature below 23°C with low wind speeds). Ensure that the weather forecast on the day of the burn, as well as the day after the burn is known, to prevent flare-ups.

The suggested burning conditions to conduct a burn are:

- Relative humidity 70-80%.
- Wind speed 8-15km/h.
- Temperature 10-20°C.
- Zululand Coast - allowed burning up to a maximum FDI of 40.

Notify all stakeholders of where and when burning is going to take place. Such stakeholders include the local district forestry office, look out/fire detection control room, relevant neighbours and the local Fire Protection Association (FPA).

Slash burning will not be permitted until at least 50mm rain has fallen and the soil is moist enough to be squeezed into a clod. Burning should only be done within three days after rain of at least 30mm to prevent damage to the soil and humus layer. No slash burning will be permitted if a FDI of more than 50 is expected within ten days of the intended burn.

As it is essential to have a cool burn, only one slash row or a small section of slash should be burned at a time. Allow burning for a while to reduce heat before lighting the next section. Start burning from the top downhill or against the wind on flat terrain.

5.1.3 **Spreading slash**

- Slash should be spread evenly.
- Slash to be cleared 5m or two tree rows away from roads and fire breaks.
5.2 Clearing land manually
When clearing land manually ensure the following:
- Vegetation should be slashed to ankle height.
- Stipulate what is to be done with brushwood.
- Brushwood shall be removed 5m from roads, open areas and fire breaks.

5.3 Clearing land chemically
The objective of land clearing is to facilitate soil preparation and planting. Planting shall only be done in a compartment free of weeds, which also forms the basis for fuel load management. It is essential to schedule the planting operations in such a way that planting is done as soon as possible after the chemical application to gain the maximum advantage allowed by the weed free period. It is recommended that all plantings should be done in an area free of weeds. If an area is not free of weeds, a chemical pre-plant spray should be applied. The following methods of chemical spraying can be applied:

5.3.1 Total chemical spray
A total chemical spray application is recommended whenever weeds are present before planting. Planting should only be done in weed free compartments. Certain weeds require specific herbicides, in which case it is essential to identify and target these weeds. Help in identifying these target weeds can be obtained from the Sappi representative or a chemical representative. Use the herbicide recommendations correctly. To minimize spray drift, spraying should only be undertaken on days with very little wind and a relative humidity of not less than 30%. Most herbicides will not give good results if it rains within 1-6 hours after spraying. For chemical land clearing, or a chemical pre-plant spraying, the weeds should not be taller than 30cm and the coppice should be about 1m in height. When doing a weeding operation in between crops, it is essential to minimize the risk of scorching the crops. Chemical drift should be limited to the absolute minimum by using the appropriate nozzles, Gloria shields, wind boxes and keeping the nozzles or wind boxes as low as possible and shielding the crops. Spray as close to crops as possible. Also take care not to damage or kill natural vegetation that should be protected.

5.3.2 Aerial chemical spray
Although aerial spraying could be a very cost effective method for clearing land for establishment and re-establishment, the hazardous nature of the operation and possible negative impacts underlines the need for stringent guidelines and control. Although this is probably the best method to use when pressed for time, it is very reliant on weather conditions.

Ensure that the site is visited with the pilot to evaluate the scope of the weed or pest problem, note terrain features and identify potential impacts on neighbouring crops, other areas and homesteads. Mark the area to be sprayed with corner flags.

Weather conditions are critical for any type of aerial spraying. There should be no wind at all when spraying, the temperature should be below 20°C and the humidity should not be below 40%.

Problems associated with aerial spraying include contamination of soil and water, contravention of legal requirements, risk to people’s health, indiscriminate loss of unplantable habitats within or near the plantable area, and possible spray drift on neighbouring crops. The hazardous nature of the operation and possible negative impacts underlines the need for stringent guidelines.
5.3.3 Killing coppice by chemical spray

Some Eucalyptus, such as E. dunnii, E. macarthurii and E. smithii, are difficult to kill using Glyphosate. The choice of the appropriate herbicide is therefore crucial. Brush-off is recommended for the more difficult species as well as for spraying coppice for weeding purposes, as it will not easily affect pines. Ensure that the herbicide is registered for use on the specific species. To obtain good results when spraying coppice, it is essential to ensure that all the leaves are sprayed. It is of vital importance to ensure that the compartment is not burnt within at least three months after the spraying, as most species will re-coppice as the fire stimulates a growth hormone.

5.4 Clearing land mechanically

When clearing land mechanically using heavy equipment, terrain will determine the effectiveness of the operation.

Mechanical land clearing is not recommended when the slope exceeds 18%. Rocks and boulders will also cause problems when using mechanical methods.

5.5 Stump treatment

Chemical stump treatment is a costly operation and it should only be used as a last resort.

5.5.1 Treating stumps by frilling and applying herbicide

Chop right around the stump (no gaps in the frill) at an angle of 45° into the cambium. In the case of multiple stumps all the stems should be frilled as low as possible. Use a narrow angle solid cone for spraying. Spray until well wet, but does not drip off or spill. Although some herbicides could be more effective, the costs should always be considered, eg a 5% Chopper (Imazapyr) application on E. macarthurii gives very good results, but it is much more cost effective to do two treatments with 10% Glyphosate.

DO NOT burn slash within at least three months after treatment, as it will coppice again. A waiting period of six months is recommended.

5.5.2 Killing stumps immediately after felling

This method of stump treatment will only be successful if the stumps are treated within 30 minutes after felling. The best results will be obtained if stumps are treated directly after felling. ICFR trials have shown that if stumps are treated within 15 minutes after felling, a kill of 80% can be expected. When the stumps are treated 30 minutes after felling, the success rate drops to 40%.

Glyphosate is the most cost effective treatment in most cases. Some herbicides, such as Chopper (Picloram) and Access (Imazapyr) have a residual affect that could adversely affect new plants or even kill them if planted too soon after treatment. Follow the manufacturer’s recommendations in this regard. Add dye to chemicals to ensure that all stumps that can be seen are treated. It is not necessary to add dye to chemicals that have a colouring agent, such as Chopper (Imazapyr). Use a narrow angle solid cone for spraying. Spray till wet, but do not let the chemicals run off.

DO NOT burn slash within at least three months after treatment, as it will coppice again. A waiting period of six months is recommended.
6.1 Introduction

The establishment or re-establishment of plantations is usually preceded by some form of land preparation. The type and method of land preparation may determine:

- seedling survival;
- initial tree growth rates; and
- final yield of timber.

Land preparation operations must be related to prevailing site conditions and must be cost-effective since these initial costs are compounded over an extended period. Incorrectly applied or careless operations particularly on sensitive soils may result in long-term damage to the site. Table 6.1 provides soil preparation methods for different slope classes.

The objective of land preparation is to achieve optimum:

- physical;
- chemical;
- hydrological; and
- biological conditions.

The required operations for establishment will vary with soil and site characteristics. Distinction should also be made between:

- sites to be established for the first time; and
- sites to be re-established.
### Table 6.1: Soils with effective soil depth >500mm, excluding diagnostic g or plinthic horizons) and with topsoil clay >15% where slope is >8%. All soils with diagnostic E horizons and/or duplex character are excluded.

<table>
<thead>
<tr>
<th>Slope (%)</th>
<th>Soil Erodibility</th>
<th>Type of Cultivation</th>
<th>Tillage Direction</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Low*</td>
<td>Full conventional</td>
<td>Across slope</td>
<td>Leave surface as rough as possible</td>
</tr>
<tr>
<td>0-8 (4.5º) 0-12 (7º)</td>
<td></td>
<td>1. Full primary cultivation with tined implement only.</td>
<td>Across slope</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Strip cultivation with any implement leavening minimum 1m between strips which may be ripped or sprayed.</td>
<td>Across slope</td>
<td></td>
</tr>
<tr>
<td>9-15 (8.5º)</td>
<td></td>
<td>Full unrestricted primary cultivation followed by secondary cultivation along the plant line only.</td>
<td>Across slope</td>
<td></td>
</tr>
<tr>
<td>13-20 (11º)</td>
<td></td>
<td>Full primary cultivation with tined implement only.</td>
<td>Across slope</td>
<td></td>
</tr>
<tr>
<td>16-25 (14º) 21-30 (17º)</td>
<td></td>
<td>Full primary cultivation with tined implement only.</td>
<td>Across slope</td>
<td>Plant within 1 month. Weed control via herbicide strip (1.5m wide or more) or hand hoe around the tree, no mechanical control.</td>
</tr>
<tr>
<td>21-30 (17º) 31-40 (22º)</td>
<td></td>
<td>Single rip/sub-soiler tiner along tree line.</td>
<td>Across slope</td>
<td>Crawler tractor recommended. Weed control as above, spray prior to planting.</td>
</tr>
<tr>
<td>&gt;30 &gt;40</td>
<td></td>
<td>Pit.</td>
<td></td>
<td>Maximum diameter 1m. Weed control as above, restrict hand hoeing to pitted areas.</td>
</tr>
</tbody>
</table>

#### 6.2 Establishment

It is generally believed that when establishing virgin land, the use of mechanical land preparation methods enhances the initial growth but that the gains are nullified over a rotation age when compared with manual methods. Whatever gains are to be realised is dependent on effective weed management of the site.

- Ploughing is an effective land preparation method for establishment of plantations into grassveld. Trials have shown that tree responses to simple surface (20cm) ploughing operations are in the order of magnitude of 20 to 48% over pitting alone. Responses to tillage in these cases are primarily due to improved vegetation control and nutrient release. One of the main objectives of land preparation on virgin grassveld sites is to break up the dense root mat along the proposed tree line and then to ameliorate the soil profile where root-impeding layers exist.

- There are generally no additional benefits to be gained by carrying out ripping/sub-soiling in addition to a ploughing operation. Trials have shown that responses to a single ripping/sub-soiling operation are in the order of 0 to 32%, reflecting the difficulty of carrying out ripping effectively under the wide range of soil conditions which are experienced in South African forestry regions. If
ripping/sub-soiling is contemplated, then soils should be ripped at water contents which are conducive to shattering and only when a known limitation to growth is present. The use of single rock-ripping tines below 30cm is not recommended. For effective sub-soiling below 30cm a wing is necessary, and below 60cm a three tine sub-soiling rig is necessary.

6.3 Re-establishment
The best site preparation method under regeneration conditions is generally the most simple and cost-effective. For example, shallow ripping is a viable and cost-effective alternative to pitting, although it is unlikely to provide better long-term growth benefits than pitting only under regeneration conditions.

- Deep ripping or sub-soiling can only be recommended when there is a problem known to affect growth, such as an impermeable sub-soil horizon or where surface water infiltration problems exist.
- Problems may arise which affect the survival of the trees and subsequent growth if ripping is carried out carelessly and on soils which are likely to be structurally poor, ie those low in organic carbon and having a texture of sandy clay, sandy loam, clay loam, silt clay loam and silt loam.
- Complete site preparation is expensive (eg de-stumping, discing and ripping) and very unlikely to improve growth in subsequent rotations.
- On very compacted soils, mechanical soil preparation such as mechanical pitting is recommended. Ripping or sub-soiling is not recommended since it may break the soil up into large blocks which create air pockets. If such an operation is contemplated, it should only be carried out on the contour and never on a gradient.
- Major land-shaping operations should generally not be attempted and if they are, close collaboration with researchers is advised. Bench terracing and ridging in combination with sub-soiling are techniques which have been employed to decrease run-off on slopes and increase infiltration. They have met with mixed success and no direct recommendation for their use can be made.

6.4 Pitting
Pitting is carried out in an effort to improve the physical environment into which a young tree is planted. Benefits generally associated with this practice are:

- decrease in the soil bulk density, and physical strength;
- improved water infiltration rates;
- promotion of higher oxygen diffusion rates;
- increased rates of organic matter decomposition in the topsoil;
- removal of weed competition around the seedling.

Pitting is an expensive operation, and cost savings can substantially reduce establishment costs.

The normal pitting standard is 25cm deep and 50 x 50cm wide. However, trials have shown that there are no sustained benefits to be gained from large pits. Small pits can reduce labour costs provided:

- careful planting ensures that no shallow planting or J-rooting occurs;
- weed control is not compromised by the smaller diameter pit.

Pit size standards should be 25cm deep and 35cm wide for re-establishment purposes, and 25cm deep and 50cm wide for establishment.
The use of smaller pits must be accompanied by good weed control and good planting practice. This means that weed control should be practiced in the area around the pit and not just in the pit as tends to be currently practiced.

One trial has indicated the advantage of planting into fresh pits, particularly if standard size pits are used.

6.5 **Planting restrictions**

The purpose of planting restrictions is to ensure compliance with all legal and other requirements when establishing or re-establishing previously planted compartments. This includes planting and coppicing.

When establishing or re-establishing compartments, the landowner must ensure that the correct distances from hydrologically sensitive areas are left unplanted. To establish the correct planting distance from such areas, the landowner needs to be familiar with the requirements of a delineation document, “Guideline for the Delineation of Riparian Zones and Wetlands”

All compartments must be delineated following the procedure as described in the above guideline document. **Tables 6.2** and **6.3** provide an indication of risk when doing land preparation on different land types.

<table>
<thead>
<tr>
<th>(a) Silvicultural operations</th>
<th>Risk category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site preparation options</td>
<td>Soil Compaction</td>
</tr>
<tr>
<td>Pitting</td>
<td>VL</td>
</tr>
<tr>
<td>Strip cultivation (Ploughing and discing)</td>
<td>L</td>
</tr>
<tr>
<td>Complete surface cultivation</td>
<td>M</td>
</tr>
<tr>
<td>Ripping (&lt;50cm)</td>
<td>L</td>
</tr>
<tr>
<td>Sub soiling (&gt;50cm)</td>
<td>L</td>
</tr>
<tr>
<td>Terracing</td>
<td>M</td>
</tr>
<tr>
<td>Ridging</td>
<td>L</td>
</tr>
<tr>
<td>Scalping</td>
<td>L</td>
</tr>
<tr>
<td>Slash management options</td>
<td></td>
</tr>
<tr>
<td>Broadcast - cool burn</td>
<td>L</td>
</tr>
<tr>
<td>Broadcast - hot burn</td>
<td>L</td>
</tr>
<tr>
<td>Broadcast</td>
<td>L</td>
</tr>
<tr>
<td>Chopper-rolled</td>
<td>M</td>
</tr>
<tr>
<td>Windrowing</td>
<td>L</td>
</tr>
<tr>
<td>Windrowing + burn</td>
<td>L</td>
</tr>
</tbody>
</table>

# Erosion hazard will vary depending on slope.

$ Windrowing along the contour will decrease the erosion hazard.

VL = very low
L = low
M = medium
H = high
VH = very high

**Table 6.2:** Silvicultural activities with associated risks.1
### Table 6.3: Soil sensitivity index based on soil texture and parent material.

<table>
<thead>
<tr>
<th>Texture</th>
<th>Organic carbon (WB)(%)</th>
<th>Typical parent material</th>
<th>Risk assessment</th>
<th>AWC*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Compaction</td>
<td>Erosion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Sand</td>
<td>n/a</td>
<td>Recent sands</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>n/a</td>
<td>Recent sands</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>&lt; 1%</td>
<td>Berea sandstone</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>&gt; 1%</td>
<td>Natal group sandstone</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Loam</td>
<td>&lt;2</td>
<td>Dwyka tillite</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Silt loam</td>
<td>&gt;2</td>
<td>Karoo sandstone</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Silt clay loam</td>
<td></td>
<td>Mudstones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandy clay</td>
<td>&lt;2</td>
<td>Natal group sandstone</td>
<td>VH</td>
<td>H</td>
</tr>
<tr>
<td>Sandy clay loam</td>
<td>&gt;2</td>
<td>Karoo sandstone</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Granite gneiss</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Granites</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomites</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>n/a</td>
<td>Karoo shale</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>(&gt;75% clay + silt)</td>
<td></td>
<td>Gneiss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay loam</td>
<td></td>
<td>Basalt</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>n/a</td>
<td>Karoo shale</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>(&gt;75% clay + silt)</td>
<td></td>
<td>Dolerite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silty clay</td>
<td></td>
<td>Diabase</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Basalt</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Schist</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 ICFR Innovations – March 2000.
2 Document can be downloaded from the Department of Water Affairs website at: http://www.dwaf.gov.za/Documents/Other/EnvironRecreation/WetlandZoneDelineationSep05.asp
7.1 Introduction
The beginning of the growth cycle for any plantation starts with the planting of the tree seedlings. A planting operation with the correct espacement, correct specie and correct site, using the correct methods will form the foundation of future crops.

General factors to take into consideration when planting:
- Quality planting rather than quantity is essential.
- Plant with water when it is not raining (wet soils).
- Plant the seedling root collar 5-8cm below the soil surface.
- Plant in the correct window period (see Table 7.1).
- Plant strictly according to prescribed espacement guidelines.

