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**AN INVESTIGATION INTO THE POSSIBLE CAUSES OF DECLINE IN  
THE *ACACIA ERIOLOBA* POPULATION OF THE KATHU AREA**

by  
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Submitted in fulfillment of the requirements for the degree of

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*“... man did not spin the web of life,  
he is merely a strand in it.  
It is like the lifeblood that ties us all together.  
And, whatever man does to the web,  
he does to himself.”*

Chief Seathl, Duwamish tribe.

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**CHAPTER 1**

**INTRODUCTION**

## 1.1. INTRODUCTION

### 1.1.1. WHY CONSERVE THE ACACIA ERIOLOBA TREE?

*A. erioloba* is included in the protected plant species list of the **South African Department of Water Affairs and Forestry**<sup>1</sup>, resulting in its protection under the National Forests Act, No. 84 of 1998 (Appendix A). Reasons for conserving *A. erioloba* are varied and range from the belief that all plants and animals have the right to exist, to the belief that future generations of people have the right to adequate resources (Given 1994).

The conservation of biological diversity (defined by Holdgate and Giovannini (1994) as “*the sum of genetic, specific and ecosystem richness on the planet*”) is of great importance to biologists (Allen-Wardell *et al.* 1998) for three main reasons, namely beauty, utility (function) and profit (Beattie 1995). Beauty is defined as “*a combination of qualities...that pleases the aesthetic senses*” (Allen 1990) and in this context goes hand-in-hand with knowledge, which is likely to increase the appreciation of beauty (Beattie 1995). The connection of utility with biodiversity is the millions of species whose metabolism and interactions cumulatively produce ecosystem functions. Lasting benefits from nature depend upon the maintenance of essential ecological processes – in which every species present plays an important role (Given 1994; Reinhardt 2000). *Acacia erioloba* could, therefore, play an important role in maintaining a stable environment, involving both the regulation and stability of environmental processes. Profit refers to the biological resources derived from biodiversity (Beattie 1995).

South Africa is regarded as possibly the third-most important country in the world in terms of biodiversity (Foxcroft 1999), thus placing a big responsibility on its inhabitants to conserve this heritage. Biological diversity is conserved by maintaining those ecological processes that occur through particular species or through ecosystems in which certain species or groups of species play key roles. It is important to realize that focusing attention on the management of a single target species, without taking into consideration other species or the entire ecosystem,

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<sup>1</sup> South African Department of Water Affairs & Forestry. ☒: Private Bag X9029, Pietermaritzburg, 3200.

can have an adverse effect on yields. In extreme cases it may even result in a decline in the yield of a particular species, with a subsequent increase in yield in another, less desirable species (Allen *et al.* 1982).

Woody vegetation, like *A. erioloba*, and its associated browsing species increase habitat diversity (Van Essen 1997; Dean *et al.* 1999). A decline in *Acacia* trees would therefore most likely result in serious losses of biodiversity (Rohner & Ward 1999), including possible co-dependent pollinators (Heywood 1995). It is, however, extremely difficult to determine the importance of a specific species, such as *A. erioloba*, in a given ecosystem (Beattie 1995).

The above considerations are, however, noble as they may sound, of little or no immediate relevance to the rural poor, and even the man on the street, who depend on nature for day-to-day survival (Melnyk 1994). *Acacia erioloba* is beneficial to this group of people in the following non-consumptive and consumptive ways:

#### Non-consumptive uses:

- The use of trees for filtering out dust and particulates from the atmosphere has long been accepted and taken advantage of (Bach 1971, 1972; Dochinger 1980; Yunus *et al.* 1985). Meetham (1964), for example, quoted a 27% reduction in dust particle concentrations in Hyde Park, London, as the result of a green area of only 2.5 km<sup>2</sup>, while Bach (1972) reported a 44% reduction in carbon monoxide levels as a direct result of a 10 x 6 m stand of bushes and trees. It is therefore postulated in the present study that mine dust from the Kathu area as well as gaseous pollutants from the Kathu-Kuruman highway is likely to have a much larger impact on daily living in the absence of *A. erioloba* trees.
- The shade of *Acacia* trees is essential for the water and energy conservation of man, several animal species and other plants (Belsky *et al.* 1993; Milton & Dean 1999; Venter & Venter 1996).
- *Acacia* species are used for stabilizing shifting sand (Roux & Middlemiss 1963).
- Pastoral people have devised long, hooked poles with which to shake pods from branches. The sound produced by this action attracts livestock from distances of 1 - 200 m, thus eliminating the need to collect animals from the veld nightly (Coe & Coe 1987).



- *Acacia erioloba* can be used for "butterfly gardening", as larvae of the topaz blue butterfly (*Azanus jesous*) feed on its inflorescences (Venter & Venter 1996).

#### Consumptive uses:

- *Acacia erioloba* leaves and pods are excellent fodder for both livestock and game (Coe & Coe 1987; Venter & Venter 1996; Dudley 1999). Cows feeding on these pods are said to show an increase in milk production (Venter & Venter 1996).
- Being relatively abundant in its distribution area and reaching considerable size, *A. erioloba* has been used locally for the construction of furniture, fence posts and mine props (Coates Palgrave 1984; Fagg & Stewart 1994; Van der Walt & Le Riche 1999).
- *Acacia erioloba* is a good source of firewood that renders in exceptionally hot coals that last a long time (Venter & Venter 1996; Van Wyk & Van Wyk 1997; Smit 1999; Van der Walt & Le Riche 1999; Van Wyk & Gericke 2000).
- The Topnaars of Namibia use large pieces of *A. erioloba* bark to cover their huts (Van der Walt & Le Riche 1999).
- Various parts of the *A. erioloba* tree have medicinal value. Tree gum dissolved in warm water acts as a flu, cough and tuberculosis remedy; bark infusions stop diarrhoea; root infusions are a good cough syrup; fine roots prevent nose-bleeds; pod pulp helps cure ear infections; and fine, burnt bark is used as a headache powder (Coates Palgrave 1984; Venter & Venter 1996; Van Wyk & Van Wyk 1997; Van der Walt & Le Riche 1999; Van Wyk & Gericke 2000).
- Minced-up bark of *A. erioloba* is eaten as porridge (Van der Walt & Le Riche 1999).
- Pod pulp is eaten by the Topnaar of Namibia in times of famine (Van Wyk & Gericke 2000).
- The stripped and pounded inner bark of *A. erioloba* produces a good quality rope (Venter & Venter 1996).
- Roast *A. erioloba* seeds are used for brewing coffee (Venter & Venter 1996; Van der Walt & Le Riche 1999; Van Wyk & Gericke 2000).
- The gum of *A. erioloba* is eaten by man, animals and birds (Coates Palgrave 1984; Venter & Venter 1996; Van Wyk & Van Wyk 1997).

- Bushman women use finely ground *A. erioloba* core-wood as make-up (Van der Walt & Le Riche 1999).
- A powder made from the inner bark of *A. erioloba* is applied to the body as a perfume by the Topnaar of Namibia (Van Wyk & Gericke 2000).

From the above it is clear that *A. erioloba* can be extremely advantageous to both the rural poor and the man on the street in both consumptive and non-consumptive ways by supplying a higher quality of life, food, medicine, construction materials, commodities and income on a long-term basis. Long-term availability can, however, only be achieved through the proper management and sustainable utilisation of this valuable resource.

#### 1.1.2. PROBLEM

A drastic decline in the size of the Camel Thorn Tree (*A. erioloba*) population of the Kathu area has been observed since the early 1980's (Laan 1998). This date correlates with the commencing of intensive mining activities at the Sishen Iscor Iron Ore Mine and it was proposed that the two be related. Further concern was expressed with more recent deaths for the following reasons:

- The Kathu Forest is one of its kind in the world and was declared a Natural Heritage Site in 1998.
- The Kathu Forest is of aesthetic, sentimental and economic value to many locals.

#### 1.1.3. PREVIOUS INVESTIGATIONS

Two previous investigations addressed the problem of *A. erioloba* deaths in the Kathu region (Anderson 1992; Laan 1998). Both these studies investigated fluctuations in the water table level caused by mining activities in the region as the main possible cause of the observed deaths. Anderson (1992) concluded that *A. erioloba* deaths in the Kathu area are natural and that the fluctuating water levels did not negatively affect the *A. erioloba* population of this area. He warned, however, that further fluctuations in the water table levels could, in the long run, be detrimental to these trees. Laan (1998) confirmed the findings of Anderson (1992), and further recommended that pod removal from the Khai-Apple Nature Reserve and the Sishen Golf



Course premises be stopped, and that a lower stocking rate of game be implemented in the Khai-Apple Nature Reserve.