7.2 Planting window

<table>
<thead>
<tr>
<th>Region</th>
<th>From</th>
<th>To</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mpumalanga Lowveld</td>
<td>October</td>
<td>March</td>
<td>Avoid hot Dec-Jan</td>
</tr>
<tr>
<td>Mpumalanga Highveld</td>
<td>September</td>
<td>February</td>
<td>Frost</td>
</tr>
<tr>
<td>Natal Midlands</td>
<td>October</td>
<td>April</td>
<td></td>
</tr>
<tr>
<td>Natal South coast</td>
<td>September</td>
<td>April</td>
<td></td>
</tr>
<tr>
<td>Natal North coast (Zululand)</td>
<td>March</td>
<td>August</td>
<td>Avoid Jan – Feb</td>
</tr>
</tbody>
</table>

Table 7.1: Planting window.
7.3 Removing plants from their trays

- The most important piece of advice is to ensure the plants in the tray are well watered.
- Plants should never be ‘yanked’ (pulled out quickly) out of a tray, as this will cause the sensitive roots to become torn, and will result in root deformity problems. Plants should be gently extracted by pulling with even pressure until they come out.
- Sticks should not be used to push the seedling out from underneath the tray. This can cause damage to both the tray and the sensitive roots. If necessary, a person’s finger can be used to push from the bottom.

To get cuttings out of the tube

- Tap the tube on the side of the Unigro tray and at the same time, gently pull the cutting out. It is best to do this holding the tube upside down, as gravity helps get it out in one piece.
- DO NOT squeeze the tube as this damages both the tube and the cutting’s roots.

7.4 Planting

The actual method of planting is best described in Figure 7.1.
7.5 Planting cuttings - some helpful hints
The information contained in this sheet is based on practical experience, and it is not intended as a scientifically correct document. Further advice can be obtained from the local nursery manager.

- Remember that a cutting has a site weakness where the roots have grown from the stem. This is sometimes because too much callous was formed before the roots initiated.
- If sufficient care is taken and the roots are left behind, keep these cuttings and report this to the nursery manager to look at.
- It doesn’t matter if the axillary bud is planted under or above the ground. It is a personal preference, but this may be a site for infection to enter the cutting.

7.6 Water planting
Water planting is practiced over a variety of sites throughout South Africa. This method is associated with poor soil moisture or intense planting with expensive plant material. It is recommended to establish the financial costs of water planting first before water planting commences.

Should water planting have financial benefits, the following process is recommended:
- open planting hole;
- pour water into the hole (2-4 liters of water per seedling);
- set the seedling (root collar 5-8cm below surface); and
- fill with soil and press the soil firmly around seedlings (using fingers only).

7.7 Blanking¹
Ensure that the maximum amount of seedlings survive and grow to ensure a good stocking at the date of harvesting. To ensure good stocking, a survey of the planted areas should be done four weeks after planting. If the survival is less than 92%, blanking should be done within six weeks after planting.

Remember to remove/return all seedlings trays from the planting site. Trays are made of a poly or plastic substance and are therefore a pollutant.

¹ SA Forestry Handbook, page 100.
8.1 Introduction
The application of fertilisers for the different species has been researched for a number of years by various institutions.

Reasons for fertilising:
- Require quick canopy closure.
- Reduce time of weed competition.
- Increase growth and shortened rotation.
- Achieve uniformity in the stand.

8.2 Fertilising methods and recommendations
- Fertiliser should be placed around the seedling 15cm from the stem (or 25cm from stem in the Zululand area), or placed in two slits adjacent to the seedling and covered.
- The full dosage of fertiliser should be given at planting, but no later than two weeks after planting.
- Fertiliser should also be re-applied to blanked seedlings.

8.3 General
- Clear all weeds before fertilising is done.
- Keep the seedlings weed free after fertilising to achieve maximum benefit.
- Keep to the recommended application guidelines (see Tables 8.1 and 8.2).
<table>
<thead>
<tr>
<th>Site preparation and/or site characteristics</th>
<th>Recommended quantity of nutrient elements (g/tree)</th>
<th>Recommended fertilizer mixtures and quantities (g/tree)</th>
<th>Macro-nutrient content of recommended mixtures (g/tree)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Re-establishment (Ripping or pitting land preparation method)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 3% organic C in topsoil</td>
<td>8+</td>
<td>12</td>
<td>60g DAP* + Zn OR 125 g 2:3:1 (22)† # + Zn</td>
</tr>
<tr>
<td>&lt; 3% organic C in topsoil</td>
<td>14</td>
<td>10</td>
<td>100g 3:2:0 (25) +Zn OR 125g 3:2:1 (25)# +Zn</td>
</tr>
<tr>
<td>Old wattle lands</td>
<td>0</td>
<td>15</td>
<td>140g single supers (10.5% P) + Zn OR 75g double supers (20% P) + Zn</td>
</tr>
<tr>
<td>Establishment (Full cultivation of virgin land)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 8% organic C in topsoil</td>
<td>0</td>
<td>15</td>
<td>140g single supers (10.5% P) + Zn OR 75g double supers (20% P) + Zn</td>
</tr>
<tr>
<td>3-8 % organic C in topsoil</td>
<td>5+</td>
<td>12</td>
<td>100g ammoniated supers +Zn OR 60g MAP* +Zn</td>
</tr>
<tr>
<td>1-3 % organic C in topsoil s</td>
<td>8+</td>
<td>10</td>
<td>100g single supers (10.5%P) + 25g LAN + Zn OR 50g DAP* + Zn</td>
</tr>
</tbody>
</table>

*MAP = mono ammonium phosphate
*DAP = di-ammonium phosphate
*LAN = limestone ammonium nitrate
# Preferred mixture for application on soils derived from sandstone and granite as they also contain potassium
† See information box at end of this document to calculate quantities for different fertilizer concentrations

Table 8.1: Fertilizer recommendations for *Eucalyptus* in the summer rainfall area (excluding Zululand). Bold typeface indicate the most likely situation.
Site preparation and/or site characteristics | Recommended quantity of nutrient elements (g/tree) | Recommended fertilizer mixtures and quantities (g/tree) | Macro-nutrient content of recommended mixtures (g/tree)
---|---|---|---
> 0.7% (High) organic C (OC) in topsoil | - | No fertilizer recommended | -
0.3 – 0.7% (Medium) OC in topsoil | 14 | 10 | 150g LAN (28% N) +Zn OR 90g Urea +Zn | 42 | 0 | 0
<0.3% (Low) OC Mostly the crest positions in some landscapes and ex-agricultural lands | 14 | 15 | 220g 5:2:0 (27) + S, Zn, B, Cu OR 150 g 4:1:1 (42) + S, Zn, B, Cu OR 350 g Agrofert (Bos #2 mix) | 42 | 17 | 0

Information obtained from:

Table 8.2: Fertilizer recommendations for *Eucalyptus* in Zululand. Bold typeface indicate the most likely (generic) situation.

Fertilizer codes explained

**Example: 3:2:1 (25)**
- The 3:2:1 refer to the elemental N:P:K ratio.
- The (25) at the end refer to the concentration of fertilizer within the bag, i.e. 50 kg bag x 25% = 12.5 kg of N, P and K.
- To calculate individual quantities of N, P and K:
  - N (Nitrogen) = 3/(3+2+1) x 12.5 = 12.5 x 6.25 = 0.5 x 12.5 = 6.25 kg
  - P (Phosphorus) = 2/6 x 12.5 = 1/3 x 12.5 = 4.17 kg
  - K (Potassium) = 1/6 x 12.5 = 2.08 kg

† How to make adjustment to fertilizer quantity if fertilizer concentration differs from recommended fertilizer

Example:
For a specific site the recommendation according to table 1 is to apply 125 g of 3:2:1 (25) + Zn to each Eucalypt seedling, but the supplier only has 3:2:1 (38) + Zn in stock.

Calculation to adjust dosage:
The fertilizer mixture is the same (3:2:1) but the fertilizer in stock is “stronger” as it contains 38% of elemental fertilizer as opposed to 25% as in the recommendation.
Thus, the available fertilizer contains 38/25 = 1.52 times the quantity of fertilizer in the recommendation and the dosage should be reduced by this ratio.
Quantity per tree = 125 g / 1.52 = 82 g.
Thus only 82 g of 3:2:1 (38) fertilizer per tree is required.
Evaluating fertilizer prices

Example:
Supplier 1 has 3:2:1 (25) fertilizer in stock for R4 000 per tonne (excluding transport cost) and supplier 2 has 3:2:1 (38) fertilizer in stock for R5 500 per tonne.

Calculation:
Because the fertilizer concentrations differ the prices cannot be compared directly. One tonne (1000kg) fertilizer from supplier 1 contains 0.25 t NPK (25%), while one tonne from supplier 2 contains 0.38 t NPK (38%). Thus you will have to buy 38/25 = 1.52 times the quantity of fertilizer from supplier 1 to get the same nutrients as from one tonne from supplier 2. Thus 1 t x 1.52 = 1.52 t of fertilizer from supplier 1 will cost R4 000 x 1.52 = R6 080.

Conclusion:
Buying fertilizer from supplier 2 is the most economic, and thus the best choice, as you will save (R6 080 - R5 500) = R582 per tonne or (R580/ R5 500)x 100 = 10.5% although supplier 2’s price per tonne is more than that of supplier 1. Further savings on transport and application can be added if fertilizer from supplier 2 is bought as it is more concentrated and less tonnes have to be transported to the plantation.
9.1 Weed control (vegetation management)

9.1.1 Introduction

Vegetation management is one of the most important factors influencing tree growth in young plantations as maximum crop production occurs in the absence of competing vegetation. The absence of competing vegetation ensures that resources such as water, nutrients, light and physical growing space are optimally available to the trees. Vegetation is also managed to improve access for silvicultural operations. During the establishing period, regular weed control is carried out. These operations are normally timed to reduce the negative impacts of competing vegetation on tree performance. Negative impacts resulting from competition on tree performance are likely to be carried through to harvest. When trees capture the site in terms of shading by their crowns, it results in the almost total exclusion of any competitive vegetation during this stage.

The need for effective vegetation management can be illustrated by the following:

- **A reduction in seedling mortality:**
  It is essential to control competing vegetation during establishment in order to reduce mortality. High mortality requires expensive blanking operations, delays canopy closure, reduces the number of trees to choose from during selective thinning operations, and reduces the yield achieved at harvest.

- **Increased uniformity:**
  Adequate weed control has been proven to lead to uniform stands. The estimation of timber yield in highly variable compartments and the subsequent planning for harvesting is difficult when yield cannot be predicted accurately as a result of ineffective vegetation management.

- **A reduction in the time to canopy closure:**
  Site capture is usually associated with canopy closure, ie when the selected crop becomes dominant on the site. In commercial plantations this would be when the crowns of the trees form a light-limiting barrier. Only shade-tolerant plants that can survive in the reduced light intensities can grow under the canopy. Early canopy closure should be one of the first and most important goals of vegetation management in plantation forestry, as all subsequent weeding costs will be reduced when this is achieved.
Fertilisation without vegetation control can result in a reduction in tree growth due to increased weed competition. Consequently, fertilisation should only be done where adequate weed control will be carried out. Adequate weed control is even more critical during periods of water stress.

Weed control should be timeous and implies:

- Reduced negative effect on tree growth.
- Competing vegetation is more susceptible to herbicide damage when young.
- The smaller size of the competing vegetation ensures that most weeds receive a complete cover spray.
- Lower herbicide application rates can be used lowering the costs involved.
- Low vegetation height allows for spraying nozzles to be held lower, thereby reducing drift.
- Weeds will be controlled before they set seed.

### 9.1.2 Critical vegetation management interventions / phases

The management of vegetation during a full rotation can be divided into three distinct phases, all of which have a direct bearing on the type and development of vegetation and therefore on the method of control.

- **Between harvesting and planting (temporary unplanted):**
  
  Plantations should be managed so that land is seldom left in an unproductive state for any extended period of time. Any vegetation developing during this period is normally sprayed as part of the pre-plant weeding operation with a non-selective, broad-spectrum herbicide. Often the control of vegetation prior to harvesting, in the form of a pre-harvest spray, may be beneficial as it reduces the need for a pre-plant spray. When a pre-plant spray is applied the time between the application and the planting operation should be minimised so that maximum benefit be realised by the newly planted stand. The pre-plant spray is also a very effective method of controlling weeds as a full cover spray can be applied without fear of damaging young seedlings. In the event of re-establishing a previous eucalyptus crop, focus should be given to kill the regrowth from stumps. This will be discussed under weeding methods.

- **Between planting and canopy closure:**
  
  As highlighted earlier, this is the most critical phase in the tree rotation in terms of vegetation management and any negative impact resulting from competition on tree performance is likely to be carried through to harvesting. The time to canopy closure varies between species and locality. Canopy closure for eucalyptus and acacia can be achieved within two years and pine in four years depending on the locality. It is advisable to keep the 1.2m ring or 1.2m line free of weeds during this period to achieve goals highlighted earlier. The grower should however look at the return on investment of any weeding activity exceeding the second year as this might influence the profitability of the stand negatively. Depending on the time of planting, quality and effectiveness of pre-plant spray, and season, the grower should get away with three weedings in the first year and two weedings in the second year. The following weeding standards have been developed to serve as a guide as to when a stand is under competition and has been developed to ensure timeous treatment as discussed earlier. The standards focus on the 1.2m ring / line as it has been proven that ring/line weeding provides superior performing trees when compared to inter row weeding. Inter row weeding is however essential to eliminate seed sources and to enhance access.
- **Weeding 0-1 year Pine:**
  1.2m ring / line : Max 25% weeds < 10cm height & Live stumps < 5%
  1.2m ring / line : Free of tuft grass, kikuyu, inkberry or noxious weeds.
  Inter row : Max weed height < 50% tree height or 25cm
  : Live stumps < 10%

- **Weeding 1-2 year Pine:**
  1.2m ring / line : Max 25% weeds < 10cm height & No live stumps.
  1.2m ring / line : Free of tuft grass, kikuyu, inkberry or noxious weeds.
  Inter row : Max weed height 30cm.
  : Live stumps < 10%

- **Weeding 0-1 year Gum / Wattle:**
  1.2m ring / line : Max 25% weeds < 10cm height & Live stumps < 5%
  1.2m ring / line : Free of tuft grass, kikuyu, inkberry or noxious weeds.
  Inter row : Tree < 1m, max weed height, half tree length or 25cm.
  : Live stumps < 10%

- **Weeding 1-2 year Gum:**
  1.2m ring / line : Max 25% weeds < 10cm height & No live stumps.
  1.2m ring / line : Free of tuft grass, kikuyu, inkberry or noxious weeds.
  Inter row : Max weed height 30cm.
  : Live stumps < 10%

Other factors to consider during this phase:

- **Browsing**
  Browsing damage by small antelope, goats and rodents have a significant impact on survival and growth of young seedlings and in particular acacia seedlings. As an example, less browsing might occur in those compartments where harvesting residue is retained rather than burned, because antelope access to the unburnt site is hindered. There might also be less browsing in the weedy than the weed free compartments. It is suggested that the 1.2m ring / line still be kept weed free with compromises made in the interrow, as the loss of tree growth resulting from weed competition would be unacceptable.

- **Planting into weed free compartments**
  Results from the majority of vegetation management trials established in the summer rainfall regions indicate that initial tree suppression occurs from as soon as one to three months after planting. It is therefore essential that young seedlings be planted into a weed free environment which can be achieved with a pre-plant spray preceding the planting operations. The site should have already been prepared (pitted or ripped) at time of pre-plant spray and sufficient time allowed for weed flush in the disturbed areas.

- **Fertilisation**
  Fertilisation without vegetation control can result in a reduction in tree growth due to increased weed competition. For the full potential of fertilisation to be realised, it needs to be applied at planting, which coincides with the stage at which the seedlings are at their most susceptible to competition from weeds. Consequently one should only fertilise those areas where adequate weed control has been or will be carried out.
Drought periods
During periods when water becomes a limiting factor, the management of vegetation is even more important. Maximum available groundwater must be made available to the seedlings by removing competing vegetation.

Gummosis (acacia)
The incidence of disease within wattle stands and in specific gummosis has a negative impact on growth and bark quality. The fact that hoed plots had significantly more gummosis than hand-weeded plots suggests that hoeing injury to the larger roots may have been contributory to the cause.

Selective management
The selective management of specific target categories (broadleaves or grasses only) should be limited to those areas where there is a uniform occurrence of a single category of weed, where the vegetation to be left after spraying has been shown not to have any negative impact on tree performance, or where vegetation is required to reduce site deterioration (erosion). It is common practise to treat all weeds (full cover spray) within the first growing year, selective (spot spray) in the second, targeting woody and noxious weeds.