Not completely satisfied with the results of these studies, the Northern Cape Nature Conservation Service approached Iscor for the funding of the present comprehensive eco-physiological study with the aim of finally elucidating the reason(s) for *A. erioloba* deaths in the Kathu area.

## 1.2. OBJECTIVES

The objectives of this study were:

- To compare the study and control areas in terms of *A. erioloba* population structure, plant production and regeneration capacity (Chapter 2).
- To identify potential problem areas through questionnaires to locals, as well as to determine the degree of concern of locals towards the decrease in the *A. erioloba* population size in Kathu (Chapter 3).
- To determine the influence of the mine dust formed as a by-product of the mining activities of the Sishen Iscor Iron Ore Mine on certain physiological aspects, as well as the germination capacity and growth potential of *A. erioloba* (Chapter 4).
- To determine the influence of the lowering of ground water levels as a result of the mining activities of the Sishen Iscor Iron Ore Mine on the population structure of *A. erioloba* (Chapter 5).
- To determine the influence of specific management strategies, namely the stocking rate of browsers and mixed feeders, pod collection and the use of non-specific chemicals for bush eradication, on the *A. erioloba* population of the Kathu area (Chapters 6, 7 and 8).
- To determine the influence of the natural phenomenon of Bruchidae seed predation on the size of the *A. erioloba* population of the Kathu area (Chapter 9).
- To make practical management recommendations on the effective conservation of the *A. erioloba* population of the Kathu area (Chapter 11).



### 1.3. BACKGROUND INFORMATION ON ACACIA ERIOLOBA

The word "Acacia" comes from the Greek word for thorn, while "*erioloba*" refers to the woolly ("erio"), half moon shaped ("loba") pod of this species (Venter & Venter 1996; Smit 1999; Van der Walt & Le Riche 1999). The English vernacular name for the species, 'Camel Thorn', is biologically inappropriate. It was mistranslated from the Afrikaans vernacular for 'giraffe-thorn', namely "Kameeldoring" (Coates Palgrave 1984; Dudley 1999; Smit 1999).

The mature Camel Thorn is a medium to large sized tree (usually 6 - 7 m, but reaching heights of up to 22 m) with a flattish, spreading, umbrella-shaped crown (Coates Palgrave 1984; Milton & Dean 1999; Van Wyk & Van Wyk 1997; Smit 1999). Variations in growth form occur throughout its distribution area, ranging from small, spiny shrubs barely 2 m high, to trees of up to 22 m high (Coates Palgrave 1984). *Acacia erioloba* has a life span of 200 - 300 years (Milton & Dean 1999; Van der Walt & Le Riche 1999).

The bark on the main stem of mature trees is coarse, dark blackish-brown to grey in colour, with deep vertical furrows (Coates Palgrave 1984; Venter & Venter 1996; Dudley 1999; Smit 1999). The heartwood is dark red-brown in colour and extremely hard, heavy ( $1\ 144\ \text{kg m}^{-3}$ ) and dense, making it resistant to termites, other wood-boring insects and fungi (Coates Palgrave 1984; Venter & Venter 1996; Dudley 1999; Smit 1999; Van der Walt & Le Riche 1999).

*Acacia erioloba* is typically phreatophytic, forming a long taproot to reach underground water sources of up to 40 m below the soil surface (Fagg & Stewart 1994; Van der Walt & Le Riche 1999). Mature individuals survive on subsurface water during the dry season (Van Wyk & Gericke 2000).

Paired stipular spines, occurring at nodes, are strongly developed, almost straight, often swollen and fused together basally (Venter & Venter 1996). The swelling is not, as was stated by Venter and Venter (1996) and Smit (1999), an 'ant gall', neither is it caused by caterpillars. This feature is genetically controlled (Gubb 1988; Young *et al.* 1997; Van der Walt & Le Riche 1999). Spine length varies from 0.5 - 6.0 cm (Coates Palgrave 1984; Dudley 1999; Smit 1999).

The bipinnately compound leaves of *A. erioloba* have 1 - 5 pairs of pinnae, with 6 - 18 pairs of relatively large, hairless microphyllate leaflets per pinnae (Coates Palgrave 1984; Van Wyk & Van Wyk 1997; Smit 1999). Leaflets are 4 - 13 X 1 - 4 mm in size (Coates Palgrave 1984), with a characteristic bluish-green colour (Smit 1999).

Bright golden-yellow, honey-scented flowers in the form of globose heads are involucrely located at the apex of hairless peduncles (Coates Palgrave 1984; Milton & Dean 1999; Van Wyk & Van Wyk 1997; Dudley 1999; Smit 1999). Fully developed flower heads have a diameter of 10 - 16 mm (Smit 1999). Up to 10 flowers, often at different stages of development, are borne at a single node (Smit 1999). *Acacia erioloba* is insect pollinated (Barnes *et al.* 1997).

The semi-woody indehiscent pods are thick, flattened, sickle-shaped, relatively large (5 - 15 cm in length x 1.5 - 5 cm width, with a thickness of up to 1.5 cm) and covered with short, velvety grey to creamy-grey hairs (Leistner 1961; Coates Palgrave 1984; Hoffman *et al.* 1989; Milton & Dean 1999; Van Wyk & Van Wyk 1997; Dudley 1999; Smit 1999). Variation in both pod size and production occur (Van Wyk & Van Wyk 1997; Van der Walt & Le Riche 1999). Peak pod-fall occurs during the early dry season, which lasts from April to June (Barnes *et al.* 1997).

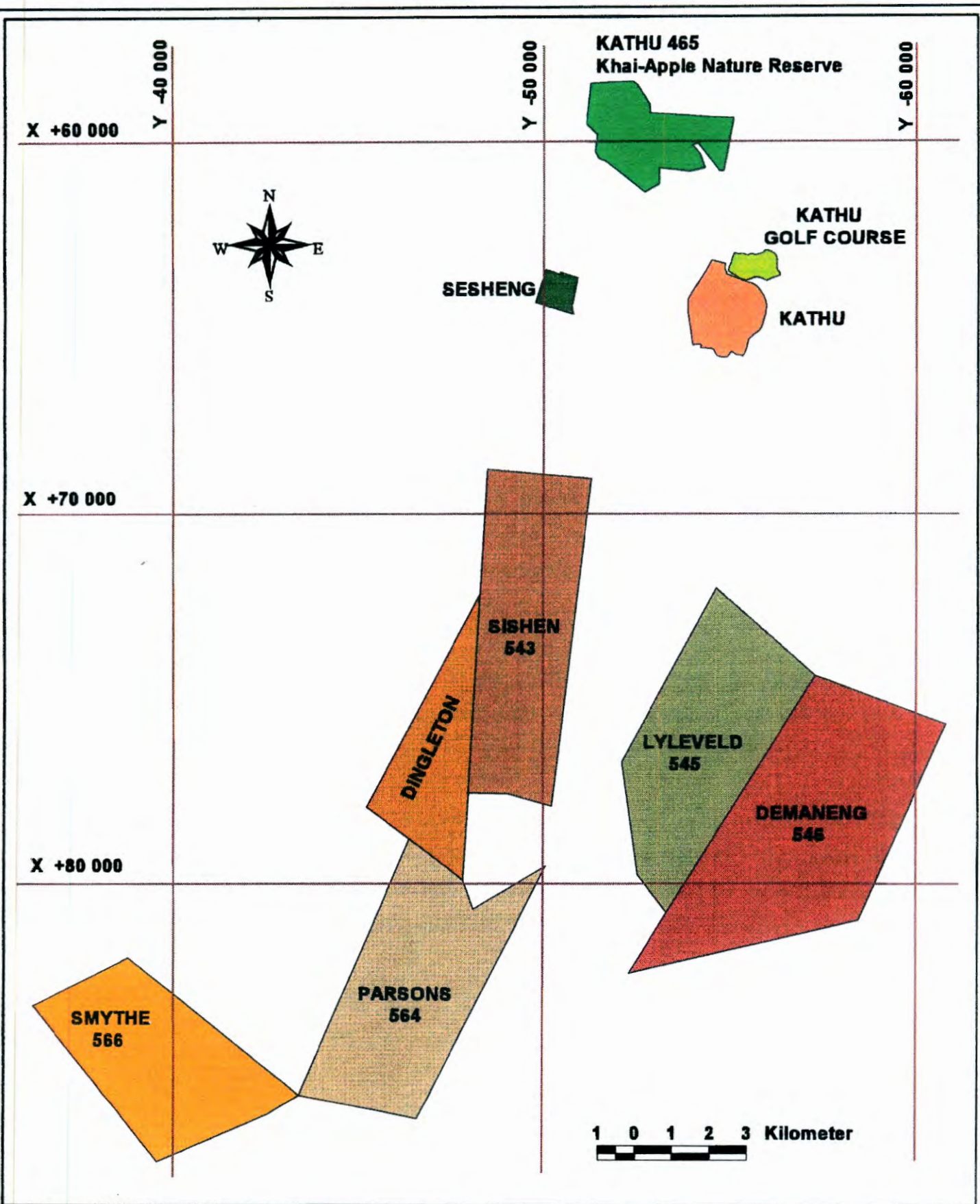
Although the Camel Thorn is typical and/or dominant in the dry, semi-desert Kalahari region, the distribution of this species is determined by the presence of deep Kalahari sands (Smit 1999; Van der Walt & Le Riche 1999). *Acacia erioloba* is widespread in Africa and occurs throughout most of the drier southern African savannas, including the southern parts of Angola, Botswana, Mozambique, Namibia, South Africa, south-western Zambia and Zimbabwe (Hoffman *et al.* 1989; Smit 1999; Van der Walt & Le Riche 1999).

## 1.4. STUDY AREA

### 1.4.1. SISHEN ISCOR IRON ORE MINE

The Sishen Iscor Iron Ore Mine near Kathu (Figure 1.1) was commissioned in 1923 (Northern Cape Tourism Authority 2000). Prospecting began in the early 1930's, with a mining workforce consisting of 30 people (Strategic Environmental Focus CC. 1999). "*Hills of glittering black*





**Figure 1.1.** Map of the study area indicating the location of the Sishen Iscor Iron Ore Mine, the Khai-Apple Nature Reserve, the Sishen Golf Course, Demaneng and Lylyveld. The farms Knapdaar and Swarthaak fall outside the range of this map, but are located to the north-west of the mine.

rock", as they were described by Rev. Moffat in 1834, turned out to be both the largest and richest iron ore deposits of its kind in the world (Repro Touch 1996). Up until 1977, mining activities in the Kathu area were, however, of a limited capacity (Lynch 1982).

Iron ore extraction officially started in 1953 (Anderson 1992; Repro Touch 1996; Rossouw 1999), with high quality hematite ore being crushed and sifted in a dry state (Rossouw 1999). A wet sifting plant was erected in 1961 and in 1963 the first heavy medium separation plant came into operation (Rossouw 1999). The export of iron ore commenced in 1976, and as a result mining activities intensified and excavations became deeper (Anderson 1992; Munro 1984; Rossouw 1999). Today the Sishen Iscor Iron Ore mine is classified as one of the five largest open-cast iron ore mines in the world (Repro Touch 1996) and the largest mine operated by the South African Iron and Steel Industrial Corporation (Rossouw 1999). According to Rossouw (1999), the Sishen Iscor Iron Ore Mine is capable of delivering 27 million tons of processed product per year, with a crude ore and refuse production of close to 110 million tons per year.

The Sishen Iscor Iron Ore Mine is situated in the north-western parts of the Northern Cape Province, approximately 50 km from Kuruman, 200 km from Upington and 280 km from Kimberley by road (Rossouw 1999).

The quarry is currently approximately 10 km in length, with an average width of 1.5 km. The average depth of the quarry is 75 m, with the deepest point currently at 140 m below the original surface. It is projected that, in its final stage, the quarry will be 11.2 km long and 2.45 km wide (on average), with a maximum depth of 375 m (Rossouw 1999).

#### 1.4.2. STUDY AND CONTROL AREAS

##### a) General

Four study sites were identified in the Kathu region: the Khai-Apple Nature Reserve; the Sishen Golf Course; and four farms, namely Demaneng and Lylyveld (jointly forming a single site), situated in the Kathu district; and Knapdaar and Swarthaak (jointly forming a single site),



situated in the Deben district (Figure 1.1). The Sandveld Nature Reserve, situated on the Free State side of the Bloemhof Dam, was selected as control site.

#### b) Khai-Apple Nature Reserve

This reserve was included in the study after a survey conducted among the residents of Kathu (Chapter 3) brought to light that *A. erioloba* deaths are highly conspicuous in this area.

After acquisition of the farm Uitkoms, Istors, a former branch of Iscor Ltd, proclaimed the Sishen Nature Reserve, in 1975. The latter was approximately 800 ha in size. Most of the animals in this reserve were translocated from the old "game camp", which formed a part of the farming grounds of Ferroland Ground Trust (PTY) Limited. The reserve was later enlarged to include the farms Kathu 465, Remnant of Simms 462 and Part 1 of Uitkoms 463 (Laan 1998), and renamed the "Khai-Apple Nature Reserve".

The Khai-Apple Nature Reserve is the property of Iscor and is leased to the Kathu Municipality for a nominal fee (Laan 1998).

Before proclamation, the area now known as the Khai-Apple Nature Reserve was utilised for intensive sheep and cattle farming. Since 1975 the vegetation has, however, been utilised exclusively by game (Van Hoven & Guldmond 1992). The following game species are permanently resident in the reserve: Black Wildebeest (*Connochaetes gnú*), Blesbok (*Damaliscus dorcas phillipsii*), Blue Wildebeest (*Connochaetes taurinus*), Burchell's Zebra (*Equus burchelli*), Camel (*Camelus dromedarius*), Duiker (*Sylvicapra grimmia*), Eland (*Tragelaphus oryx*), Gemsbok (*Oryx gazella*), Giraffe (*Giraffa camelopardalis*), Impala (*Aepyceros melampus*), Kudu (*Tragelaphus strepsiceros*), Ostrich (*Struthio camelus*), Red Hartebeest (*Alcelaphus buselaphus*), Springbok (*Antidorcas marsupialis*), Steenbok (*Raphicerus campestris*), Waterbuck (*Kobus ellipsiprymnus*)<sup>2</sup>. The reserve is furthermore home to more than 200 bird species (Repro Touch 1996).

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<sup>2</sup> Official game count results for January 2000.

The reserve occupies a single, fenced-in area of 2 312.5 ha (Van Hoven & Guldemond 1992; Strategic Environmental Focus CC. 1999) and is situated approximately at 27°40' S and 23°00' E (Van Hoven & Guldemond 1992), off the R380 from Kathu to Deben, 5 km from Kathu (Figure 1.1).

### c) Sishen Golf Course

The Sishen Golf Course was chosen to be included in the study after the results of a survey conducted among the Kathu residents (Chapter 3) indicated that *A. erioloba* deaths are highly conspicuous in this area.

Situated in the largest *A. erioloba* forest in the world, this course was built and is maintained by the Sishen Iscor Iron Ore Mine. The course, designed by Robert Grimsdell, was officially opened in 1979 and was rated the ninth best golf course in South Africa in 1999 (Vodacom 1999).

The Sishen Golf Course occupies an area of 80.5 ha (Strategic Environmental Focus CC. 1999) and is situated on the outskirts of Kathu in what is known as the "Kathu Forest Reserve". The latter includes the entire mining town of Kathu and was proclaimed in 1994 (Repro Touch 1996) (Figure 1.1).

### d) Demaneng and Lylyveld

These two adjacent farms were included in the study because of their down-wind location in relation to the Sishen Iscor Iron Ore Mine (Figure 1.1). Two farms (and therefore a relatively large surface area) were chosen for survey purposes, as the prevailing wind distributes dust over a greater distance in the downwind direction, compared to the upwind direction (Hegazy 1996).

Prior to 1963, the farm Demaneng was utilised for cattle and sheep farming, whereafter it was (and still is) used exclusively for cattle farming. Game species that are currently permanently resident on the farm include Springbok (*Antidorcas marsupialis*), Blesbok (*Damaliscus dorcas*



*phillipsii*) and Gemsbok (*Oryx gazella*). Iron ore mining was previously practiced on the farm, as well as on the adjacent Lylyveld (Van Rensburg, pers. comm.<sup>3</sup>).

Both Demaneng and Lylyveld are situated on the R386 – the former in the direction of Dingleton and the latter in the direction of Lohatlha. Demaneng covers an area of 3210 ha, and Lylyveld an area of 2223.94 ha.

#### e) Knapdaar and Swarthaak

These two farms were included in the study because of their up-wind location in relation to the Sishen Iscor Iron Ore Mine. Two farms were chosen because of irregularities in the *A. erioloba* population structure, caused by management strategies of previous owners, over large parts of the farm Knapdaar. Only the latter farm was initially identified for survey purposes.

Both these farms are currently used primarily for cattle farming and were obtained by the present owners in 1998. Prior to this the area was used for small stock farming.

Knapdaar and Swarthaak are situated adjacent to one another approximately 20 km SW of Deben, to the north-west of Kathu.

Knapdaar occupies an area of 472 ha and Swarthaak 982 ha (Engelbrecht, pers. comm.<sup>4</sup>).