Between canopy closure and harvesting:
The ability of the trees to capture the site in terms of shading by their crowns, results in the almost total exclusion of any competitive vegetation during this stage. The frequency and intensity of vegetation management during this phase is reduced and tends to precede thinning, pruning or harvesting operations to improve access. The effective weed control during this stage reduces the need for subsequent weed control operations before and after felling. The management of vegetation during this phase becomes selective with perennial broadleaves and known or listed noxious weeds being targeted.

9.1.3 Weed control methods
Vegetation methods are the suppression of the weed population to or below a predetermined level (Weeding standards). This implies that the target weed may still have an effect on tree growth, but the benefit to cost ratio is acceptable.

Weeds can be controlled by one or more, or a combination of the following methods:

- Physical weed control
  - Manual
    
    Manual weed control relies on the removal of weeds by hoeing, slashing or pulling out by hand. Chemical operations have been proven to be more cost effective and the effects more long lasting and manual operation should therefore be minimised if not excluded from the weeding program. When the operation takes place it should be restricted to the 1.2m ring / line to reduce costs and minimise site impacts such as topsoil loss.

  - Mechanical
    
    Mechanical weed control utilises tractor-drawn implements such as rotary slashers or rotary hoes to either cut the weeds or to incorporate them into the soil. Some factors to be taken into consideration would be:
    - Access into plantation due to plantation residue for compartments not burned.
    - Close planting espacement not allowing entry.
    - Stumps from previous rotation.
Additional disadvantages associated with physical weed control methods is the disturbance of the soil leading to conditions conducive to the stimulation of seed germination, damage to the root systems and soil compaction resulting from the use of tractors.

- **Chemical weed control**
  Chemical weed control is the most widely used form of vegetation management. Herbicides are either selective or non-selective with respect to the kinds of plants affected. Herbicides can kill on contact or may have to be translocated to target sites within the plant following absorption. Herbicides applied to the soil target either the root systems of existing plants or affect the germination of existing seeds (pre-emergent herbicides). For recommendations and advice please contact your local herbicide supplier.

  o **Manual**
    Most post–emergence herbicides used in plantations are applied as a foliar application using knapsack sprayers. Various other types of applicators are available on the market but the most commonly used would be the knapsack type sprayer. Manual chemical spray can be applied as full cover spray or spot spray, only targeting the intended weeds.

  o **Aerial**
    The use of aircraft to apply herbicides is a worthwhile alternative given the smaller cost associated with the large areas that can be done in a relatively small time. Effective pre-spray planning is necessary and the operation is dependant on favourable weather conditions. The use of aircraft has been limited to pre-plant sprays. The pressure on environmental issues as well as the very real threat of drift to adjacent compartments / crops has contributed to this method not being used as often.

### 9.2 Pruning

Branches form knots which are the most common defects of timber, especially those formed by dead branches. The lateral grain distortion around knots leads to reduced timber strength. Live knots are harder, denser and often contain more resin, and shrinkage is different to that of surrounding tissue. Knots contain a lot of compressed wood which spreads into the stems at volumes three to five times the knot volume. During mechanical pulping, knots are powdered instead of broken into fibres, resulting in decreased pulp yield. Resinous knots produce pulp of undesirable colour and therefore require more bleaching chemicals.

Natural or self-pruning of pines is generally much slower than that of eucalyptus. Complete freedom from grain distortion is only achieved after the first 3 or 4cm of new wood. The sooner pruning commences, and the longer the rotation of the crop, the higher will be the proportion of knot–free timber.4

Pruning regimes are largely determined by the intended market. The most intensive regimes are applied to timber intended for the saw log market and pole markets with pruning limited to facilitating access for pulp markets.

The objectives of pruning are to:4

- improve timber quality, ie to prevent the formation of dead (loose) knots, produce clear timber and reduce the size of live (sound) knots. The aim with saw timber is to limit the knotty core to 15cm and to have a radius of at least 10cm knot-free timber put on after the pruning operation to justify it economically;
facilitate movement in stands for other operations, eg marking for thinning, extraction, and control of fires, pests and diseases; and
reduce fire hazards, for example creating vertical fire breaks.

9.2.1  Effects of live pruning
Properly conducted pruning is not harmful to the tree provided that:

- pruning cuts must be made flush with the tree trunk (except for *Acacia mearnsii*);
- broken stubs must be removed;
- the surrounding bark must stay intact;
- cambium should not be damaged as this will lead to formation of resin pockets;
- correct tools are used; and
- pruning is done during winter months to avoid secondary pathogen infections.

It is recommended that pruning should never exceed the removal of more than 50% of the live crown, as this will cause temporary increment reductions. Pruning up to 25% of the living crown will not affect increment and pruning to 70% causes longer lasting increment problems.

9.2.2  Tools
- Handsaws
  This is the most commonly used type of equipment for pruning. Various types and configurations are available which can be applied depending on the application. Handsaws are safe, fast, effective and enable pruning closer to the stem than is possible with other tools.

- Mechanical saws
  Comprised mainly of small chainsaws with associated fast cutting action. Relative high costs are associated with the purchase of chainsaws, running costs, additional PPE and training requirements of operators. Damage to cambium can be a problem and operators must take care.

- Edged tools
  This comprises axes and slashers. Given the tools are sufficiently sharp and the labour suitably trained, this method would be second choice to hand saws. It is however dangerous working with these tools. Damage to cambium can be severe if the labour is not suitably trained.

- Pruning shears
  These tools are also used but leave longer stubs. Productivity is generally low and this is not the preferred method. It is however advisable where thinner branches are being pruned which do not offer much resistance to handsaws and edged tools. These tools are widely used for *acacia* corrective pruning.

- Clubs
  These are used to remove already dead branches from eucalyptus trees (this is not recommended).

9.2.3  Corrective pruning – *Acacia*
Some wattle trees tend to produce multiple leaders or may fork as a result of damage to the apical bud or leaders by insects, browsers, wind, hail or snow. As the tree grows, the weight of
the foliage on the limbs of the fork increases and splitting often occurs during windy conditions. Such splitting often occurs at a later stage, when all the branches below the fork have died due to shading, and ultimately results in the whole tree dying. There may be leaders (below the break) but they will be deformed and the growth rate will be impaired. Corrective pruning must therefore occur to remove the weaker leaders during the first two years, before the height of the trees makes it impractical and costly. It is common with black wattle, to have two or more shoots coming vertically out at the base and if unchecked these could compete with the leader. Such shoots hinder the development of the main stem and should be removed before they are 2.5cm thick. Early browsing damage normally does not require corrective pruning as a natural leader arises. When browsing damage occurs at a height of 0.6m or more, corrective pruning should be performed.

The removal of living branches alters the growth of the tree temporarily due to the removal of foliage, therefore altering the rate of photosynthesis. The ‘live-pruning’ should be restricted to only correcting forking and the removal of basal shoots. Lateral shoots should never be removed unless they are interfering with access.

9.2.4 Corrective pruning in relation to disease
The cut ends of shoots produced during pruning operations can serve as a source of entry for disease and the following precautions should be adhered to:

- Pruning should be limited to winter months.
- Limit pruning to absolute necessity (stem malformations, forking and hazardous stem side branches).
- A 15cm stub should be left when pruning.

9.3 Thinning
Artificial thinning is the removal of a proportion of individual living trees from a stand before clear felling. It is generally understood to take place after the onset of competition. However, pre-commercial thinnings or respacings may take place when trees start to compete with each other. This implies that the initial planting espacement has made provision for quick canopy closure and having enough stems to select from.

The major objectives of thinnings are to:

- provide remaining trees with more space for crown and root development to encourage stem diameter increment and thus reach the desired size sooner;
- remove trees of poor form;
- prevent severe stress, which may induce pests, diseases and stand instability; and
- provide an intermediate financial return from sale of thinnings.

9.3.1 Management objectives
Thinning regimes are determined by the intended market for the stand. For the production of pulp and mining timber, volume production in a stand must be maximised, ie no thinning or only a light thinning is required. For the production of saw timber, veneer and poles, heavy thinnings are required to produce final crop of trees which will meet the market requirements. There are two main types of thinnings practised, selective and non selective thinnings. Selective thinnings are carried out where the final crop is required to meet a required quality standard saw timber or poles, trees of poor form are removed. Non selective thinnings are used when the stand density is reduced by felling whole rows ie every third row is felled to achieve a 33% reduction row. Thinnings are generally used to limit the cost of the harvesting operation.

The Sirex wasp attacks stressed trees which creates an ideal habitat for their life cycle. The thinning of pine stands is a function of management objectives in saw timber. Stands are
thinned to prevent competitive stress between trees within the same stand. While research into pulp wood thinnings is in progress, good bio-control measures are essential, and it may be considered to reduce the stocking by 30% or up to 1,000 stems per hectare by using selective thinnings at an age of eight years old before the onset of competition. Priority should be given to better sites because trees compete earlier due to the faster growth, making them vulnerable to Sirex infestations. Each fifteenth row can be felled to aid the harvesting operation.

9.3.2 Marking for thinning
This operation is extremely important and must be done by competent persons. The marking should be checked at frequent intervals. A deviation of up to 10% of the prescribed s.p.ha is generally acceptable. The following decision criteria should apply listed in priority:

- Firstly look for defective and diseased trees.
- Secondly look for trees below average size.
- Thirdly even distribution of remaining trees must be maintained.

Plots are laid throughout the compartment generally 20m X 20m apart, which gives an area of 400m². The trees in the plot are counted and then certain trees are selected to reduce the stocking to the required level. To reduce to 1000spha, 40 trees must remain per plot. The trees selected to be removed are marked with paint. The compartment should be checked before harvesting to ensure that the marking was done correctly.

9.3.3 Thinning acacia stands
Acacia stands are generally established at high initial spha. To ensure the production of trees large enough to produce good bark and timber in rotations of 8 to 12 years, it is necessary that these high initial densities be reduced by successive thinning operations.

Thinning is done primarily to reduce the stand density at various stages of the rotation. This is done to reduce competition and ensure an increase in tree growth, and at the same time remove trees that are diseased, damaged, and malformed or those that have been suppressed.

The most valuable function of thinning is the production, from the final crop, of material specific to the demand of the market. Wattle is grown both for its bark and timber and therefore thinning may be adjusted so as to favour either the quality or quantity of production of bark and/or timber. Bark quality is determined by the thickness of the bark, which usually correlates with stem diameter. Relatively heavy thinnings are done to ensure a greater stem diameter in the final crop. When bark is the primary product and timber the secondary product, thinnings should begin early and successive thinnings should be well timed to avoid suppression and prevent rapid growth. Unthinned stands produce a higher number of diseased trees as well as higher suppression, which affects the strip ability and results in a reduction of utilisable timber.

Two different thinning regimes exist for stands established with the natural regenerated / line sowing method and planted stands independently.

Naturally regenerated and direct seeding method:
When the plantation average height is 20-30cm a combination of weeding and spacing is done. Trees are spaced 0.6m apart and first selective thinning is done when the average height is 2m. This results in the trees being spaced 1.2m apart and gives a stand density of 3,000 trees/ha. This thinning is mainly to remove any diseased, damaged, deformed, or suppressed trees. The second thinning is done when the stand is approximately 4.0m high and the density after thinning is approximately 2,000 trees/ha. The final thinning is done when the trees are an average height of 7.0m with a density of 1,500 trees/ha after thinning, on medium quality sites; 1,650 trees/ha on good quality sites and 1,350 trees/ha on poor quality sites.


Planted stands:
Two or more thinnings are required in plantations established with seedlings. When the initial density is 2,222 trees/ha, two thinnings are planned. The first thinning is done when the average height of the trees are 4.0m high and the stand is reduced to a density of 2,000 trees/ha. The second thinning is done when the trees are 7.0m tall and the stand is reduced to 1,500 trees/ha, or less if on a poor site. (See stocking densities in Table 9.1). A ten meter rope is used when marking trees for thinnings. The rope is pulled between two rows creating a 60m² plot 10m x 6m’s (for 3m row spacing) and trees are marked to leave the required number of trees along the rope.

<table>
<thead>
<tr>
<th>Age in years</th>
<th>Ht</th>
<th>Operation</th>
<th>Stocking</th>
<th>Espacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>Seedlings</td>
<td>2222</td>
<td>3m x 1.5m</td>
</tr>
<tr>
<td>± 2</td>
<td>4m</td>
<td>1st Thinning</td>
<td>2000</td>
<td>1900</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Method: use 10m rope between 2 rows and leave.</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>3-4</td>
<td>7m</td>
<td>2nd Thinning</td>
<td>1650</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Method: use 10m rope between 2 rows and leave.</td>
<td>10</td>
<td>9</td>
</tr>
</tbody>
</table>

**Table 9.1:** Stocking densities.

---

1 Richardson – 1993.
5 WRI – 1959.
10.1 Introduction

The preparation for coppice reduction commences with the harvesting of a compartment as harvest planning should take cognisance of whether the compartment will be replanted or coppiced. The trees should be felled leaving a stump height of between 10–15cm above ground height. Ensure that bark is not stripped downward below the 10–15cm stump height; this will ensure that the bark remains intact around the stump. This will reduce infections, stump mortality, poor coppice growth and attachment of the stem to the stump. It will also not destroy any dormant buds.

With regards to *Eucalyptus nitens*, the higher the stump left, the greater the number of epicormic buds available for regeneration. Coppicing of *E. nitens* should only be considered if there are sufficient live stumps and the coppice regrowth is healthy, failing which it would be advisable to replant the area.

During harvesting ensure that all stumps remain free of bark and brush. Also ensure that no stump damage occurs during extraction operations as this may rip the bark off the stump or bruise the dormant buds. For this reason, extraction routes should be planned prior to harvesting operations commencing to ensure that the minimum area of a compartment is damaged.

Coppice reduction should only be considered if the compartment has more than 1,100 live stumps per hectare. This will allow one to bring the stand back to the original stocking of the planted stand by leaving additional stems per stump to compensate for dead stumps within the compartment. In considering coppicing a compartment versus replanting, one needs to consider the following:

- Amount of live stumps per hectare and consider the entire compartments health.
- Consider the number of times the compartment has been coppiced and consider the benefits of the improved quality of seedlings which have been produced over the length of your previous rotation. These improved seedlings have improved fibre yield giving one a better mean annual increment (MAI) for the next rotation, if the area is replanted.
- Consider that costs per hectare of doing coppice reduction verses re-establishment costs and carrying these costs for a rotation length.
- Bare in mind that, even with coppice or re-establishment the best returns and growth on eucalyptus are achieved from a compartment that have had limited weed competition.
10.2 First coppice reduction

- Depending on the areas and hence the growth, the first reduction must be done when the shoots are between 2 - 4m in height and should be reduced to two or three stems per stump.
- The reduction is best performed by means of a hatchet to reduce the damage to adjacent stems. A cane knife has a wider blade and therefore cuts into adjacent stems which could result in wind falls.
- Stems should be cut as low as possible, preferably flush with the stump. This ensures improved callusing and therefore better attachment of the stem to the stump. It also ensures less feathering on the cut stems.
- The remaining shoots must be dominant, well spread around the stump, firmly attached and the lowest on the stump.
- The shoots should be well matched in height, have a straight form and the difference in their diameter should be less than 1cm.
- Shoots should preferably be on the windward side of the stump, especially on exposed sites and if only one stem is present on the stump. This will reduce the effect of windfalls.
- Although it is best to do coppice reduction during the winter months, try to avoid doing work in exposed sites during July/August where berg winds could damage the thinned stand and blow the newly thinned coppice over.

10.3 Second coppice reduction

- Stump mortality should be calculated before the second coppice reduction is undertaken to determine the percentage reduction.
- The number of shoots should not exceed the original compartment stocking; therefore two or one shoot per stool is left once the shoots are 6–7m in length.
- If more than one shoot per stump is required to fill gaps (as a result of dead stumps), and thus ensure adequate stocking, select the larger diameter stumps adjacent to the gap.
- Leave two shoots per stump for stumps which occur along the compartment boundary.

10.4 Feathering

- After the first and second coppice reductions new growth may appear around the base of the stump. This feathering should be kept in check and removed by means of a hatchet to ensure optimum coppice growth. Feathering should not be allowed to grow more than 0.5m in height.
- Coppice dominance and the shading effect from the coppice will reduce the re-occurrence of feathering.
11.1 Pruning
The aim of pruning is to improve the form of the tree. Pruning may be required if heavy side branches develop or forked growth occurs. This may occur due to mechanical damage, insect, hail, animals. Trees should be pruned before they are 2m in height. All basal shoots and weak leader forks should be removed using secateurs. It is important to leave a 15 to 20cm stub to prevent gummosis entering the main stem.