#### f) Sandveld Nature Reserve

The Sandveld Nature Reserve (Figure 1.2) was chosen as control site for this study for the following reasons: It is situated on more or less the same latitude as the study area and the vegetation of this area is similar to that of the Kathu area.

After the completion of the Bloemhof Dam, soil from this building site was used for the development of Sandveld Nature Reserve. The reserve was proclaimed by the former

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<sup>3</sup> Mr Dihan van Rensburg. Owner: Demaneng. ☒: P.O. Box 678, Kathu, 8446.

<sup>4</sup> Mrs. M. Engelbrecht. Owner: Knapdaar & Swarthaak. ☎: 0537910527.



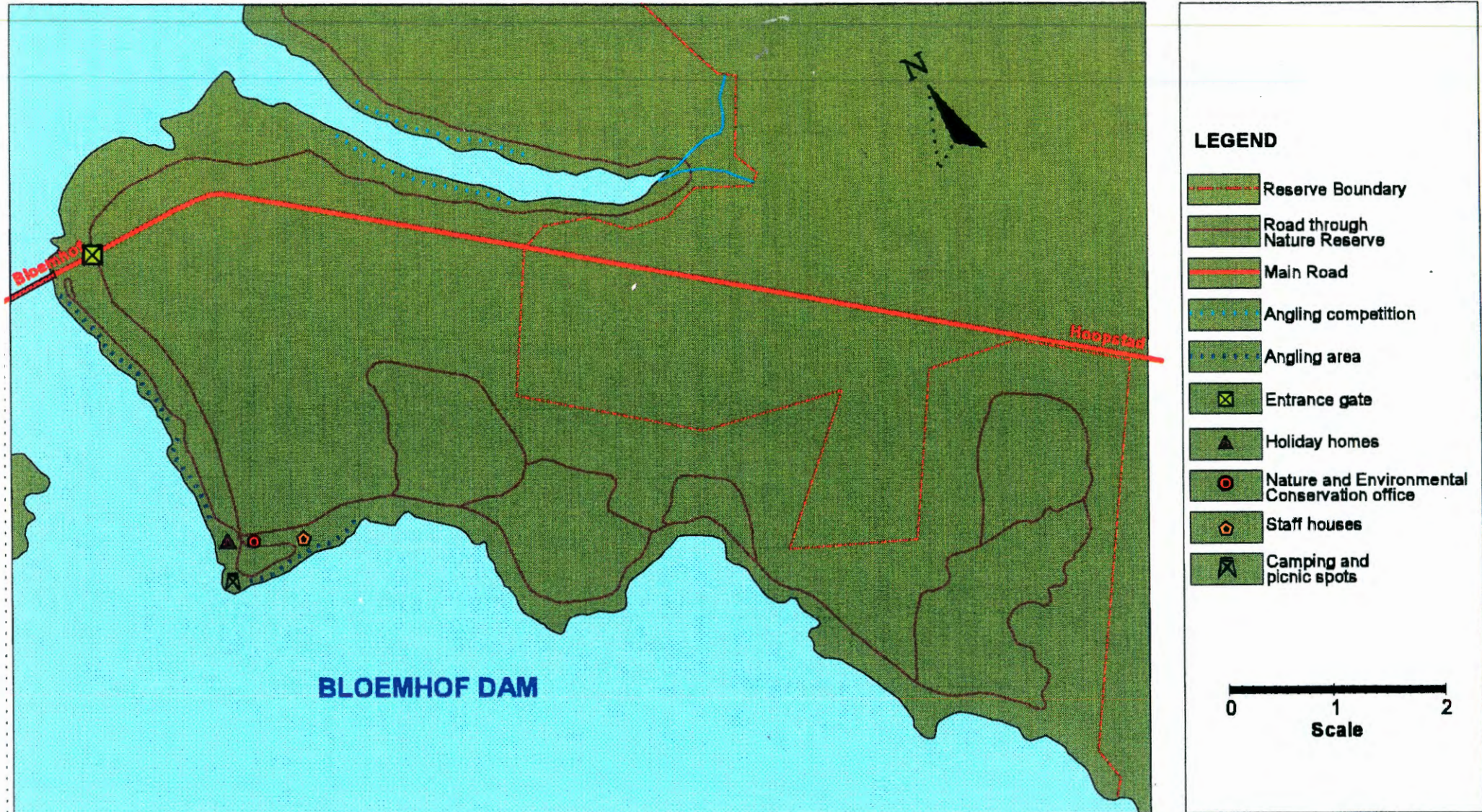


Figure 1.2. The Sandveld Nature Reserve, situated on the Free State Side of the Bloemhof Dam, served as control site.



Department of Nature Conservation of the Provincial administration of the Orange Free State in 1979, making it the first provincial nature reserve in an *Acacia*-savanna (Viljoen 1979).

The following game species are currently permanently resident in the Sandveld Nature Reserve: Black Wildebeest (*Connochaetes gnu*), Blue Wildebeest (*Connochaetes taurinus*), Buffalo (*Syncerus caffer*), Burchell's Zebra (*Equus burchelli*), Common Duiker (*Sylvicapra grimmia*), Eland (*Tragelaphus oryx*), Gemsbok (*Oryx gazella*), Giraffe (*Giraffa camelopardalis*), Impala (*Aepyceros melampus*), Kudu (*Tragelaphus oryx*), Red Hartebeest (*Alcelaphus buselaphus*), Roan Antelope (*Hippotragus equinus*), Sable Antelope (*Hippotragus niger*), Springbok (*Antidorcas marsupialis*), Steenbok (*Raphicerus campestris*) and White Rhino (*Ceratotherium simum*) (<http://wildnetafrika.co.za/directory/client0226.html>). The Sandveld Nature Reserve is furthermore regarded as a prime birding spot boasting a checklist of approximately 295 species (<http://www.sabirding.co.za/birdspot/090505.asp>).

The reserve is situated on the Free State side of the Bloemhof Dam (Figure 1.2) at S27.67916 and E25.50228 ([http://www.gpswaypoints.co.za/WTP\\_parks\\_and\\_reserves.htm](http://www.gpswaypoints.co.za/WTP_parks_and_reserves.htm)). It is located on the R34 between Hoopstad (Free State) and Bloemhof (North West Province), approximately 35 km from the former and 10 km from the latter (Viljoen 1979; Repro Touch 1996). The Sandveld Nature Reserve covers an area of 14 700 ha, with the Bloemhof Dam adding an additional 25 000 ha (<http://wildnetafrika.co.za/directory/client0226.html>).

## 1.5. CLIMATE

### 1.5.1. GENERAL

Climatic data of both the study and control areas was obtained from the **South African Weather Bureau**<sup>5</sup>. Due to its close proximity to the study and control areas, data from the following weather stations was considered most suitable for use in the present study: study area - the Sishen Weather Station (Station Number: 0356857AX; Latitude: 27°47'S; Longitude: 22°59'E; Altitude: 1204 m); and control area - the Bloemhof Police Station (Station Number: 0362159 5; Latitude: 27°39'S; Longitude: 25°36'E; Altitude: 1234 m).



### 1.5.2. RAINFALL

In South Africa, climatic data collected over a minimum period of 20 years is regarded as most accurate, because of the domination of a twenty-year rainfall cycle (Liversidge & Berry 1996).

The mean annual rainfall for the study area over a fifteen-year period is 375.2 mm. Rainfall data from the Sishen Weather Station is only available for the period 1977 to 1992 and mean figures may therefore be slightly inaccurate considering the 20-year rainfall cycle of South Africa (Liversidge & Berry 1996). The given figure does, however, indicate that the study area is situated inside the arid region of South Africa. The latter region is defined by Liversidge and Berry (1996) as receiving a maximum of 400 mm of rainfall per annum.

The mean annual rainfall for the control area, calculated over a period of 96 years (1903 - 1999), is 494.3 mm. This area is therefore, situated outside of the arid region of South Africa (Liversidge & Berry 1996).

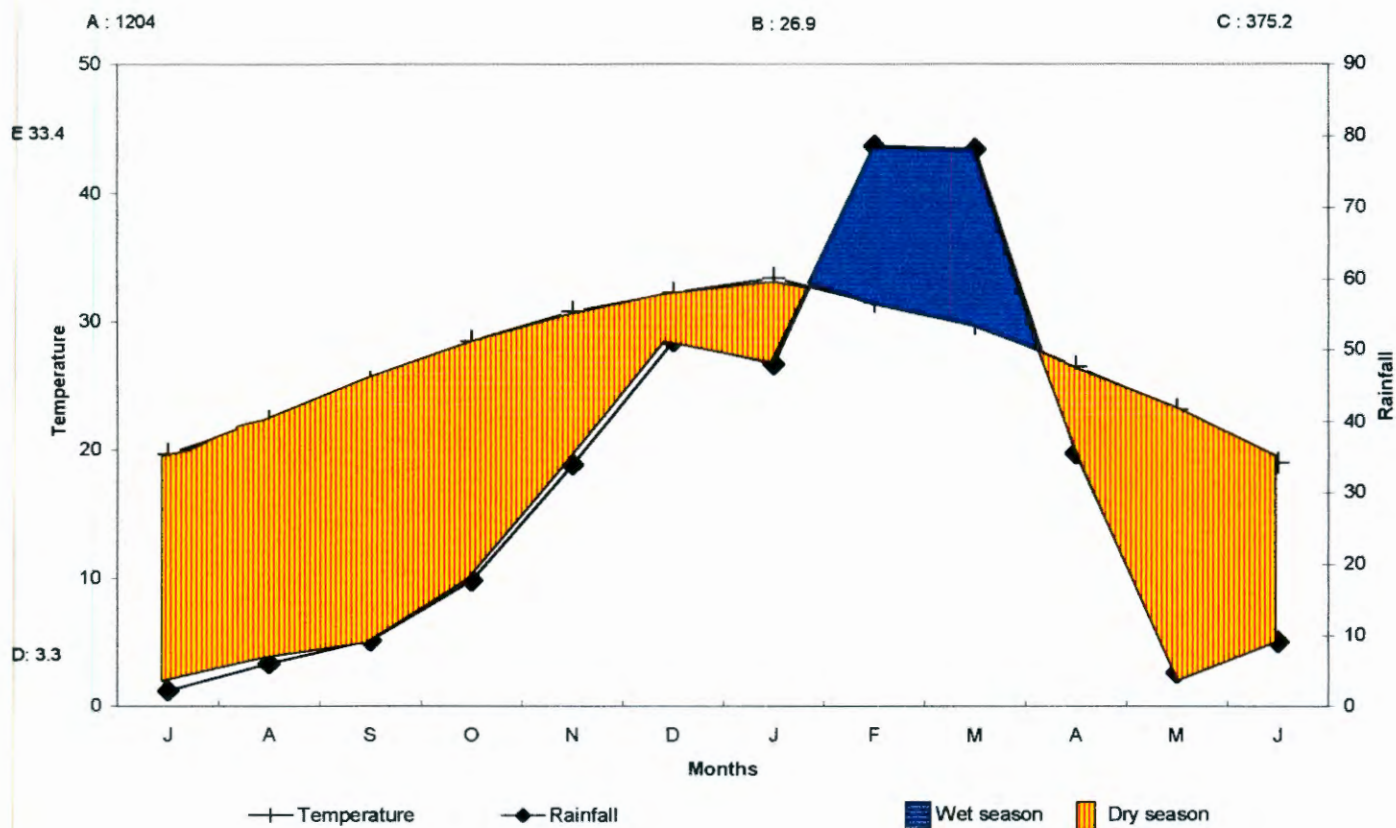
Climatograms of the study and control areas (Figures 1.3 & 1.4) were compiled according to the convention of Walter (1963). From these figures it is clear that the rainy season of the study area extends from February to March, with 41.84% of the mean annual rainfall occurring during this period (Figure 1.3 - Blue Area). The peak of the wet season is reached in February (mean rainfall: 78.70 mm). The dry season extends from April to January (Figure 1.3 - Yellow Areas), with July being the driest month (mean rainfall: 2.20 mm). Extending from December to March, the rainy season of the control area (Figure 1.4) is longer than that of the study area. Sixty-two percent of the mean annual rainfall occurs during this four-month period (Figure 1.4 - Blue Area). The peak of the wet season is reached in January (mean rainfall: 87.2 mm). The dry season extends from April to November (Figure 1.4 - Yellow Areas), with June being the driest month (mean rainfall: 5.0 mm).

### 1.5.3. TEMPERATURE

The mean annual maximum air temperature for the study area over a 21-year period (1978 - 1999), is 26.90 °C.

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<sup>5</sup> South African Weather Bureau. ☐: Department of Environmental Affairs, Private Bag X447, Pretoria, 0001.



- A – Altitude (m)
- B - Mean annual temperature (°C)
- C - Mean annual rainfall (mm)
- D - Mean daily minimum (coldest month) (°C)
- E - Mean daily maximum (warmest month) (°C)

**Figure 1.3.** Climatogram of the study area, based on the convention of Walter (1963). Rainfall and temperature data from the Sishen Weather Station (station number: 0356857AX; Latitude: 27°47'S; Longitude: 22°59'E; Altitude: 1204 m) were used in the construction of this diagram.





Complete temperature data for the control area is only available for the past six years (1993 - 1999). Mean figures may therefore be slightly inaccurate considering the 20-year rainfall cycle of South Africa (Liversidge & Berry 1996). The mean annual maximum air temperature calculated for this period, is 26.35°C, which is only slightly lower than that of the study area.

From the above it is clear that the climate of the study area is both drier and hotter than that of the control area. The potential effect of these climatic differences on the *A. erioloba* populations of both of these areas will be kept in mind throughout this study.

## 1.6. PHYSIOGNOMY

### 1.6.1. KATHU AREA

The altitude of the Kathu area varies from 1 181 m above sea level in the western parts of the Khai-Apple Nature Reserve to 1 230 m above sea level in the eastern parts of the reserve (Van Hoven & Guldmond 1992). The topography of the Kathu area is generally flat, with a slope of less than 3°.

### 1.6.2. SANDVELD NATURE RESERVE AREA

The Sandveld Nature Reserve is situated at an altitude of approximately 1 244 metres above sea level. The topography of the area is flat to undulating, with valleys along the Vaal River (Mans 1968).

## 1.7. SOILS

### 1.7.1. KATHU AREA

The soils of the Kathu area can generally be described as red and dark, with a high base status. These soils are rarely deeper than 300 mm, with surface calcrete being abundant. Two soil types are dominant in the area, namely Glenrosa and Mispah. The former is subdivided into two series: Williamson and Southfield. The Mispah form, on the other hand, is

subdivided into three series: Mispah, Kalkbank and Loskop (Strategic Environmental Focus CC. 1999).

Van Hoven and Guldemond (1992) classified the soils of the Khai-Apple Nature Reserve as that of the Plooyburg Form. This soil form consists of an Orthic A Horizon over a Red Apedal B Horizon, with an underlying Hardpan Carbonate Horizon. The Orthic A Horizon, consisting of organic material and above ground particles, is prone to disturbance. The Red Apedal B Horizon consists of porous micro aggregates with a distinct red colour under well-drained conditions. The red colour is the result of the presence of hematite ( $Fe_2O_3$ ) in the soil. The Hardpan Carbonate Horizon is an ongoing, wavy horizon that occurs within 4.5 m from the soil surface (MacVicar *et al.* 1991; Van Hoven & Guldemond 1992).

#### 1.7.2. SANDVELD NATURE RESERVE AREA

According to Van der Merwe (1962), the well known "sandveld" of this area partially originated from Kalahari sands. Due to a higher annual rainfall and the limited depth of sandy layers in the Sandveld area, a soil type slightly different to Kalahari sands developed here, despite the fact that both areas (Sandveld and the Kalahari) are underlain by Ecca series. The sandy layer varies in depth from a few metres to more than 32.50 metres (Mans 1968).

### 1.8. VEGETATION

#### 1.8.1. KATHU AREA

According to Van Rooyen and Bredenkamp (1996a), the mining town of Kathu is situated in the Kalahari Plains Thorn Bushveld (Veld Type 30) of the Savanna Biome of South Africa. This veld type is described as having a fairly well developed tree stratum, with Camel Thorn and Shepherd's Tree (*Boscia albitrunca*) being dominant. Scattered individuals of Belly Thorn (*A. luederitzii*) and Silver Clusterleaf (*Terminalia sericea*) occur and may be locally conspicuous. The shrub layer is moderately developed and represented by individuals of Black Thorn (*A. mellifera*), Weeping Candle Thorn (*A. hebeclada*), Karee-Thorn (*Lycium hirsutum*), Grey Camel Thorn (*A. haematoxylon*) and Wild Raisin (*Grewia flava*). Grass cover is determined by the amount of rainfall during the growing season. Conspicuous graminoids

include Lehmann's Loyegrass (*Eragrostis lehmanniana*), Silky Bushman Grass (*Stipagrostis uniplumis*) and Sour Bushmangrass (*Schmidtia kalahariensis*).