11.2 Thinning
A useful formula for calculating the correct stem count:

\[
100000 / (2 \times \text{average row width} \times \text{target stem count}) = \text{Distance in meters between two rows over which the stem count is reduced to ten trees within the length calculated.}
\]

11.3 First thinning
- The objective is to remove any diseased, deformed or small trees and leave a uniform stand of 2,000 trees per hectare.
- This thinning may be unnecessary as high mortality may have occurred prior to planting and blanking.
- When the trees are 4m tall reduce the stocking to 2,000 stems per hectare.
- A practical method is to leave 12 of the best trees along a 10m length of rope which is laid down along the inter-row. This is applicable to plantations planted at a 3 x 1.5m espacement. Select the best trees from both rows adjacent to the rope. See Table 11.1.
- A hatchet should be used to perform the operation and the trees should be cut below the ground level, or the bark peeled down below the soil level.
### Chapter 11: Wattle Specific Silviculture

#### 11.4 Second thinning

- The second thinning is imperative. The first thinning may be delayed or left out, but the final yield will be reduced if the second thinning is not done.

- At a height of 7m reduce the stocking to 1,500 trees per hectare. Using the rope method, lay a 10m length of rope down within the inter-row and leave 9 trees within the 10m length, selecting trees from both rows adjacent to the rope. See Table 11.1.

- The spacing of the trees should be taken into account during the second thinning as the weaker trees should have been removed with the first thinning operation.

- This operation should generally be completed by the end of the second year of growth.

<table>
<thead>
<tr>
<th>Age</th>
<th>Ht</th>
<th>Operation</th>
<th>Stocking</th>
<th>Site Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Seedlings</td>
<td>2,222</td>
<td>3 in rows x 1.5m in row</td>
<td>Site Quality</td>
</tr>
<tr>
<td>+/-2</td>
<td>4m</td>
<td>1st Thinning</td>
<td>2,000</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Method: use 10m rope between 2 rows and leave</td>
<td>II</td>
<td>1,900</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>III</td>
<td>1,800</td>
</tr>
<tr>
<td>+3-4</td>
<td>7m</td>
<td>2nd Thinning</td>
<td>1,650</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Method: use 10m rope between 2 rows and leave</td>
<td></td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>II</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>III</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6-12 months before clearfelling: Pre harvest cleaning of non-strips</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clearfelling</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clearfelling</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Table 11.1: Wattle thinning – rope method.²

---

² Sappi RMS Doc. ES1, Doc 022.
12.1 Introduction

Wildfires are a risk to life, property and the environment. South Africa is becoming more and more vulnerable to veldfires because of urbanisation and the development of rural areas.

Without preventative measures, veldfires will continue to burn for as long as the weather is favourable and there is vegetation to burn. Anyone owning land has the first responsibility to manage fire risks and to control fires on his or her property. The National Veld and Forest Fire Act 101 of 1998 (hereafter referred to as the Act) is applicable to all landowners and not only to forest owners. Fire management can be subdivided into three elements – prevention, protection and suppression.

This chapter will cover the most important aspects of fire management.

12.2 Fire prevention

The first step to manage fire risk is to do a fire risk assessment. Each possible risk must be listed and analyzed to understand the condition, the non-conformance and then it must be rated to determine a risk index, which is classified as a high, medium or low risk.

A preventative or corrective action must be drawn up to manage the risk or to eliminate the risk. The different types of risks include non conforming firebreaks, power lines, high fuel loads, charcoal kilns, arson, beehive theft or inadequate communication systems.

The fire management plan must then be based on the risk assessment.

12.3 Fire protection

Fire protection is the process of protecting your assets against wild fires. The Act stipulates the responsibilities of people in control of land:

- prepare firebreaks on their side of the boundary if there is a reasonable risk of veldfire;
- have the necessary equipment, protective clothing and trained personnel for extinguishing fires;
- do everything in their power to stop the spread of the fire.
12.3.1 Fire breaks

- The Act doesn’t specify requirements for fire breaks. This is because requirements will vary from one situation to the next. For example, on the Cape peninsula, firebreak requirements would be different to what is needed in the eastern Free State.
- Local practice and local issues should determine the requirements.
- The Act states that the owner must pay attention to weather, climate, terrain and vegetation in deciding on how to prepare the breaks.
- The fire break must:
  - be wide enough and long enough to have a reasonable chance of stopping the veldfire;
  - not cause soil erosion; and
  - be reasonably free of flammable material.
- **Table 12.1** provides a guideline for fire break regions.

<table>
<thead>
<tr>
<th>Fire break type</th>
<th>Burning prescription</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Breaks (EB)</td>
<td>Burn annual</td>
</tr>
<tr>
<td>Internal Breaks (IB)</td>
<td>Burn bi-annual</td>
</tr>
<tr>
<td>Conservation Areas (CA)</td>
<td>Burn bi-annual</td>
</tr>
<tr>
<td>Power Lines (PL)</td>
<td>Burn annual</td>
</tr>
<tr>
<td>Public Roads (PR)</td>
<td>Burn annual</td>
</tr>
<tr>
<td>Buffer Zones (BZ)</td>
<td>Low fuel load areas</td>
</tr>
</tbody>
</table>

**Preparation of fire breaks:**

- Prepare a trace in advance on the perimeter of the fire break.
- Traces can be graded, hoed, chemical treated or disked (see **Photo 12.1**). Trace belts are normally between 2 and 3m wide.
- Chemically prepared traces must be burned after the treatment to create a clean strip.
Fire break burning

Burning of fire breaks must be done within set parameters in order to reduce risk. **Figure 12.1** provides an example of the possible impacts on fire break burning. Get permission from your FPA and inform your neighbours.

### Photo 12.1: Various trace types.

<table>
<thead>
<tr>
<th>Hoed trace</th>
<th>Chemical trace</th>
<th>Graded</th>
<th>Disked</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Hoed trace" /></td>
<td><img src="image2.png" alt="Chemical trace" /></td>
<td><img src="image3.png" alt="Graded" /></td>
<td><img src="image4.png" alt="Disked" /></td>
</tr>
</tbody>
</table>

### Figure 12.1: Fire management activity checklist.†

<table>
<thead>
<tr>
<th>Quality</th>
<th>Supervisor</th>
<th>Contr Manager</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 or X</td>
<td>0 or X</td>
<td>0 or X</td>
<td>0 or X</td>
</tr>
<tr>
<td>1. Weather suitable for burning; Max FDI forecast 50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. FDI &gt; 45: Burning only allowed if adjacent fuel loads relatively low; good radio communications between burning teams, contractor and forester; sufficient resources used; standby resources available immediately in case of emergency; break easily accessible by road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Maximum foroos; 3 days not exceed 55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Inland FDI readings; to be recorded every hour when FDI &gt; 45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. All stakeholders notified as required</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. If on boundary, neighbour or his representative present</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Sufficient resources as required by the forester (as per local SOP)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Burn according to local SOP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Avoid outside traces; sufficiently green to facilitate safe burning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Grass on traces dry enough to ensure a clean burn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Clean burn obtained (no poorly burnt; patches)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Proper mopup done according to local SOP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Forester and all other stakeholders notified of burning completed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Area guarded when required (as per local SOP)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Health &amp; Safety</th>
<th>Supervisor</th>
<th>Contr Manager</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 or X</td>
<td>0 or X</td>
<td>0 or X</td>
<td>0 or X</td>
</tr>
<tr>
<td>1. Correct PPE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Compliance with WCB?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. All fire tools, equipment, and vehicles in good working condition</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fuel load management
Fire needs oxygen, fuel and heat to burn. In the process of growing trees we add fuel to the forest floor which adds to the intensity of any fires which may occur. The more intense the fire is, the more difficult it is to contain and the greater the damage to the growing crop. The critical success factor is to create low fuel load zones inside the plantation from which wild fires can be contained. Fuel load management is the best tool to reduce the risk inside a plantation. To understand the risk of high fuel loads it is necessary to do a fuel load classification for each compartment. Based on this classification the owner can then update his fire management plan to address the high risk areas. This assessment must be done annually.

Fuel load management tools
To reduce the buildup of fuels inside a plantation it is important to burn harvesting residue after harvesting, and to keep compartments weed free until canopy closure.

Coppice and pruning operations create plantation residue, which increase fuel loads. The fuel loads can be reduced by selling droppers out of coppice residue. Residue can be mulched or rotary slashed.

Keep compartments weed free to ensure low fuel loads. Grazing of natural areas and compartments older than three years will reduce fuel loads.

Fire equipment
It is a requirement of the Act that each landowner must have adequate fire fighting equipment. Equipment requirements should be proportional to the risk. The local Fire Protection Association will normally have minimum requirements, as well as agreements between neighbours for assistance during wild fire events.

Fire crews
Section 17 of the Act and the Occupational Health and Safety Act require an owner to have trained personnel for extinguishing veldfires. Regulations under the latter Act provide minimum standards for protective clothing and training of firefighters. The local Fire Protection Association will specify any other minimum requirements. People younger that 16 and older than 60 are not allowed to be involved in fire fighting.

Communication
The ability to communicate with all role players in the fire fighting process is critical.

12.3.2 Water filling points
The availability of water during the fire fighting process is crucial. Water filling points throughout the property will reduce refilling time, therefore increasing the availability of water. These points can be:

- dams;
- river crossings with an available suction point;
- overhead pipes (hydrants);
- overhead tanks;
- pump facilities (borehole/dam).
12.3.3 **High danger zones**

Large volumes of combustible material need to be identified and additional preventative measures are required. High concentrations of mature plantations in one specific area should be isolated to reduce financial loss. This can be done by clearing all roads and routes of combustible materials. The compartments can be divided into 5-hectare sections by clearing certain interrows but this may be a costly exercise. During high fire index periods these areas should be patrolled more often.

12.3.4 **Lookouts / camera systems**

Fire detections systems on a 24-hour basis are essential for any timber plantation.

Lookouts are situated on predetermined vantage points for the maximum cover of a plantation. The lookouts are normally shared by different plantation owners and the lookouts are in contact with all the different land owners. The shared detection lookouts became more advanced in the late 1990s when digital camera systems replaced the manned lookout towers.

12.3.5 **Fire Protection Associations (FPA)**

Chapter 2 of the Act regulates the formulation of Fire Protection Associations (FPA) as follows:

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**INTRODUCTION TO FIRE PROTECTION ASSOCIATIONS (FPAs)**

**Reasons for FPAs**

- Co-operation among rural owners and managers of land is required for the effective management and prevention of veldfires.
- Government cannot take on the duties and responsibilities of landowners for fire protection. The Act places this responsibility on landowners.

**Advantages of FPAs**

- Promote co-operation in fighting and preventing veldfires.
- Cost saving by avoiding duplication of services.
- The fact that FPA rules are enforceable in the FPA area protects members from the actions of non-members.
- Fire protection officers (FPOs) are empowered to enforce the Act and FPA rules.
- Advice and assistance to members.
- Improved communication between members.
- Improved communication between members and the Minister and other role players.
- Possible relief from certain prevention measures, for example, the duty to create and maintain firebreaks.
- Decreased risk of veldfires.
- Organised groups have better negotiation powers.
- Possible decreased insurance premiums.
- Possible assistance from the Minister.
- No presumption of negligence in civil claims.

**Costs in forming an FPA**

- The costs of forming and running an FPA include:
  - Time needed for meetings to set up and run the FPA.
Having to report to the Minister on fire statistics and provide information for the fire danger rating system.
- Possibly having to pay FPO and other officials.
- Administrative efforts of keeping an FPA running, for example, keeping a register of all members and informing members of the current fire danger rating.
- Other maintenance costs, for example, costs incurred by the FPO in travelling to inspect members’ land.

**Costs versus benefits**
- An FPA should not be formed where its costs will be greater than the benefits it provides to members (FPAs should be cost-beneficial).
- FPAs should be established in areas where the hazard of veldfires justifies the costs of organising and maintaining the FPA.
- The justifiable level of hazard must be judged locally.
  - For example: in the Cape Peninsula, the hazards of veldfires on the urban edge are so great that establishing an FPA is cost-beneficial.

**When may an FPA be formed?**
Section 3 of the Act says any group of owners who wish to co-operate to predict, prevent, manage and extinguish veldfires may form an FPA.

**Who is an “owner”?**
“Owner” has its common law meaning and includes:
- any landowner with a title deed to property
- lessees
  - lessees who lease DWAF commercial plantations
  - a person who rents land from the owner
- any person controlling land under a contract
  - a lease is a type of contract
- any person controlling land under a law
  - for example, managers of State forests who control the land under the National Forests Act
- any person controlling land under a will
  - for example, where someone has the right to control land until he/she dies, at which point it will go to the heir
  - any person controlling land under an order of the High Court
- the executive body of a community set up under its constitution, law or custom
- a Minister or person authorised by him/her where the land is State land and it is not controlled by someone else
- a member of the executive council or a person authorised by him/her where the land is provincial land and is not controlled by someone else
- the chief executive officer of any local authority or a person authorised by him/her.

**What about communities?**
- Land controlled by a community could be private land (where the community owns it), or State land held in trust.
Most land controlled by communities is held in trust by the State or the Ingonyama Trust.
The National Veld and Forest Fire Act states that where land is controlled by a community, regardless of the ownership of the land, the executive body of that community is the owner.
The executive body can exist in terms of:
- its constitution (where the community has formed a communal property association and owns the land)
- any law (for example, where a tribal authority was appointed by law) or
- custom or customary law (where a chief or headman and the tribal elders may control the land)

Several different communities might control different portions of a single piece of State land held in trust.
Each community should be represented in the FPA by its executive body.

What about State land?
Only where State land is not controlled by:
- a person contemplated in s2(1)(xiii)(a) (a title deed holder, lessee, or person controlling the land in terms of a contract, will, law or order of the High Court) or
- a community
will the Minister of the government department or member of the provincial executive council exercising control over the land, or a person authorised by him or her, need to be represented on the FPA.

Membership of FPAs is voluntary for most owners
- Landowners can choose whether to join the FPA or not.
- This is because:
  - the right to freedom of association in the Constitution must be upheld; and
  - landowners themselves need to make firm commitments to co-operate through FPAs.

Who is compelled to join an FPA?
- The owners of:
  - State land
  - municipal land where there is a fire service
  - State land means:
    - national or provincial land
    - land held in trust for communities by the Minister of Land Affairs or the Ingonyama Trust
    - excluding municipal land

Boundaries of FPAs
- Section 3: The area where an FPA is formed should be relatively uniform in terms of
  - having regular veldfires or
  - its veldfire risk or
  - its climatic conditions or
  - its forest types or other vegetation
• Form FPAs only where they are definitely needed.
• The area of an FPA should be optimum, that is, not too big to be able to fulfill duties and not too small to justify the costs involved.
• The Act leaves this matter open – each case must be judged on its own circumstances.
• An FPA may usefully correspond with one or more local municipalities (category B).
• But there may be cases where an FPA would for good reasons include only part of the area of a local municipality.

Prioritisation of FPAs
• DWAF will establish the framework for priorities in the country, by using a “risk assessment” modeling approach that ranks district municipalities according to the overall fire risk in each district.
• These will be discussed and finalised with provincial disaster management centres (DMCs) by DWAF.
• DWAF Fire Advisors will then inform local DMCs.
• Fire Advisors will establish communication with local initiators of FPAs:
  o district DMCs
  o fire services (chief fire officers (CFOs))
  o emerging umbrella FPAs
  o local leaders
  o nature conservation authorities
• Fire Advisors will advise initiators on the priorities for their districts and the optimum configuration for FPAs in their districts.

Where no FPA has been formed
• The Minister may intervene when no FPA has been formed in an area in which he/she is of the opinion one should be formed.
• Minister may call a meeting to discuss setting up an FPA and to establish what kind of support is required.
### 12.3.6 Fire danger rating (FDI)

<table>
<thead>
<tr>
<th>Alert Stages</th>
<th>BLUE</th>
<th>GREEN</th>
<th>YELLOW</th>
<th>ORANGE</th>
<th>RED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Danger Index</td>
<td>0 - 20</td>
<td>21 - 45</td>
<td>46 - 60</td>
<td>61 - 75</td>
<td>76 - 100</td>
</tr>
<tr>
<td>Behaviour</td>
<td>Safe</td>
<td>Moderate</td>
<td>Dangerous</td>
<td>Very Dangerous</td>
<td>Extremely Dangerous</td>
</tr>
<tr>
<td>Flame Lengths</td>
<td>0 - 1</td>
<td>1 - 1,2</td>
<td>1,2 - 1,8</td>
<td>1,8 - 2,4</td>
<td>2,4+</td>
</tr>
<tr>
<td>Control Guide</td>
<td>Fires are not likely to start. If started they spread very slowly or may go out without aid from suppression forces. There is little flaming combustion and intensity is low under all conditions. Control is readily achieved and little or no mopping up is required.</td>
<td>Ignition may take place near prolonged heat sources (campfires etc) spread is slow in forests, moderate in open areas. These are light surface fires, with low flames. Control is readily achieved by direct manual attack methods and with minimum forces, difficulty may be experienced on exposed, dry slopes and some light mopping up will be necessary.</td>
<td>Extreme caution should be taken when controlled burning is carried out. Aircraft should be called in at the early stages of the fire.</td>
<td>Ignition can occur readily, spread may be fast in the forests though not for sustained periods. Grass fires could outstrip forces with a spread of approx. 7km/hour. Fires may be very hot with local crowning and &quot;short to medium range&quot; spotting. Control will be very difficult requiring indirect attack methods with major assistance necessary. Mopping up may require an extended effort.</td>
<td>Ignition can occur from sparks. Rate of spread will be extremely fast for extended periods. Fires will be extremely hot with a dangerous heat effect on people within 10m of fire and there may be extensive crowning, fire whirls and &quot;long range&quot; spotting. Control may not be possible by frontal attack during the day and fire fighters should limit their efforts to containing lateral spread - until weather changes. Damage potential total and mopping up operations may be very extensive and difficult. Full assistance necessary throughout.</td>
</tr>
</tbody>
</table>

The local FPA will have standard operating procedures and regulations during high FDI periods.
12.3.7 Fire fighting equipment
The equipment required by the grower for effective fire fighting is influenced by assistance from neighbors and fire fighting associations. The FPA will set minimum requirements.