#### 1.8.2. SANDVELD AREA

The Sandveld Nature Reserve is situated in the Kimberley Thorn Bushveld (Veld Type 32) of the Savannah Biome of South Africa (Van Rooyen & Bredenkamp 1996b). This vegetation type is described as an open savannah and is confined to sandy plains underlain by calcrete. *A. erioloba* and Umbrella Thorn (*A. tortilis*) are dominant woody species, with scattered individuals of *B. albitrunca* and Sweet Thorn (*A. karroo*) occurring in places. The shrub layer is poorly to moderately developed. Individuals of *A. mellifera*, *G. flava*, Camphor Tree (*Tarchonanthus camphoratus*) and *L. hirsutum* are widely scattered. The grass layer of this veld type is fairly well developed. Conspicuous grass species include *E. lehmanniana*, Redgrass (*Themeda triandra*), Common Nine-Awn (*Enneapogon cenchroides*), Copper Wire Grass (*Elionurus muticus*) and Turpentine Grass (*Cymbopogon plurinodis*).



**CHAPTER 2**

**ECOLOGICAL COMPARISON AS A MEANS OF  
IDENTIFYING POTENTIAL PROBLEM AREAS**

## 2.1. INTRODUCTION

Vegetation structure is used world-wide as an indication of the regeneration process of a population (Primack 1995), as it is the age and density structure of a population that determines whether a species can persist (Clark 1991). By comparing the age structure of the *A. erioloba* population of the Kathu area with that of the control area, an idea can be formed of the fitness of the regeneration process of the former, thus identifying problem areas that are potentially responsible for the decline in this population's size.

Seed production and viability are essential for the sustainability of plant populations and therefore is essential in the consideration of population fitness (Eriksson & Ehrlen 1992; Silvertown *et al.* 1993). These factors are, however, influenced by both internal factors, e.g. the rate of pollen tube attrition (Aizen & Raffaele 1998) and external factors (Nilsson 1992), e.g. pollination frequency, which is, in turn, influenced by, among other factors, browse pressure (Strauss *et al.* 1999). An indication of the fitness of the *A. erioloba* population of the Kathu area can therefore be obtained by comparing the seed production of this area to that of the control area.

The *A. erioloba* populations of the study and control areas were compared on the bases of vegetation structure, tree production and reproductive capacity. Significant differences in any one of these areas, which are not a direct result of the climatic and/or environmental variation discussed in Chapter 1, could be indicative of the presence of a potentially harmful factor and could direct further investigations.

## 2.2. OBJECTIVES

The aims of this investigation were to:

- Identify differences (if any) between the *A. erioloba* structure of the study and control areas by means of the Variable Quadrat method.
- Compare the distribution of *A. erioloba* deaths within height classes between the study and control areas by means of the Variable Quadrat method.
- Identify significant differences (if any) between the production and density of *A. erioloba* trees of the study and control areas by means of the BECVOL method.

- Identify significant differences (if any) between the reproductive capacity of the *A. erioloba* populations of the study and control areas by comparing the germination- and growth potentials of *A. erioloba* seeds and seedlings.

## 2.3. METHODOLOGY

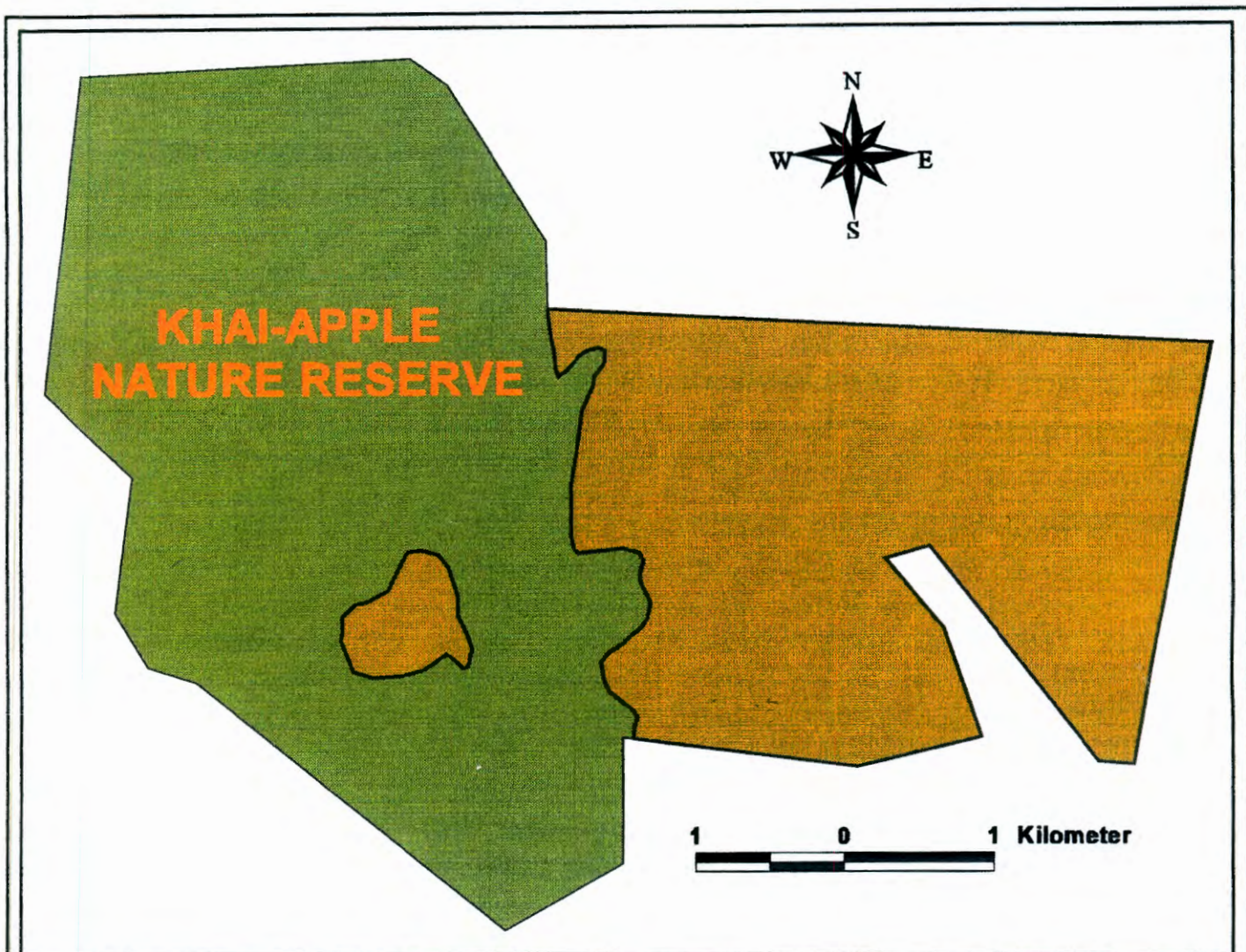
### 2.3.1. DETERMINATION OF ACACIA ERIOLOBA STRUCTURE BY MEANS OF THE VARIABLE QUADRAT METHOD

The Variable Quadrat method of Coetzee and Gertenbach (1977) was used for the description of *A. erioloba* structure. The main considerations in selecting this method were its non-destructive nature; the elimination of the subjectivity of estimation that is present in, e.g., the dead wood estimation method (García *et al.* 1999); and the fact that expensive apparatus is not required.



The Variable Quadrat method uses tree height for describing age structure, a parameter also used by Garcia *et al.* (1999). Other methods use stem basal area (Knowles & Grant 1983; Parker & Peet 1984; Walker *et al.* 1986; Garcia *et al.* 1999; Steenkamp 2000), annual rings (Knowles & Grant 1983; Parker & Peet 1984; Richardson 1988; Skoglund & Verwijst 1989; Steenkamp 2000), and the quantity of dead wood on an individual (García *et al.* 1999). Tree height was accepted as an appropriate single measure of tree size, as no height modifications caused by fire or chopping (Walker *et al.* 1986) commonly occur in either the study or control areas. The correspondence between plant height and age class can be affected by two main factors: the micro-environment where the individual plant develops, and the density of individuals in a stand. Lower resource availability or higher density would influence heights for a specific age group (Hutchings 1986).

The growth form, total height and crown diameter of every *A. erioloba* individual in each of the four quadrants per quadrat were measured with the aid of a calibrated measuring rod and recorded for each of the following sites: the *Acacia erioloba* Woodland community of the Khai-Apple Nature Reserve (Figure 2.1), Knapdaar, Lylyveld-Demaneng, the Sishen Golf Course and the Sandveld Nature Reserve. Variables are summarised below.





**LEGEND**

-  *Acacia mellifera* Shrubland community
-  *Acacia erioloba* Woodland community

**Figure 2.1.** Vegetation communities of the Khai-Apple Nature Reserve, as identified by Van Hoven and Guldmond (1992).

### 2.3.1.1. Growth form

Growth form was classified as one of the following (Coetzee & Gertenbach 1977):

- Tree – An individual with a single stem.
- Light or sparse shrub – An individual with 2 - 4 stems.
- Bushy shrub – An individual with more than four stems.

### 2.3.1.2. Strata

The following strata were distinguished for height classification: 0.75 m, 0.75 - 1.50 m, 1.50 - 2.50 m, 2.50 - 3.50 m, 3.50 - 5.50 m and >5.50 m. Heights lower than 0.75 m were round off to 0.50 m (class 1), while heights higher than 0.75 m were round of to the nearest meter: 1 m (class 2), 2 m (class 3), 3 m (class 4), 4 - 5 m (class 5) and >5 m (class 6) (Coetzee & Gertenbach 1977).

### 2.3.1.3. Quadrat-size

Quadrat size was determined independently for every height class at every sample plot, so as to suit the density and distribution of the vegetation. Low densities and irregular distributions resulted in large quadrats containing few individuals, while the opposite was true with small quadrat sizes. Test quadrat sizes were enlarged step-by-step in each of the four quadrants from the center-point of the relevé until at least one individual of a specific height class was present in all four quadrants. Quadrant enlargement took place in the following sequence: 5 X 5 m, 10 x 10 m, 20 x 20 m and 25 x 25 m (maximum quadrant size). The maximum size of a sample plot (quadrat) was therefore 50 x 50 m or 0.25 ha (Coetzee & Gertenbach 1977).

### 2.3.1.4. Procedure

Cables or ropes, calibrated at 5 m intervals, were used to form a rectangular cross of which every arm was 25 m in length. The point of intersection of the two ropes served as the center of the plot (Coetzee & Gertenbach 1977). If present, one of the ropes was always placed in the direction of an incline. In the absence of an incline one of the ropes were always placed in a



North-South direction (University of the Free State Practical Plant Ecology Guide, Unpublished<sup>1</sup>).

By determining the nearest rooted individual of a specific height class in each quadrant, four test quadrats (one for each quadrant of the cross) were determined for every height class. The largest of these four test quadrats determined the sample plot size for that specific height class. The quadrat is therefore "a square with its center at the center of the cross and divided by the cross into four quarters (quadrants), each the size of the largest test square" (Coetzee & Gertenbach 1977). This procedure was repeated to determine a suitable quadrat size for every height class (Coetzee & Gertenbach 1977).

For every *A. erioloba* individual of a specific height class in the sample plot, the following information was recorded:

- A species code, made up of the first three letters of the generic name of the plant, followed by the first three letters of the specific epitheton.
- Growth form code ("T" for tree, "SS" for sparse shrub or "S" for shrub).
- Stem diameter in centimeter, for plants with a stem diameter greater than 10 cm.
- The maximum crown diameter in centimeter in every height class as is seen from the direction of the center point of the sample plot. Extremes were ignored.

#### 2.3.1.5. Data processing

Data was processed by calculating it manually. The age structure of the populations was determined by taking the mean percentage of the total population represented by each height class.

#### 2.3.2. DETERMINATION OF TREE PRODUCTION AND DENSITY WITH THE AID OF THE BECVOL METHOD

The BECVOL (Browse Estimate from Canopy Volume) method (Smit 1996) has been successfully used for the quantitative description of woody plant communities in various parts of Africa, including Kenya, South Africa and Zambia (Schmidt 1992; Orban 1995; Brown 1997; Van Essen 1997; Cauldwell 1998; Brits 1999; Von Holdt 1999). This method was selected for use in

<sup>1</sup>  Department of Botany and Genetics, University of the Free State, Bloemfontein, 9301.



the present study because it is fast and accurate, it involves no destruction of leaf material, and it is not labour intensive (Smit 1996; Van Essen 1997; Von Holdt 1999).

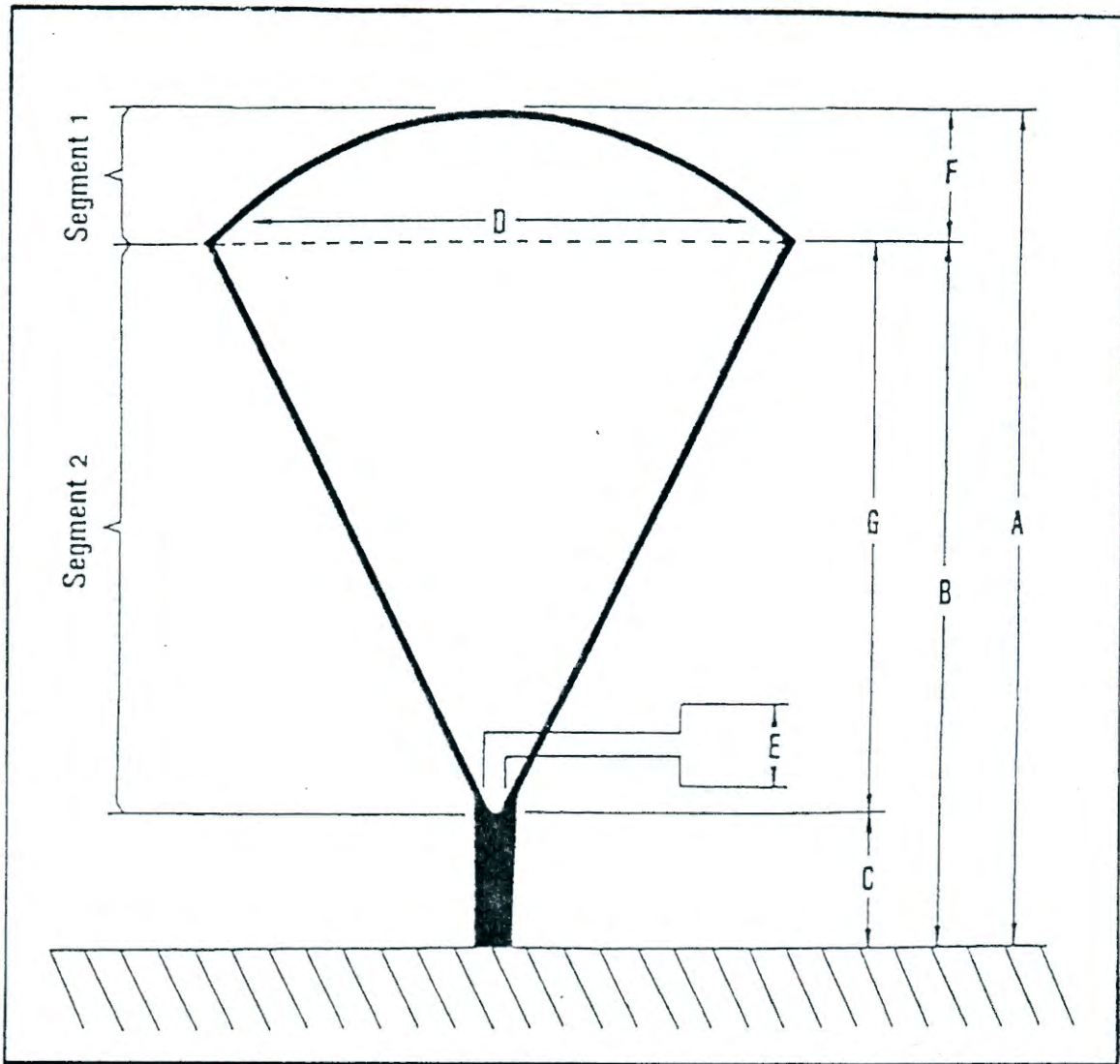
BECVOL can be classified as a descriptive model that provides an estimate of the leaf volume as well as the leaf mass of individual trees. These estimates are derived from the relations between spatial canopy volume and the tree's true leaf volume and leaf mass (Smit 1996).

*Acacia erioloba* populations were surveyed by using the BECVOL belt transect method of Smit (1989). A total of 11 transects were surveyed in the *Acacia erioloba* Woodland community (Van Hoven & Guldmond 1992) of the Khai-Apple Nature Reserve (Figure 2.1); ten in the Sandveld Nature Reserve; four on the Sishen Golf Course premises; five in Lylyveld-Demaneng; and five in Knapdaar-Swarthaak. Sampling was done along a 100 m line transect with a 2 m range rod held horizontally to delineate the boundaries of the belt transect, for a total survey area of 200 m<sup>2</sup>. A rope was used to mark out each transect. Each transect was delineated along a north-south axis. The dimensional measurements of all *A. erioloba* individuals rooted within the transect area were measured with the aid of a calibrated measuring rod (Smit 1996).

The description of an ideal tree was used as a basis for the calculation of the spatial volume of all recorded *A. erioloba* individuals, regardless of its shape or size (Brits 1999). An ideal tree (Figure 2.2) is regarded here as a single tree with a canopy consisting of a dome-shaped crown and a cone-shaped base (Von Holdt 1999). Spatial canopy volumes were calculated from the following dimensional measurements in metres, for each tree (Smit 1996):

- Tree height.
- Height of maximum canopy diameter.
- Height of first leaves or potential leaf bearing stems.
- Maximum canopy diameter.
- Base diameter of the foliage at the height of the first leaves or potential leaf bearing stems.