Standard or minimum equipment will be:
- quick reaction unit (bakkie sakkie);
- water tanker (truck or tractor drawn);
- rake hoes;
- fire beaters; and
- knapsack sprayers.

12.3.8 Aerial fire fighting associations
Aerial fire fighting associations have been part of forestry for a number of years. The decision by the landowner to join the association and share in the benefit of this quick reaction unit is voluntary. Since 2001, insurance companies require land owners to be active members of the associations in order to qualify for insurance and discounts.

12.3.9 Insurance
The value of forests throughout South Africa has more than doubled during the past ten years. Many private growers have converted from mixed farming practices to pure timber farms and their total income depends on their timber crop. It is for this reason important for the grower to insure his timber based on the value of the timber, and this should be done annually to ensure adequate cover.

12.4 Suppression
Suppression includes all the actions to contain and to extinguish a fire. Pre suppression planning is critical to ensure early detection, quick response and a well organized suppression operation.

Each FPA area will have a Standard Operating Procedure for high fire danger days. These operating procedures set certain standard to which all landowners must conform, in order to ensure that crews are ready for any call outs to a fire.

Your local FPA will be able to assist with the planning during a high danger day, provide landowners with weather information and any other support needed. Working together during fire suppression activities is critical. Take part in your FPA's readiness actions.
12.5 Mopping up

Please Note!
As soon as the burning operations start, the real work begins: “MOP-UP”!

CHECKLIST

<table>
<thead>
<tr>
<th>RULE</th>
<th>WHAT?</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Procedure</td>
<td>Always have a small team available right from the beginning to guard the rear (completed section of the burn) and start mopping-up as soon as a section has been burned and continue following up as the burn progresses. This unit should consist of a bakkie-sakkie or strike unit on smaller burns, and a fire tender in the case of larger burns and slash burns with a few trained labourers, depending on the size of the burn. The mop-up unit should always be able to keep up with the pace of the burning crew! The mop-up unit will only move forward if the section is 100% safe, if not, slow down the burning process!</td>
</tr>
<tr>
<td>Start mopping-up as soon as a section of the burn has been completed</td>
<td>Work from the fire line toward the centre of the fire. On larger burns, such as large open areas or slash compartments, mop-up a minimum of 30m, or to such a distance that nothing will blow, roll or spot across the line.</td>
</tr>
<tr>
<td>Secure and extinguish burning materials</td>
<td>Arrange burning fuels so that it cannot roll across the line. Spread smouldering fuels and apply water. Scatter fuels away from the line. Open up stumps and roll over logs and ensure it is completely extinguished.</td>
</tr>
<tr>
<td>Reinforce the fire line</td>
<td>Widen and clean the fireline next to problem areas. Burn out islands (unburned sections). Dig out dead or burning roots that cross under the fireline. Feel for hot material along the fireline. (Or make use of Knox scanner). Ensure that this line is properly anchored on both ends.</td>
</tr>
<tr>
<td>Check for spot fires</td>
<td>Constantly check for spot fires, especially downwind from the fireline. Check heavier fuels (logs, snags, slash, etc.) for smouldering material.</td>
</tr>
</tbody>
</table>

Trace line construction

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Width of Hand line</th>
<th>Width of mineral soil in Hand line area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>0.5 to 1 meter</td>
<td>0.05 to 1 meter</td>
</tr>
<tr>
<td>Medium shrubs</td>
<td>1 to 2 meters</td>
<td>200 to 400mm</td>
</tr>
<tr>
<td>Heavy shrubs</td>
<td>1 to 2 meters</td>
<td>0.5 to 1 meter</td>
</tr>
<tr>
<td>Very heavy shrubs or harvesting slash.</td>
<td>7 meters</td>
<td>1 meter</td>
</tr>
<tr>
<td>Inside Plantation</td>
<td>7 meters</td>
<td>1 meter</td>
</tr>
</tbody>
</table>

1 Sappi RMS.
13.1 Introduction

This chapter deals only with the major diseases of commercial forestry trees in South Africa. Only the common commercial tree species affected are mentioned, and where applicable photographs are inserted.

Further detailed information and help can be obtained from:
Prof. Mike Wingfield or Dr. Jolanda Roux
The Tree Protection Co-operative Programme (TPCP)
FABI (University of Pretoria)
Tel: 012 420 3938
Fax: 012 420 3960
www.fabinet.up.ac.za

Acknowledgement for help and material used in this chapter is given to FABI - Prof. M. Wingfield, Dr. J. Roux and R. Heath, ICFR - Prof. C. Dyer and SAWGU - J. Feely. Extensive use was made of most of the FABI/TPCP disease pamphlets that are freely available from FABI. Before collecting and submitting any samples to FABI, please consult the relevant FABI pamphlet on sample collection and submission.

13.2 Eucalyptus Diseases (gum)

13.2.1 Leaf diseases

(a) BACTERIAL BLIGHT

The causal agent of bacterial blight is *Pantoea ananatis*. Other bacterial leaf spots, caused by *Xanthomonas* sp. also occur, but under field conditions *P. ananatis* is the major problem.

*Species affected:*

It has been reported from *Eucalyptus* clones, hybrids and species including *E. grandis*, *E. saligna*, *E. dunnii*, *E. nitens*, *E. smithii*, *E. grandis* x *E. camadulensis* (GC) and *E. grandis* x *E. urophylla* (GU).
### Symptoms:

Typical symptoms of bacterial blight include tip die-back and leaf spots on young leaves (Photo 13.1). The leaf spots are initially water-soaked and often coalesce to form larger lesions. The pathogen appears to spread from the leaf petiole into the main leaf vein and from there to the adjacent tissue. Thus lesions on the leaf are often concentrated along the main veins. Leaf petioles become necrotic, which results in pre-mature abscission of the leaves. Trees assume a scorched appearance in the advanced stages of the disease and after repeated infections become stunted. In humid conditions bacterial exudates are often evident on diseased tissue. The trees have a bushy appearance.

### Spread of disease:

Bacterial blight and die-back on *Eucalyptus* is more prevalent in areas in South Africa where the summer temperatures are warm, rather than hot and the relative humidity high. Bacteria such as *P. ananatis* can be spread by water, infected plant material, insects and equipment such as pruning shears in nurseries.

![Photo 13.1: Tip die-back symptoms caused by *P. ananatis*](image)

### Management:

Bacterial blight and die-back has become a serious problem in nurseries and young plantations throughout South Africa. There are differences in susceptibility among *E. grandis* clones, and disease tolerant plants should be selected.

(b) **BACTERIAL WILT**

Bacterial wilt, caused by *Ralstonia solanacearum* is economically one of the most important diseases of bacterial origin, in the world.

### Species affected:

*Eucalyptus* spp. differ in their susceptibility to this pathogen but the most susceptible are: *E. grandis*, *E. saligna* and *E. grandis* x *E. urophylla* hybrid.

### Symptoms:

Bacterial wilt is reported to be most severe on young *Eucalyptus* trees of approximately 18 months old and younger. Early symptoms include foliar discolouration or death of single branches, often towards the lower end of the canopy. Infected trees wilt and die as a result of root rot. Internal symptoms of infection include the discolouration of the wood (Photo 13.2) and the exudation of slimy bacterial ooze from cut roots and root collars. The wood of infected plants are stained a dark brown with darker blue or black streaks. Infected trees mostly die.
Spread of disease:
A variety of modes of transmission exist and these tend to be associated with planting stock and soil. The bacteria wilt pathogen may be transmitted to new areas on vegetative planting material such as infected cuttings, insects, nematodes, mechanical transmission, root to root transmission, water and soil. *Ralstonia solanacearum* enters plants through wounds made in roots and from there spreads to the xylem vessels through which the bacteria systemically infect the plant. This bacterium thrives in sub tropical to tropical areas, typically Zululand coastal region.

Management:
It is recommended that only bacteria-free propagation material should be used and that pruning sheers should be disinfected when moving from one *Eucalyptus* plant to another. Infected soil should be kept fallow for about a year and frequently disked during the dry season to accelerate desiccation of plant material and the death of bacteria. Many weed species are hosts of *R. solanacearum*. Therefore, weed control should minimise outbreaks of the disease in an infected area.

(c) MYCOSPHAERELLA LEAF BLIGHT
*Mycosphaerella* leaf blotch is a serious disease of cold tolerant *Eucalyptus* spp. grown in South Africa. More than 30 species of *Mycosphaerella* has been reported from *Eucalyptus* spp. world-wide, although not all result in disease epidemics. In South Africa, *M. nubilosa* is the major cause of disease.

Species affected:
Several *Eucalyptus* spp. are affected by *Mycosphaerella* spp., but in South Africa problems of economic importance have only been recorded from *E. nitens* and *E. globulus*.

Symptoms:
The disease can be identified by the presence of necrotic spots or patches on the leaves (Photo 13.3). The foliage may be crinkled or distorted. In severe cases, premature abscission of leaves occurs. Lesions can vary in colour from light to medium brown. Differences in lesion colour have been recorded between the upper and lower surface of...
leaves. Lesions can be angular to circular or irregular. They can be surrounded by margins, which are often raised and darker than the centre of the lesion. These margins can vary in colour from yellow to red or red-purple. Several species have the ability to cause blotches through the coalescence of spots. These symptoms ultimately result in the distortion of the leaf lamina.

**Spread of disease:**
The spores of these fungi are wind-borne. The spores are released when the relative humidity is high. Rain splash also disperses the fungus within a tree. Optimal temperatures for infection vary from 15 to 20°C.

**Management:**
*Mycosphaerella* leaf blotch is most serious on juvenile leaves of susceptible trees. Once adult leaves appear, usually within a year, the disease is of minor importance. In severe cases infection and subsequent defoliation may result in reduced photosynthesis and thus reduced growth. Chemical control could be effective in plantations in the first year of growth and this is currently under consideration. Selection of disease tolerant provenances is possible. In South Africa for example it is recommended to plant the Northern Provenance of *E. nitens*. *Mycosphaerella* leaf blotch is also more severe where *E. nitens* is planted below altitudes of 1,300m in KwaZulu Natal and 1,500m in Mpumalanga.

13.2.2 Stem diseases

(a) **BOTRYOSPHAERIA CANKER**
*Botryosphaeria* canker and die-back is one of the most important and common diseases of *Eucalyptus* spp. in South Africa. The disease in South Africa is caused by *Botryosphaeria eucalyptorum* and *B. ribis*.

**Species affected:**
All species of *Eucalyptus* especially *E. camaldulensis* and *E. grandis*. 

Photo 13.3: Blotches on *Eucalyptus* leaves, caused by *Mycosphaerella*.
Symptoms:
There are many symptoms associated with *Botryosphaeria* infection on *Eucalyptus* species. A common symptom is death of tree tops and this can lead to infection of the pith and a core of discoloured wood surrounded by a healthy sheath of outer wood that often extends throughout the entire length of the tree. This often develops after trees have been exposed to hot winds or the growing tips of young (one to two year-old) trees have been damaged by late frost (Photo 13.5).

A serious symptom associated with *Botryosphaeria* infection is the development of stem cankers. These cankers are most common on trees stressed by drought and are characterised by stem swelling, bark cracks and exudation of copious amounts of black/red kino. These kino pockets persist in the wood and render it unacceptable for saw timber production. Also, *Botryosphaeria* spp. are endophytes, which means that they can infect trees without causing visible signs of disease. Only after the onset of stress does infection become apparent when the fungus starts multiplying and spreading within the tree, causing disease symptoms.

*Botryosphaeria* spp. may infect trees through stomata on the leaves. *Botryosphaeria* canker is especially common on trees planted off-site, resulting in the development of stem cankers. These first become visible as small cracks, with the exudation of kino (Photo 13.4). These cracks may develop into larger, girdling cankers which seriously affects wood quality and growth, and may result in stem breakages.

Spread of disease:
The fungus is an opportunistic pathogen that manifests itself under conditions of environmental stress. These stress symptoms include drought, frosts, cold and hot winds, branch pruning, insect damage and off-site planting. Species of *Botryosphaeria* spread via airborne spores that can also be spread through rain splash.

Management:
Select clones of *E. grandis* that have a high degree of tolerance to *Botryosphaeria*. Prevent unfavourable growing conditions by means of site species matching.
(b) **CRYPHONECTRIA CANKER**

There are two species of *Cryphonectria* causing disease of *Eucalyptus* spp. in South Africa. *Cryphonectria eucalypti* (synonym: *Endothia gyrosa*) is a secondary stress related pathogen in the country, while *Cryphonectria cubensis*, is one of the most important diseases of *Eucalyptus* in areas of the world where these trees are grown as exotics in plantations.

Disease caused by *C. cubensis* was discovered in South Africa in 1988 and has already resulted in the elimination of a number of valuable *Eucalyptus* clones.

**Species affected:**

*E. grandis, E. camaldulensis, E. saligna* and hybrids (GU and GC).

**Symptoms:**

*Cryphonectria* canker caused by *C. cubensis* commonly kills young trees in the first two years of growth by girdling stems at the base. Girdled trees wilt and appear to die suddenly in the summer during hot dry periods (*Photo 13.7*). Susceptible trees that escape death tend to have swollen bases surrounded by cracked bark (*Photo 13.6*) on which the asexual fruiting structures of the fungus can easily be seen using a simple hand lens. These trees may die as competition in developing stands increases during the rotation.

Infection by *C. eucalypti* mostly results in superficial bark cracks on the basal parts of the stem. These cracks may provide entry sites for *Botryosphaeria* spp. Under conditions of stress, *C. eucalypti* may kill trees, but generally it is not considered a serious pathogen in South Africa.

*Photo 13.6* (left): Cracked and swollen base typical of *Cryphonectria* canker on older trees.

*Photo 13.7* (right): Young trees wilt and die.
**Spread of disease:**
*Cryphonectria cubensis* infects trees through wounds. Infection of the bases of young trees is the most common. Infection sites are presumed to be natural growth cracks at the root collar. The spores are dispersed by rain splash.

**Management:**
The most effective means of avoiding losses due to *Cryphonectria* canker is to select disease tolerant clones. Relative susceptibility of clones can be assessed by artificial inoculation of trees and such screening has proven to be particularly useful in reducing the incidence of the disease in South Africa. More rapid techniques to screen trees for tolerance to infection by *C. cubensis* are currently being developed.

(c) **CONIOPTHYRIUM CANKER**
*Coniothyrium* canker of *Eucalyptus* spp. has emerged as one of the most serious threats to the South African forestry industry. *Coniothyrium zuluensi*, the causal agent of *Coniothyrium* canker was thought to be native to South Africa, but has in the last few years been found in several other countries, including some in South America, Asia, Central America and Africa.

**Species affected:**
Clones and hybrids of *Eucalyptus grandis*.

**Symptoms:**
The initial infections occur on the young, green stem tissue and give rise to small discrete spots on the bark. These lesions may merge to give rise to large patches of dead, black bark that is often cracked and exudes copious amounts of kino (*Photo 13.9*). *Coniothyrium* canker in South Africa is often referred to as "measles disease" (*Photo 13.8*). Infection typically occurs at the start of the growing season. Spores of the fungus are washed down the stem of the trees, resulting in infections lower down the stems. These infections give rise to spindle-shaped swellings on the stems of trees. In cases of severe infection, epicormic shoots are produced on the stems around the spindle-shaped swellings and the tops of trees begin to die. Lateral branches will attain apical dominance but these will in turn also become infected resulting in cessation of height growth.

**Spread of disease:**
Small, single celled spores are spread by wind and water. The spores infect the stems directly through the epidermis of the young stem tissue. *Coniothyrium* stem canker mostly affects trees in the Zululand area, starting from approximately age 2 of the trees, however a few cases of *Coniothyrium* stem canker have been reported from the Witbank area of the country.

**Management:**
The most effective means of avoiding *Coniothyrium* canker is through planting of resistant clones and hybrids. Susceptible clones must not be planted in high risk areas.
13.2.3 Root diseases

(a) PHYTOPHTHORA ROOT ROT

Phytophthora root and collar rot is a serious disease associated with die-back and collar rot of eucalypts. This disease is caused by P. cinnamomi and P. nicotianae in South Africa.

Species affected:
Cold tolerant eucalypts: - Eucalyptus smithii, E. nitens, E. fraxinoides and E. fastigata. The disease has also been reported from E. grandis in the Tzaneen area of South Africa.

Symptoms:
The most obvious symptom on infected trees is a general wilting of the leaves (Photo 13.11). This follows the rotting of the cambium of the roots and root collar (Photo 13.10). The bark from these roots easily slips off the woody parts. If the root collar of the tree is infected and girdling occurs, trees die. When older trees are infected, growth and subsequent yield is negatively affected. Phytophthora root and collar rot may also lead to secondary causes of mortality such as wind-throw due to reduced root systems. This is common in three to four year old E. smithii trees.
Spread of disease:
Water logging and the resulting poor aeration of the soil predisposes the roots to infection. Spores are commonly spread via infected soil or water. *Phytophthora* spp. has motile spores which readily swim through the water to find fresh roots and root collars for infection. Off-site planting also commonly predisposes trees to infection.

Management:
*Phytophthora* spp. commonly occurs in irrigation and soil water and can cause serious losses in eucalypts nurseries. The chemical treatment of water, particularly river water, is necessary to control the disease caused by the pathogen. Repeated use of media in the nursery can also cause outbreaks of the disease.

The only safe approach to escape the disease is to avoid species and sites that favour the disease.

Research is underway to identify disease tolerant families.

13.3 **ACACIA DISEASES (wattle)**

13.3.1 **Leaf diseases**
(a) **CAMPTOMERRIS AND UROMYCLADIUM LEAF SPOT**
Leaf diseases of Australian acacias are not generally problematic in South Africa. Infection by leaf pathogens in the country generally result in slight defoliation, especially in autumn.
13.3.2 Stem diseases

(a) CERATOCYSTIS WILT

*Ceratocystis* wilt, also known as wattle wilt, was first described in 1989 from the KwaZulu Natal Midlands. The causal agent of the disease was identified as *Ceratocystis albofundus*. *Ceratocystis albofundus* has been shown to be capable of killing one-year-old trees within six weeks and affects trees of all ages.

*Species affected:*

*Ceratocystis albofundus* is known only from Africa. It affects *A. decurrens* and *A. mearnsii*.

*Symptoms:*

Symptoms include wilting and death of trees. Wilting may be accompanied by external symptoms such as the formation of black/red mottled lesions and cankers on the bark of affected trees, the copious exudation of gum from lesions (*Photo 13.12*) and the formation of blisters (swollen gum pockets). Internal symptoms in the wood are an uneven brown discoloration in the form of streaks (*Photo 13.13*).

*Spread of disease:*

*C. albofundus* requires wounds for infection. Such wounds can originate from insect damage, wind, hail and silvicultural practices. Severe disease outbreaks have especially been found after hail and silvicultural damage. The spores of *Ceratocystis* can only infect for a short period of time after wounding. Wounding during warm, humid/wet summer months are more likely to result in infection.

*Management*

Wounding of trees during hot, moist periods of the year should be avoided. The planting of selected seed will reduce the chance of disease.

*Photo 13.12* (left): Mottled lesions with gum exudation caused by *C. albofundus*.  
*Photo 13.13* (right): Wood discoloration (streaking) caused by *C. albofundus*. 
(b) **BOTRYOSPHAERIA WILT AND CANKER**
This disease is caused by a number of *Botryosphaeria* spp., similar to those on *Eucalyptus* spp. in South Africa. The disease is most common when trees are exposed to unfavorable growing conditions such as shallow soils, hot winds and drought.

**Symptoms:**
Symptoms include tip die-back and death of trees. The stems of affected trees show a red/black discolouration of the bark (Photo 13.14) and in advanced stage the bark will crack. Internal symptoms of infection are the dark brown discolouration of the cambium, often resulting in rings of discolouration indicative of the season of infection.

**Species affected:**
*Acacia mearnsii* and *A. decurrens*.

**Management:**
Prevent unfavorable growing conditions and off-site planting.

![Photo 13.14: Dark brown/black bark lesion on A. mearnsii after Botryosphaeria infection.](image)

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13.3.3 Root diseases
(a) **PHYTOPHTORA ROOT ROT/BLACK BUTT**
Black butt of *Acacia mearnsii* caused by *Phytophthora nicotianae* is perhaps the best known disease of this tree in South Africa. Black butt generally does not lead to tree death, but reduces both the yield and quality of the bark. This disease affects trees of all ages.

**Species affected:**
*Acacia mearnsii* and *A. decurrens*. 
**Symptoms:**
The black butt symptom is only visible on older trees and refers to the black discolouration of the bark on the butt log of the tree. This discoloration is accompanied by cracking of the bark and the exudation of gum from active cankers (Photo 13.15).

Black butt affects the thickest, most valuable bark at the base of trees (Photo 13.16). It not only reduces the quality of the bark, due to the cracking and blackening, but also results in difficulty with bark stripping. It does not always kill trees except in extreme cases, but it reduces tree growth. Trees often die during drought periods as a result of the root death caused by P. nicotianea infection.

**Spread of disease:**
*Phytophthora* species require moist conditions for spread and infection, since infection takes place by motile, water-borne zoospores. The pathogen is spread via infected soil and water.

**Management:**
The best strategy for disease avoidance is to plant selected seed, tolerant to this disease. Limiting damage to the roots and bases of the trees is also advised, as well as the avoidance of water logged soils.

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Photo 13.15 (left): Basal canker typical of black butt.²
Photo 13.16 (right): Developing canker exuding gum from small lesions.²
13.4 PINUS DISEASES (Pine)

13.4.1 Needle diseases

(a) **DOTHISTRAMA NEEDLE BLIGHT**

Dothistroma needle blight, also known as red band needle blight, is a serious foliar disease of many pine species. It is caused by the fungus *Dothistroma septospora*.

**Species affected:**

Affects only *P. radiata* in South Africa.

**Symptoms:**

Early symptoms on the needles are deep green bands and yellow and tan spots on needles (Photo 13.17). Later, the spots turn brown to reddish-brown, and finally become necrotic. The infected needles turn brown and die.

The disease first appears on the needles on the main stem and at the bases of the lower branches. In wet weather the fungus may spread throughout the tree and cause the loss of all needles except those at the branch tips.

*Photo 13.17: Red bands caused by Dothistroma septospora. Note small black fruiting structures in middle of red band.*

**Spread of disease:**

The spores of this fungus are dispersed in wind-blown rain and in heavy mist conditions.

**Management:**

Considerable progress has been made in identifying families of *P. radiata* that are tolerant to *D. septospora*. This work is proceeding rapidly and hybrids of *P. radiata* and other species are also most promising.
13.4.2. **Stem diseases**

(a) **DIPLODIA PINEA CANKER AND DIE-BACK** (*Sphaeropsis sapinea*)

*Diplodia pinea* is one of the most important pathogens of pine in South Africa and occurs throughout the country.

**Species affected:**

*Diplodia* canker and die-back affects all *Pinus* spp., but is especially common and most severe on *Pinus patula*, *P. pinaster* and *P. radiata*. A root disease of *P. elliottii* and *P. taeda*, caused by *D. pinea* has also been found.

**Symptoms:**

The symptoms include shoot blight or die-back (*Photo 13.18*), stem cankers, root diseases and blue stain. Many of these symptoms become apparent after hail damage or when trees are stressed due to factors such as drought. The root disease is always associated with stress from overstocking, drought or planting on poor sites. Characteristic symptoms of the root disease are dark-blue, radial lesions in young roots which extend to larger roots and into the trunk of diseased trees. Needles become yellow (chlorotic) and are shed.

*Photo 13.18: Dead tops of *P. radiata* after infection by *D. pinea*.*

**Spread of disease:**

*Diplodia pinea* exists as both an endophyte and saprophyte in/on healthy and dead tissue. This fungus is an opportunistic pathogen causing disease symptoms when wounds or other stress factors occur. It may also infect young, unwounded pine shoots, where moisture and warm conditions occur at the onset of growth. The fungus is spread via airborne spores.

**Management:**

The only practical means of controlling losses due to *D. pinea* is to plant resistant species in hail affected areas (for example, *P. patula* should not be planted below 1,200m in the summer rainfall area). Eliminating stress factors should also be attempted. It is usually
not necessary to clearfell affected stands and even in severe cases, the majority of trees often recover if environmental conditions favourable for tree growth occurs. Pruning wounds can become infected with *D. pinea*. To avoid infection taking place through wounds created in this manner, it is recommended that pruning takes place in winter when the fungus is less active and conditions are less favourable for infection.

### 13.4.3 Root diseases

**a) RHIZINA ROOT ROT**

The causal agent is *Rhizina undulata*. This disease occurs throughout South Africa.

**Species affected:**

Most *Pinus* spp., especially *Pinus canariensis*, *Pinus elliottii*, *Pinus kesiya*, *Pinus patula*, *Pinus pinaster*, *Pinus radiata*, *Pinus roxburghii*, *Pinus sylvestris*, *Pinus strobus*, and *Pinus taeda*.

**Symptoms:**

The fruiting bodies of *Rhizina* can be seen in the ground on old wood such as cut stumps and roots. They are red/brown in colour with light margins (Photo 13.19 and Photo 13.20). *Rhizina* causes symptoms similar to those induced by drought and water logging. Fire stimulates spore germination and under suitable environmental conditions they colonise roots of the previous tree stand. When roots of newly planted seedlings come into contact with infested roots, they become infected and the seedlings die. Where larger trees are subjected to burning but not killed by fire, *Rhizina* can lead to the onset of disease and death. In such situations patches of dying trees are often found in plantations and death of trees can continue over a number of years.

**Spread of disease:**

This pathogen only occurs where there has been a previous rotation of pines. Thus, burning of veld prior to planting poses no danger. The fungus can be spread via airborne spores, infected soil and roots.

**Photo 13.19 (left):** Young *Rhizina* fruiting bodies that are red/brown in colour with light margins. These are often associated with dying seedlings.

**Photo 13.20 (right):** Fruiting body that has become darkened with age.
Management:
Burning after clearfelling should be avoided. Accidental forest fires do unfortunately occur and the most effective method to reduce losses is to delay re-planting until the pathogen ceases to be active. The period of activity of *Rhizina* is variable and influenced by factors such as time of the year of the fire, rainfall and soil type. In order to avoid widespread losses, it is recommended that monitoring plots be planted randomly on affected sites. Once seedling death abates in these plots, commercial planting can begin. The application of fungicides at planting has also been shown to reduce tree death.

(b) **ARMILLARIA ROOT ROT**
*Armillaria* root rot is caused by *Armillaria fuscipes* in South Africa. It occurs throughout the country and is especially problematic in areas where indigenous trees have been cleared to establish *Pinus* plantations.

**Species affected:**
All Pines (also been recorded on *Eucalyptus* spp. in the Sabie area, and on *A. mearnsii*).

**Symptoms:**
The trees have yellow needles, a reduced shoot growth and crown die-back. These symptoms are more noticeable after the dry season. A flush of new cones are often produced on dying trees. Gum or resin is also usually found on roots or root collars of infected trees. *Armillaria* root rot is recognised by a thick mat of white mycelium under the bark of roots or root collars of dead and dying trees ([Photo 13.21](#)). During conducive conditions, mushrooms of *A. fuscipes* may also be found at the base of infected trees, or growing from infected roots.

**Photo 13.21:** White mycelial mat under the bark of a dead tree associated with *Armillaria*.
Spread of disease:
The pathogen moves from tree to tree via root contact or by root-like fungal structures, called rhizomorphs. May also spread via airborne basidiospores.

Management:
There is currently no effective, economically viable management strategy available for *Armillaria* root rot. The avoidance of planting softwood species in infected areas, or where indigenous has been felled will reduce the incidence of the disease. Report all diseases to TPCP.

(c) PITCH CANKER FUNGUS
Pitch canker is one of the most serious threats to commercial forestry in South Africa. It is caused by the fungus *Fusarium circinatum* and is currently a serious problem in the USA. *Fusarium circinatum* was introduced into South Africa around 1990, but was for many years only a problem in forestry nurseries in the country. It has however, recently also been found causing the deaths of up to 3-year-old trees in the field.

Species affected:
Many *Pinus* spp., especially *Pinus patula* and *P. radiata* in South Africa. It however, also infects *P. elliottii* and *P. taeda*.

Symptoms:
In South Africa, unlike the USA, the disease is largely restricted to nurseries (Photo 13.22 and Photo 13.23). Infection of nursery trees in South Africa results in root rot and in some cases stem infection. The disease first becomes visible when the tips of trees start wilting and bend, followed thereafter by the death of the entire tree. Investigation of the roots will reveal extensive root death, while cutting into the root collar will show a brown, often resinous discoloration of the young wood. Under field conditions in South Africa, the symptoms are similar to those experienced in the USA. These include root rot and resinous cankers at the bases of infected trees. Chopping into the bases will reveal pitch/resin soaked wood.
Chapter 13: Forest Diseases

Silviculture

Spread of disease:
*Fusarium circinatum* is capable of infecting both vegetative and reproductive structures of pines at any stage of their maturity. It is an opportunistic pathogen and relies on wounds for infection. Spores of the fungus are soil and air-borne. Insects such as *Ips* spp., *Pityophthorus* spp., *Pissodes* spp. and *Conophthorus* spp. have been reported to be associated with the disease.

Management:
Methods of controlling *F. circinatum* in South Africa nurseries rely heavily on sound nursery sanitation, ie clean water, clean medium, insect control, clean seed etc. (see website of Fusarium Working Group). For effective plantation management sound selection and breeding of disease tolerant genotypes are essential.

Photo 13.22: Healthy roots of uninfected seedling (Left) and diseased roots of seedlings infected by *F. circinatum*.

Photo 13.23: Early symptoms of infection by *F. circinatum*. 
chapter 13: forest diseases

1 Forestry and Agricultural Biotechnology Institute
2 Photos by J. Roux © FABI, UP.
14.1 Introduction

As in the previous chapter, this chapter deals with the more serious forest insect pests that affect the common commercial forestry tree species. There are several insects pests that were a serious threat to commercial forest plantations in the past, but biological control has bought these pests under some form of control. These pests will not be mentioned in this chapter. Where applicable, photographs have been inserted to aid in insect identification.

Further detailed information and help can be obtained from:

- Prof. Mike Wingfield and/or Brett Hurley
- The Tree Protection Co-operative Programme (TPCP)
- FABI (University of Pretoria)
- Tel: 012 420 3938/9
- Fax: 012 420 3960
- www.fabinet.up.ac.za

Acknowledgement for help and material used in this chapter is given to FABI¹ – Prof. Mike Wingfield and Brett Hurley, ICFR – Prof Colin Dyer and SAWGU - John E. Feely. Extensive use was made of two publications, the Wattle Pests and Diseases booklet issued by ICFR and SAWGU and the South African Forestry Handbook 2000 section 5.2.²

NOTE:
Before any insecticide treatment is undertaken, it is advisable to check with insecticide agents for registration of effectiveness on target insect and to check with FSC representatives for FSC approval and compliance. The insecticide information as supplied at the end of several sections in this chapter is intended as a guide and not as a prescription.
14.2 PESTS OF *EUCALYPTUS SPP.* (gum)

14.2.1 CUTWORMS

These greyish-black to greyish brown caterpillars with a smooth skin are the larval stage of several species of indigenous nocturnal moths (*Photo 14.1*), commonly *Agrotis segetum* and the black cutworm, *A. ipsilon*. Often associated with high rainfall and dense weed coverage.

*Species affected:*
All commercial *Eucalyptus* species grown in Southern Africa.

*Damage caused:*
The root collar, stems and branches of seedlings and small trees are damaged or cut through by the nocturnal feeding action of the caterpillar.

*Life cycle:*
Several generations per year. More commonly, eggs are laid in the soil at the base of the plant during summer months. During the day the caterpillars will hide in the soil near the stem where they will pupate during autumn and winter.

*Control:*
Keep planted areas weed free. Apply Deltamethrin 5% SC at a rate of 0,5ml added to 1-2ℓ of water at the time of planting or later when caterpillars are discovered. Several synthetic pyrethroids and chlorpyrifos are effective.

14.2.2 WHITE GRUBS

These six legged, C-shaped thick white grubs are the larvae of the indigenous nocturnal cockchafer beetles (*Photo 14.2* and *14.3*). Typically they have a dark brown head and the bluish gut can be seen through the semi-translucent abdominal skin. Length of grub can vary from 3–36mm depending on age and species.
Species affected:
All commercial *Eucalyptus* species grown in Southern Africa.

Damage caused:
The grubs feed on the roots and cambium of the lower stem and the adult beetles may feed on the leaves.

Life cycle:
During September to January, eggs are laid in humus rich soil and will hatch after two to three weeks. The grubs will pupate after a year or two depending on the species and the adults will emerge after spring rains.

Control:
In the Natal Midlands, white grubs are common after previous wattle and sugarcane rotations. Determine the potential threat of white grub before planting and use insecticides as a preventative measure before any damage is noted. Apply Deltamethrin 5% SC at a rate of 0.5ml added to 1-2ℓ of water at the time of planting. Carbosulfan and chlorpyrifos can also be used. Avoid the use of gamma BHC, as this may violate international forest certification codes of practice.

14.2.3 TERMITES
These well-known and easily recognised small white subterranean ant-like insects are indigenous to South Africa. Most damage is caused by *Macrotermes natalensis*.

Species affected:
*E. grandis* and *E. fraxinoides* are most susceptible, with *E. nitens*, *E. paniculata* and *E. camaldulensis* being moderately susceptible and *E. smithii*, *E. macarthuri*, *E. dunnii* and *E. fastigata* being the most tolerant species.

Damage caused:
Roots are eaten away to form a point below the root collar ([Photo 14.4](#)), or the plant is ring-barked.
14.2.4 GRASSHOPPERS AND CRICKETS

*Description:* There are many species of these easily recognised jumping and flying insects. One of the more common grasshopper pests is the elegant grasshopper, *Zonocerus elegans*, which is widespread in Mpumalanga and KwaZulu Natal, as is the shiny black cricket, *Gryllus bimaculatus*.

*Species affected:* All commercially planted *Eucalyptus, Acacia* and *Pinus* spp.

*Damage caused:* By stripping off seedling bark at lower levels and feeding on the underlying tissue, grasshoppers can cause serious damage and can even chew through thin stems and branches. Both adult and young hoppers cause damage. Being diurnal, grasshoppers are easily spotted, but crickets are nocturnal and are difficult to see.

*Life cycle:* One to two generations per year.
**Control:**
As there are several insecticides registered for the control of crickets, it is advisable to consult your local insecticide tech-rep for up-to-date and relevant information for both crickets and grasshoppers (Carbaryl 85% WP).

### 14.2.5 EUCALYPTUS BORERS

There are two native Australian nocturnal longhorn beetles - *Phoracantha semipunctata* (Photo 14.5) and *P. recurva* - which are established in South Africa. Both look very similar and are dark brown to black, about 24mm long, with a broad yellowish band across the wing shields and have antennae that are as long or longer than the body. The larvae are off white in colour, cylindrical with an enlarged front-section (just behind the head), are distinctly segmented and can measure up to 32mm in length.

**Photo 14.5:** Adult *Phoracantha semipunctata* beetle.

**Species affected:**
All commercially grown *eucalyptus* spp. in South Africa.

**Damage caused:**
Trees that are dead, dying or under stress from drought, fire or poor site conditions are attacked and ring barked by the larvae. The larvae initially feed on the cambium and phloem layers, but later bore into the xylem as well. As they feed and tunnel they leave tightly packed frass behind in tunnels that indent into both the inner side of the bark and the outer side of the timber.

**Life cycle:**
Most egg laying usually occurs between February and March, the eggs being laid under loose bark. The larvae feed for two to four months before they bore into the heartwood where they pupate after ten days. Adult beetles live for a few months and are active throughout the year in warm areas, but on the highveld their activity is confined to the summer months.

**Control:**
To avoid high beetle populations it is advised not to leave any dead or felled timber with bark on for any length of time. Remove the breeding sites and remove the pest.
14.2.6  **EUCALYPTUS SNOUT BEETLE**

This Eucalyptus snout beetle, *Gonipterus scutellatus* is native to Australia. It is mainly a problem in areas above 1,200m in KwaZulu Natal and 1,500m in Mpumalanga where cold tolerant *Eucalyptus* spp. are attacked during the spring and summer. It does occur throughout the country, and high infestations are also known to occur below the cut-off altitudes but biological control is maintained by the introduced egg parasitoid, *Anaphes nitens*. The adult snout beetle is 7–9mm long, rusty red to brown in colour and has a characteristic ‘X’ on its back ([Photo 14.6](#)). The larvae are yellowish green, about 11mm long when fully grown and have a characteristic black faecal strand attached to the end of the abdomen ([Photo 14.7](#)). Eggs are covered in excrement, forming a hardened black capsule 2–3mm long, which encases an average of ten eggs.

**Species affected:**

Most *eucalyptus* species in South Africa and on the Highveld mainly *E. smithii*, *E. dunnii*, *E. maidenii* and *E. viminalis*.

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**Photo 14.6:** Adult beetle with dark cross on back.

**Photo 14.7:** Snout beetle larva with typical long black excrement filament.
Damage caused:
Adult beetles and the larvae feed on young leaves (Photo 14.8), which may result in severe stunting or even death of the tree during long periods of heavy infestations.

Life cycle:
Egg capsules are usually laid twice a year when a new flush of leaves is available. Summer beetles usually live two to three months and the autumn/winter beetles survive for up to seven months. The larvae are noticeable on the leaves for 28 to 40 days, after which they drop off and pupate on the ground.

Control:
In areas below 1,200m biological control is maintained by the introduced egg parasitoid, *Anaphes nitens*. In higher lying areas there is a reduced efficacy of *A. nitens* and research is needed to test the efficacy of alternative biological control agents and insect growth regulating chemicals. No insecticides are registered against this pest.

14.3 PESTS OF ACACIA SPP. (wattle)

14.3.1 CUTWORMS
Black wattle is susceptible to cutworm attack. Avoid burning brush lines after felling, as this may attract the adult moths to the regenerating wattle seedlings. See Section 14.2.1 for details on cutworms, including control.

14.3.2 WHITE GRUBS
See Section 14.2.2 for detail and control.

14.3.3 TERMITES
See Section 14.2.3 for detail and control.

14.3.4 GRASSHOPPERS AND CRICKETS
See Section 14.2.4 for detail and control.

14.3.5 WATTLE BAG WORM
These are small caterpillars of the indigenous moth, *Chaliopsis junodi* that live in bags constructed of silk and host plant material (Photo 14.9). Mature bags are 50-60mm long. The
adult female is grub-like and lives inside its bag. The adult male is a small, stout, brown moth with clear wings.

**Species affected:**
*Acacia mearnsii* and several indigenous *Acacia* species.

**Damage caused:**
Damage ranges from light infestations to heavy infestations where trees may be completely defoliated. Infestations may cause poor stripping of the bark during harvesting. Bark yields are reduced if trees experience a second, successive infestation. Wood yields may also be affected if infestations occur in two successive years. The poorer the site the greater the effect of defoliation.

**Life cycle:**
During September and October tiny caterpillars appear and are dispersed on fine silken threads by the wind and start feeding as soon as they land on a suitable host. They feed and grow until April when they pupate. The pupal stage lasts from April to July and the adults appear in July and August. Males are active on sunny days. Eggs are laid in the bag and the hatching larvae feed on the remains of the female and unhatched eggs, before they leave the bag. There is one generation per year.

**Control:**
Plantation inspections should be done during October to December. Spraying should be done before the end of January to be most effective.

Several synthetic pyrethroid insecticides are registered for aerial application. Before expensive aerial spraying work is undertaken, consult your local insecticide tech-rep for up-to-date information and advice. Synthetic pyrethroids are used to avoid insects building up resistance.

14.3.6 **WATTLE MIRID**

The adult of this indigenous insect, *Lygidolon laevigatum*, is a small (3mm) black or chestnut brown bug, with a yellow spot on its back. The nymphs are green and wingless and should not be confused with the benign wattle leafhopper – *Lassomorphus cedaranus*. Inspections for this pest should be done during the mirid season, December to May and best on cold days.
Species affected:
Acacia mearnsii and several indigenous Acacia species.

Damage caused:
The insects suck sap and inject toxic saliva into young trees (0 to 3 years old) while feeding. Trees shed their leaves and the bark becomes a dull greyish green with dark blotches. Evidence of mirid attack will be dead or dying shoots and hooked pinnules with red-brown, necrotic feeding spots. Also noticeable can be mass defoliation and multiple branching occurring on damaged leading shoots. Costly corrective pruning is usually needed to rectify mirid damage.

Life cycle:
Eggs are laid in young buds and hatch after 6-14 days. There are five, nymphal stages, each lasting 14-20 days. The adult female starts laying eggs nine days after mating and lives for 40 days. The entire cycle takes 4-5 weeks in summer.

Control:
Chemical control should only be considered when mirid populations reach five or more adults per sapling. An aerial application of the unregistered systemic insecticide monocrotophos 40% SC, at a rate of 100ml / 30ℓ can be used. In ground trials the following were also found to be effective on both adult and nymph when used with a mist blower; Deltamethrin 5% SC @ 0,0015gr a.i./tree, Deltamethrin 2,5% EC @ 0,003gr a.i./tree, acephate 75% WSP @ 0,17gr a.i./tree for trees up to about six months old and 0,34gr a.i./tree for older trees.

14.4. PESTS OF PINUS SPP. (pine)

14.4.1 CUTWORMS
See Section 14.2.1 for details on cutworms, including control.

14.4.2 WHITE GRUBS
See Section 14.2.2 for detail and control.

14.4.3 GRASSHOPPERS
See Section 14.2.4 for detail and control.

14.4.4 GREEN BRONZE BEETLES
The adults are smooth, brightly coloured, rounded beetles ranging in length from 4 to 8mm.

Species affected:
Young pine trees

Damage caused:
The beetles defoliate seedlings by feeding on the young soft needles and shoots.

Life cycle:
The adults are active flyers and often cluster on the shoot tips during late winter and spring, when most of the damage is done. The larvae live in the soil, feeding on roots. One generation per year.
Control:
No insecticides are registered.

14.4.5 PINE TREE EMPEROR MOTH
These indigenous moths, *Imbrasia cytherea* are large and robust with wing spans ranging between 100 and 170mm. The main coloration of the wings ranges between yellow and reddish-brown, with conspicuous eyespots on each wing. The caterpillars are a dark brick red with short stiff hairs on each segment, as they get older there are yellow, green and blue pearl spots on the body segments (Photo 14.10).

Species affected:
The main trees affected are *Pinus patula* and *Pinus radiata*.

Damage caused:
The caterpillars feed on the foliage of pine trees and large populations may completely defoliate the trees.

Life cycle:
The moths are active from January to May. The eggs are about 2mm in diameter, creamy white with brown to purplish markings. They are cemented in clusters of 3 to 40 eggs on terminal shoots and pine needles. Pupae are present under the needle mat for most of the summer. Defoliation occurs during the winter months.

Control:
The use of the biological insecticide *Bacillus thuringiensis* var. *kurstaki* is recommended.

14.4.6 PINE BROWN TAIL MOTH
These indigenous moths, *Euproctis terminalis* are deep yellow in colour with a satiny sheen on the forewings. They have a wingspan of 25 to 30mm, with a distinct dark brown tuft of hair at the end of the abdomen. The moths are strong flyers and active during the day.

Species affected:
Mainly *Pinus patula*.
**Damage caused:**
Severe to complete defoliation of pine trees may occur.

**Life cycle:**
Moths fly and lay eggs from October to February. Eggs are deposited on the trunks and on foliage, in elongated, irregularly shaped masses. All the caterpillar stages are extremely hairy. These hairs cause intense irritation when in contact with the human skin and are dangerous to the health of forestry workers. Caterpillars are black to olive-brown, older ones have tufts of long, white hairs at the sides of each segment and a narrow centre-line of white along the back.

**Control:**
The brown tailed moth has a lot of natural enemies. No insecticides are registered against this pest.

### 14.4.7 BROWN LAPPET MOTH
This indigenous moth, *Pachypasa capensis* is pinkish-grey to pinkish-brown and has a wingspan of 50 to 70mm. The young caterpillars are greyish to olive-black. Older caterpillars are black, white and ginger brown with a black band along the back, outlined by a white stripe. Below the white stripe is a narrow band of ginger brown hair. A grey-white fringe of longer hairs occurs along both sides of the caterpillar. Fully-grown caterpillars may be up to 10cm long.

**Species affected:**
It attacks several pine species, although *P. patula* is its main host.

**Damage caused:**
Severe to complete defoliation of pine trees may occur.

**Life cycle:**
The moths occur from September to March. They are nocturnal and are strong flyers. Eggs are about 1mm in diameter, creamy white with brown markings and are laid in clusters of about 50, on the needles. The caterpillars occur from late summer to late spring, during the day the caterpillars are gregarious and cluster on the trunks and major branches ([Photo 14.11](#)). At night they move out to feed on the young foliage. A yellowish-brown cocoon is spun in the lower part of the tree amongst the foliage.

![Photo 14.11: Caterpillar of the brown lappet moth.](#)
Control:
No insecticides are registered for the control of the brown tappet moth.

14.4.8 SIREX WOODWASP
This very destructive woodwasp, Sirex noctilio, is native to Eurasia and North Africa. The female wasp is steel blue in colour with two pairs of transparent, amber-tinted wings (Photo 14.13). The male has a broad orange band that covers most of its abdomen (Photo 14.12). The size of the wasps varies greatly and ranges from less than 1cm to greater than 3cm. The larvae live in the sapwood and are creamy white with a characteristic dark spike at the posterior end. Sirex was first detected in Cape Town in 1994, but has since spread rapidly into some of the country’s major pine growing areas and is expected to be present throughout South Africa in the near future.

Species affected:
Pinus radiata, P. elliottii, P. patula, P. pinaster, P. taeda, P. pinea and other Pinus species.

Damage caused:
Stressed trees are killed when the wasp injects mucous and a fungus (Amylostereum areolatum) into the wood during oviposition. The mucus prevents sugars from being passed down from the leaves, which would otherwise form fungal toxins at the site of the infection. This allows the white rot fungus to spread within the tree, causing the tree to dry out and eventually die. Thus, it is a combination of the mucus and fungus that kills the tree. The larvae, which feed on the fungus, make tunnels in the wood. Sirex has the potential to cause severe losses and is currently the number one threat to South African pine forestry.

Life cycle:
The sirex female is attracted to a stressed tree where she drills a hole through the bark into the sapwood. The female inserts the mucus and fungus into the tree and if the tree is suitable will also deposit eggs. The eggs hatch and the larvae bore into the wood, feeding on the fungus. The larva forms a U-shaped tunnel, eventually pupating in the outer layers of the sapwood. Generally, there is one generation per year, but shorter lifecycles are known to occur elsewhere in the world and the possibility of certain areas in South Africa having more than one generation per year still needs to be investigated. The emergence period occurs within the period October to April, depending on the area. Mating takes place above the canopy with the pair alighting on a surface. The female lives for five days and the male for 12 and neither feeds during this time.

Photo 14.12: Adult male sirex wasp emerging from a pine tree.
Control:
Chemical control of sirex is not feasible. Maintaining the vigour of plantation trees and biological control are the best options. The parasitic nematode *Beddingia siricidicola* is currently being re-introduced into South Africa as a biological control agent against sirex.

14.4.9 PINE BARK BEETLE

The pine bark beetle, *Hylastes angustatus*, is one of the three bark beetles on pine that is known to occur in South Africa. Mature beetles are dark brown, about 4mm long and are usually found on the inner bark of pine stumps, as are the small white larvae.

**Species affected:**
*Pinus* species

**Damage caused:**
The major damage is caused when the beetles feed on the green bark of roots and the root-collars of seedlings, killing them by under-bark girdling. The pine bark beetle may result in over 50% mortality of planted pine seedlings on the Highveld.

**Life cycle:**
After maturation feeding on the green inner bark of a pine seedling, the beetles seek out a stump or log in which to breed. On average 55 transparent, oval-shaped eggs are laid in a short, winding egg gallery. The larvae feed on the inner bark. Pupation occurs in a pupal chamber constructed at the end of the larval tunnel. The life cycle takes on average 38 days to complete - the larval stage accounting for 24 days. Five generations can be completed in a year.

**Control:**
Control is primarily geared for the prevention of damage to seedlings. Forest hygiene reduces population levels by denying the beetle breeding sites. The stumps from previous rotations remain a source of beetles for up to three years. Where there is a high risk of infestation, chemical protection is the only effective measure. Apply Deltamethrin 5% SC at a rate of 0,5ml added to 1-2ℓ of water at the time of planting.
14.4.10 EUROPEAN BARK BEETLE
The European bark beetle, Orthotomicus erosus, is 2.8 to 3mm long and dark brown when mature. The first indication of its presence is the appearance of small piles of reddish frass in cracks in the bark.

Species affected:
All Pinus species.

Damage caused:
The European bark beetle feeds by tunnelling in the inner bark of dead or dying trees. Trees stressed by drought, fire, excessive pruning, or attacks by other insects or pathogens are targets for this beetle. Once the beetles have entered the bark, the death of a tree is accelerated by ringbarking.

Life cycle:
The males construct individual chambers in the inner bark of suitable hosts, from where they release a sex pheromone. One or more females then join the male, each constructing a tunnel radiating from the male's nuptial chamber. Eggs are laid in notches on both sides of these tunnels. The hatching larvae feed at right angles to the female tunnel, thus forming a distinctive fish-bone pattern in the bark. Pupation takes place in a pupal chamber at the end of each larval tunnel. The life cycle takes about six weeks to complete, allowing several generations per season.

Control:
Chemical control is not feasible. Forest hygiene and maintaining tree vigour, are currently the best defence against the European bark beetle.

14.4.11 THE PINE WEEVIL
The adult pine weevil, Pissodes nemorensis, is a typical snout beetle, about 7mm long, reddish-brown with two large creamy-white spots on the wing shields, or elytra.

Species affected:
All Pinus species

Damage caused:
The pine weevil breeds in dead or dying pine trees. The weevil also kills the leaders of young healthy P. radiata trees, which results in timber loss and malformation of trees (tip die back). The pine weevil is also suspected of being a potential vector in the pitch canker pathogen, Fusarium circinatum, if this pathogen spreads to older trees.

Life cycle:
P. radiata trees from age seven are attacked, usually during the winter months. The beetles make feeding punctures in the fresh growth of the leaders and lay eggs in the phloem. The larvae feed on the inner bark, girdling the leader. Pupation takes place in a chip-cocoon, constructed just below the bark. There are one to two generations a year.

Control:
No insecticides are registered against pine weevils. The pruning of infested leaders allows young trees to recover without deformities, but is costly. Forest hygiene is important as the pine
weevil will breed in stumps. Research is underway to investigate possible biological control agents against the pine weevil.

14.4.12 **BLACK PINE APHID**

The black pine aphid was once considered the most serious pest of pine in South Africa, but its importance has decreased since the successful introduction of a biological control agent by the ARC – Plant Protection Research Institute in 1983. The mature insect is pear-shaped, soft bodied, greyish-black and about 4mm long.

**Species affected:**
All species of pine trees grown commercially in South Africa.

**Damage caused:**
The aphid extracts large amounts of sap through its stylets from the phloem tissue of the host tree, as is indicated by the copious honeydew that it secretes. High infestations will reduce the growth of the tree and when trees are under drought stress, heavy infestations may kill tops or even the whole tree. Such heavily infested trees may appear black due to the sooty mould fungus that grows on the honeydew.

**Life cycle:**
Large colonies form on the undersides of the branches and on the trunks of the trees during winter. At first the colonies consist mostly of wingless aphids but as the numbers increase so do the numbers of winged aphids. Peak aphid numbers occur during late winter and spring when large swarms of flying aphids may cause severe irritation to people working in the forests. The life cycle can be completed in 16 days.

**Control:**
Chemical control is not considered feasible. The biological control agent introduced by the ARC, the parasitic wasp, *Pauesia cinaravora*, has been very effective in controlling black pine aphid numbers.

14.4.13 **PINE WOOLLY APHID**

The pine woolly aphid, *Pinea boerneri*, is a small sucking insect. Its presence on pine trees is revealed by the white "woolly" wax that it secretes to protect itself and its eggs. Winged and wingless forms occur. Adults are about 1mm long with a round sac-like body containing a reddish-brown fluid.

**Species affected:**
All economically important pine species in South Africa.

**Damage caused:**
Trees damaged by heavy infestations of the woolly aphid may remain stunted for life. Heavily attacked pine plantations may suffer severe losses in terms of tree deaths, stunting and reduction of wood increment.

**Life cycle:**
Small clumps of "wool" initially appear at the bases of the pine needles on the growing tips, signalling the presence of the aphid. As aphid numbers increase the "wool" spreads down the branches on to the trunk. The aphids lay clumps of oval-shaped, yellow eggs, each about 0.5mm long, under the "wool". The pine woolly aphid is most abundant during winter. Their numbers increase from May until October when the winged form appears.
Control:
Chemical control is not feasible because of the protection afforded by the ‘wool’ secreted by the woolly aphid. Losses during heavy outbreaks may be minimised by reducing stress levels on the trees, typically by thinning.

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1 Forestry and Agricultural Biotechnology Institute
2 See the References section of this Forestry Guidelines package.
3 Photos from Wattle Pests and Diseases, ICFR.
4 Photos © FABI UP.
5 Photos © Marius Strydom, MTO.
A forestry road network is not only built for timber transport but should also cater for silvicultural and general access purposes. In today’s forestry operations, properly located, constructed and maintained road networks are required for efficient and environmentally sound operations.

Road design and construction however is a specialized area and is best left to professionals in the field. It is however important that tree farmers/foresters have some basic knowledge of road design, road construction and road maintenance issues.

15.1 **Road planning**

- Match road design to the functional requirements of the transport vehicles in order to minimise user cost (i.e. minimise gear change and maximise average vehicle speeds).
- Do not exceed maximum allowable gradient (7%) or minimum radius curvature (vehicle length and type).
- Avoid steep and unstable sites, large rocks and cliffs, sites prone to landslides and environmentally sensitive areas, such as swamps, sandy soils and natural drainage channels and riparian zones where possible.
- Make use of natural topographical features such as saddles, ridge tops, natural benches and flatter slopes.


- Determine potential river crossings.
- Minimise the number of stream crossings.
- Ensure crossings are at right angles to the stream.
- Plan route on contour map and with field visit.
- Construct roads parallel to a stream as straight as possible and not following the stream flow path.
- Avoid designated scientific, archaeological and historical sites.

### 15.2 New road networks

The following aspects will influence any new road development:

- The topography of the area.
- Skidding distances and equipment.
- Direction of transport.
- Environmental considerations.
- Expected timber volumes.
- Transport costs – current and future.
- Road construction and maintenance costs.
- Seasonal climatic variations.
- Silvicultural and fire protection activities.

The location of roads and proposed harvesting systems are linked in the way that the potential road location will be influenced by the choice of harvesting system, but if a road is already in place the choice of harvesting system is restricted by the road location. This is a situation that is very common in South African forestry and if not carefully managed can lead to unnecessary roads being constructed. A trade-off between the harvesting system in place and an alternative system should be investigated before any road is constructed.

Road density is theoretically determined by dividing the total road length by the total land area. A guideline to aim for is anything between 20ha to 30ha (planted) per kilometre of constructed road. It must be noted that the optimum road spacing should only be used as a guide to assist in road planning, because most logging areas are not perfectly flat. As a general rule, if you must deviate from the optimum road spacing, it is best to increase the distance between roads rather than to decrease it.

See Table 15.1 for optimum road spacing guidelines for varying terrain conditions.

<table>
<thead>
<tr>
<th>Ground (%)</th>
<th>Road spacing Slope (m)</th>
<th>Road Density (m/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 15</td>
<td>800</td>
<td>27</td>
</tr>
<tr>
<td>15 to 30</td>
<td>600 to 800</td>
<td>37 to 27</td>
</tr>
<tr>
<td>30 to 60</td>
<td>300 to 400</td>
<td>73 to 55</td>
</tr>
<tr>
<td>&gt; 60</td>
<td>400 with uphill cable yarding</td>
<td>55</td>
</tr>
</tbody>
</table>

(Source: South African Forest Road Handbook)

**Table 15.1: Optimum road spacing**
15.3 **Road classes**

Forestry roads are normally classified into road classes. The following classes are an example of one type of road classification system (Sappi Forests 2003).

<table>
<thead>
<tr>
<th>Category / Class</th>
<th>A</th>
<th>B</th>
<th>B1</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Level</td>
<td>Arterial</td>
<td>Transport</td>
<td>Transport</td>
<td>Work access</td>
<td>Edge tracks or valley bottom roads</td>
</tr>
<tr>
<td>Service requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary (P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary Intermediate (SI)</td>
<td>&lt; 22m</td>
<td>&lt; 22m</td>
<td>&lt; 22m</td>
<td>&lt; 22m</td>
<td>&lt; 15m</td>
</tr>
<tr>
<td>Secondary Terminal (ST)</td>
<td>&lt; 22m</td>
<td>&lt; 22m</td>
<td>&lt; 22m</td>
<td>&lt; 22m</td>
<td>&lt; 15m</td>
</tr>
<tr>
<td>Axle load (tons)</td>
<td>8.2</td>
<td>8.2</td>
<td>8.2</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>Availability (season)</td>
<td>All weather</td>
<td>All weather</td>
<td>All weather</td>
<td>Dry season</td>
<td></td>
</tr>
<tr>
<td>Cross-sectional data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road reserve (width m)</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Formation (m)</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>3-4</td>
<td>2-10</td>
</tr>
<tr>
<td>Gravel wearing course (width m)</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Shoulders</td>
<td>2x1</td>
<td>2x1</td>
<td>2x1</td>
<td>0 or 2x0.5</td>
<td></td>
</tr>
<tr>
<td>Curve widening</td>
<td>11</td>
<td>9</td>
<td>9</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Camber / Crossfall (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camber</td>
<td>3-5</td>
<td>3-5</td>
<td>3-5</td>
<td>3-5</td>
<td></td>
</tr>
<tr>
<td>Outsloping roads</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Inslaping roads</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
А good forest road classification system should:

- permit dialogue without confusion over terminology;
- provide a basis for the design of any new road; and
- provide a basis for the evaluation of existing roads.

15.4 **Construction of roads**

- For the building of any new road, the road must be pegged by someone suitable.
- Existing roads must follow the same alignment in both horizontal and vertical levels.
- All fences and timber are to be removed to allow for workspace.
- Use the following guidelines:

<table>
<thead>
<tr>
<th>Road class</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road reserves</td>
<td>18m</td>
<td>12m</td>
<td>9m</td>
<td>3m+</td>
</tr>
</tbody>
</table>

- All areas of the road should receive at least 5 hours of sunlight per day. If not, have the shade cut back.
- All brushwood is stacked at least two rows from the road reserve.
- All waterways must be cleared of brush.
15.5 **Guidelines for cross section of road**

<table>
<thead>
<tr>
<th>Road class</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction width</td>
<td>8m</td>
<td>6m</td>
<td>3m</td>
<td>3m+</td>
</tr>
<tr>
<td>Gravel wearing course</td>
<td>6m</td>
<td>4m</td>
<td>3m</td>
<td>Spot Gravel</td>
</tr>
<tr>
<td>Shoulders</td>
<td>1m</td>
<td>1m</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Curve widening</td>
<td>11m</td>
<td>9m</td>
<td>5m</td>
<td>-</td>
</tr>
</tbody>
</table>

15.6 **Road structure**

The drawing below depicts a cross section of a typical forestry road.

![](Figure 15.1: Cross section of a typical forest road.

15.7 **Roadbed preparation**

- During the roadbed operation, all soft/wet areas must be taken out and refilled with suitable material, either from quarry or local borrows.
- All side drains must tie into pipe culverts or mitre drains.
- The road shape must be re-checked prior to the importing of gravel.
15.8 **Road building materials**

The transport of suitable road building and gravelling material is in the majority of cases the most expensive activity in a road building or road maintenance operation. It is therefore important to establish a source of good material as close as possible to the road to be constructed.

Before using any material for road building activities, it is advisable to have the material tested by a local soil testing facility.

15.9 **Processing of gravel**

Factors influencing gravel thickness are as follows:

- Traffic load and volume.
- Standard and life expectancy of the road.
- Curvature, longitudinal slopes and crosses sectional slopes.
- Season and rainfall pattern when surfacing is to commence.
- Types and limitation of transport and construction equipment.
- Sub-grade characteristics.

**Procedures**

- After the quarry material has been dumped on the road, the material must be rowed to one side and brought back in small ‘bites’ onto the compacted sub-grade.
- The material can then be gridded ‘bite’ by ‘bite’ to approximately 50mm.
- This operation must be done using a 13.5ton grid roller, travelling at a speed of at least 12km/hr.

**Figure 15.2: Roadbed preparation**

![Diagram of roadbed preparation](image)
• When all the quarry material has been broken down, it must be mixed with water to OMC (Optimal Moisture Content), placed and shaped. To the correct width and thickness, and compacted to 90% mod ASSHTO (mod ASSHTO - standard level of compaction that meets AASHTO specifications).
• Density tests and thickness tests must be taken at required intervals and recorded.
• All excess material must be removed from the side drains, and mitre drains must be checked for clear run-off.

15.10 Humps
• Humps must be constructed at an angle of 30° where needed, and must be a minimum of 300mm higher than the road surface with a gradual incline at its beginning and end over a distance of at least 1.5m.
• The total length of the hump must be a minimum of 4m. This will reduce wear and tear on vehicles.

15.11 Pipe culverts
• Space culverts according to road grade, soil erodability and rainfall intensity.
• Build culverts at all points where a road crosses a natural watercourse.
• Culverts must be laid within 50m of a stream crossing to prevent water entering the stream unchecked.

See Table 15.3 for guideline on placing of pipe culverts.

### Culvert Spacing

<table>
<thead>
<tr>
<th>Road Class</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1-5%</td>
<td>120-150m</td>
<td>120-150m</td>
<td>-</td>
</tr>
<tr>
<td>Grade 6-10%</td>
<td>90-120m</td>
<td>90-120m</td>
<td>-</td>
</tr>
<tr>
<td>Grade 11-15%</td>
<td>75-90m</td>
<td>75-90m</td>
<td>-</td>
</tr>
<tr>
<td>Grade 16-20%</td>
<td>35-70m</td>
<td>35-70m</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 15.3: Culvert spacing**

15.12 Bridges
Specialist should be consulted where bridges are needed.

15.13 River crossings
• Do not alter the natural flow of the stream (slope and alignment).
• Avoid steep approaches to stream crossings.
• Where possible, stream crossings should be at correct angles to the stream.
• Select natural crossing with easy approaches.
• Design permanent stream crossing to withstand specified flood levels (eg 50 years).
15.14 **Forest road maintenance**

The maintenance of forest roads is an important aspect that is often overlooked due to lack of awareness and/or budgetary constraints. This however can lead to excessive road maintenance and repair costs during later harvesting or other forestry operations.

![A poorly maintained road](image1.jpg) ![A well maintained road](image2.jpg)

The first objective of road maintenance is to keep the road in such a condition that it sheds water quickly. If a road does not shed its water quickly, the surface will become soft, and ruts and pot-holes will appear rapidly.

The maintenance of forest roads can be divided into four categories:

- Roadside maintenance.
- Road drainage maintenance.
- Road surface maintenance.
- Regravelling.

15.15 **Roadside maintenance**

The roadside can be defined as the area next to the road from the road shoulder and is normally known as the road reserve.

The maintenance activities include:

- Grass cutting and clearing of excessive bushes and undergrowth.
- Erosion repair and establishing of vegetation and other methods to prevent erosion.
- Vegetation removal to encourage quicker drying and prevent moisture build-up.

15.16 **Road drainage**

Road design (camber), side drains, mitre drains and cross drains (eg culverts) are required to ensure that forest roads drain excess water efficiently.

All drainage structures should be inspected regularly and cleaned and repaired if necessary. Inspection should be done especially after heavy rains or excessive use of a length of road.
15.17 **Road surface maintenance**
The road surface is maintained by regular blading where required.

15.18 **Regravelling**
Regravelling is often the most expensive maintenance procedure for gravel roads. Regravelling is needed when the existing surfacing no longer allows the road to achieve the management objectives. Regravelling should take place before the subgrade is exposed in order to avoid:
- Deformation that will necessitate reconstruction
- Loss of the strength that has been built up in the subgrade by traffic moulding over time
- Contamination of residual surfacing material, preventing it from being re-used

Improvements to any drainage deficiencies should be made prior to regravelling.

15.19 **Road quarries and borrow pits**
The choice of gravel pits to be used must take into consideration the following:
- Quality of material.
- Ability to break down.
- Accessibility.
- Haul distance.
- Available quantity.

15.20 **Working the quarry**
- Before commencing excavations, the quarry must be planned and the perimeter pegged out.
- The area must be cleared, and all topsoil stockpiled on a suitable site.

15.21 **Selection of gravel**
- Borrow pit material should be tested for suitability.
- In situ material should be tested for suitability.
- Wearing course must comply with road standards.

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1 MacDonald – 1999.
4 Ackerman and Strydom - 2000.