Tree height was taken as the height of the main tree crown, ignoring any small, protruding stems. The maximum canopy diameter was calculated as the mean of two measurements ( $D_1$  &  $D_2$ ) taken rectangular to each other, whenever the tree canopy was elliptical in shape (i.e. it is measured horizontally). The same procedure was applied to the base diameter measurements ( $E_1$  &  $E_2$ ). Only live tree parts were included in the measurements taken (Smit 1996).



- A – Tree height
- B – Height of maximum canopy diameter
- C – Height of minimum canopy diameter
- D – Maximum canopy diameter
- E – Minimum canopy diameter
- F – Dome
- G – Cone

Figure 2.2. Schematic illustration of an ideal tree and the parameters used (adopted from Smit 1989).



Measurements, together with the exact Global Positioning System (GPS) reference of each transect, were recorded. The data was, where possible, grouped according to previously identified plant communities and was analysed with the aid of the BECVOL 2.0 computer program. This DOS-based program calculates the spatial volume of each tree segment (Smit 1989).

### 2.3.3. COMPARISON OF REPRODUCTIVE CAPACITY

#### 2.3.3.1. Pod collection

*A. erioloba* pods were randomly collected from the ground. Pods were, whenever possible, collected immediately after falling. The seeds were used in the germination studies.

#### 2.3.3.2. Optimization of germination conditions

Optimal germination conditions were determined prior to germination studies. This was done by incubating a random mixture of 20 scarred, sterilised *A. erioloba* seeds in dark conditions in Labcon Model L.T.G.C. growth chambers, using different temperature and incubation volume combinations, namely 27°C, 30°C and 32°C, and 10 ml, 12.5 ml and 15 ml of distilled water. Seeds were placed on a single layer of 90 mm Schleicher and Schuell filter paper in a covered 90 mm glass petri dish, whereafter the desired volume of distilled water was added. Treatments were done in triplicate.

The following incubation conditions were found to be optimal for the germination of *A. erioloba* seeds in the present study: 15 ml of incubation medium at 30°C in the dark.

#### 2.3.3.3. Optimization of dormancy breaking treatments

Several seed scarification treatments have been recommended for *Acacia* species (Clemens *et al.* 1977), including hot water, dry heat, freezing, organic solvents, hot and cold acid, and mechanical scarification (Osborn & Osborn 1931; Harding 1940; Jones 1963; Larsen 1964; Brown & Booysen 1969; Clemens 1977; Burger 1988; Hoffman *et al.* 1989; Tietema *et al.* 1992; Venter & Venter 1996). The results obtained by Burger (1988), Hoffman *et al.* (1989) and Tietema *et al.* (1992), whose work were all based on *A. erioloba*, lead to the consideration of only two of these scarification treatments for use in the present investigation, namely

mechanical scarring and treatment with concentrated sulfuric acid at room temperature. These treatments previously resulted in a relatively high final percentage germination of seeds in a relatively short period of time (Burger 1988; Hoffman *et al.* 1989; Tietema *et al.* 1992), although these scarification treatments cannot be guaranteed to promote the germination of all viable seeds (Clemens 1977).

Only non-predated seeds were considered for scarification treatments.

Seeds were mechanically scarified by grinding through the testa, at the end furthest from the embryo, using an industrial bench grinder.

The acid treatment comprised the complete submergence of seeds in concentrated sulfuric acid at room temperature, followed by continuous stirring on a magnetic stirrer for a predetermined time period of 90 min. This was followed by the thorough rinsing of seeds in distilled water.

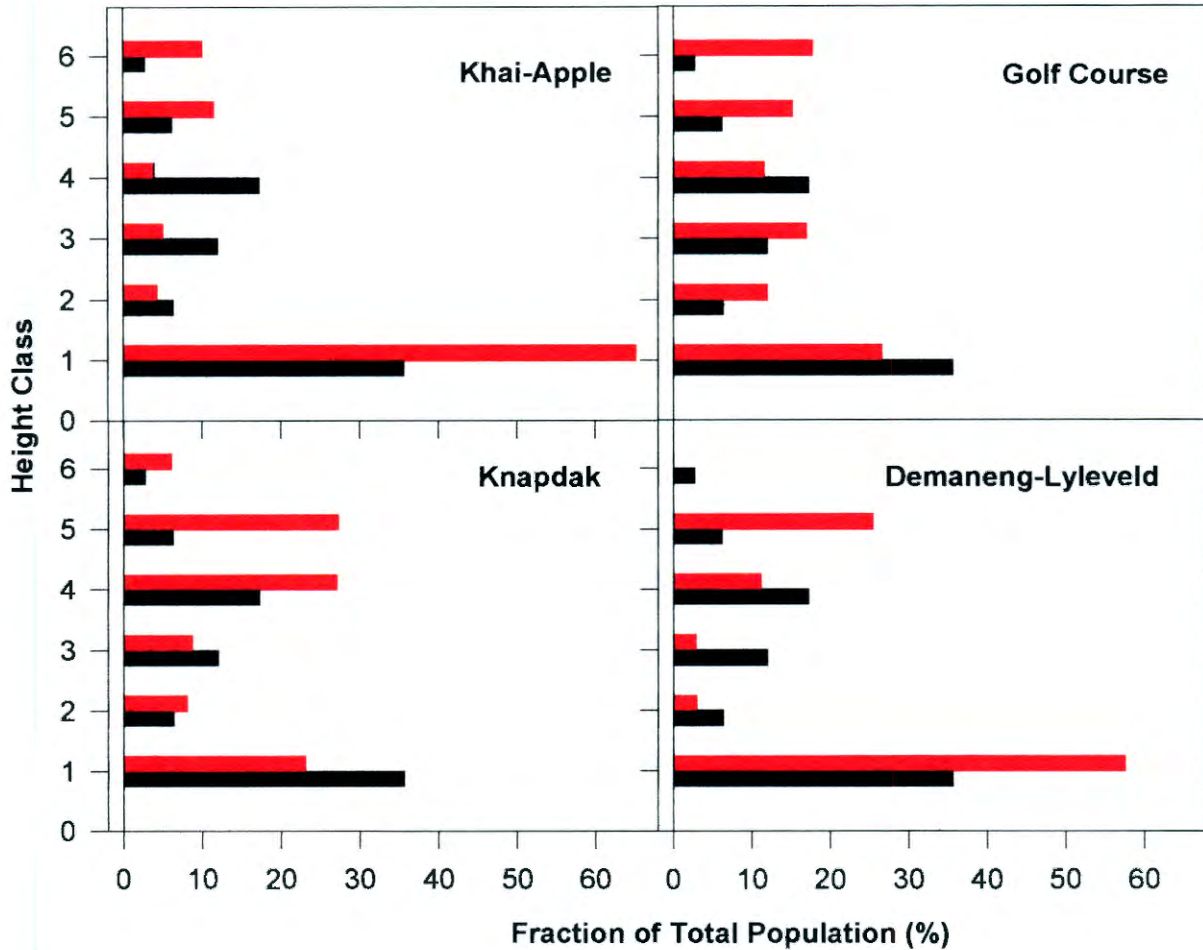
Scarified seeds were sterilised with a 0.50% solution of the fungicide "Panacide". Seeds were submerged in Panacide for five minutes, after which it was repeatedly washed with sterilised, distilled water. Seeds were blotted before further use.

## 2.4. RESULTS AND DISCUSSION

### 2.4.1. *ACACIA ERIOLOBA* STRUCTURE

More than 35% of the *A. erioloba* population of the Sandveld Nature Reserve falls within the first height class (0.50 m) (Figure 2.3). According to Thrash *et al.* (1991) a relatively large percentage of the population of long-lived perennials often fall in its lowest height class, as this increases the chances of survival of some individuals to adulthood, in this way securing the future of the population (Thrash *et al.* 1991). The presence of large quantities of germinated seedlings does not, however, guarantee a species' survival. Environmental factors such as rainfall distribution; grass competition; the size of predatory insect and rodent populations; the availability of resources; and the suitability of the microhabitat are all determining factors in the successful establishment of seedlings (Thrash *et al.* 1991; Steenkamp 2000).





**Figure 2.3.** Population structure of the *Acacia erioloba* populations of the Khai-Apple Nature Reserve (■), Knapdaar (■), Lylyveld-Demaneng (■), the Sandveld Nature Reserve (■) and the Sishen Golf Course (■). Both ■ and ■ indicate the fraction of the total population represented by each height class.

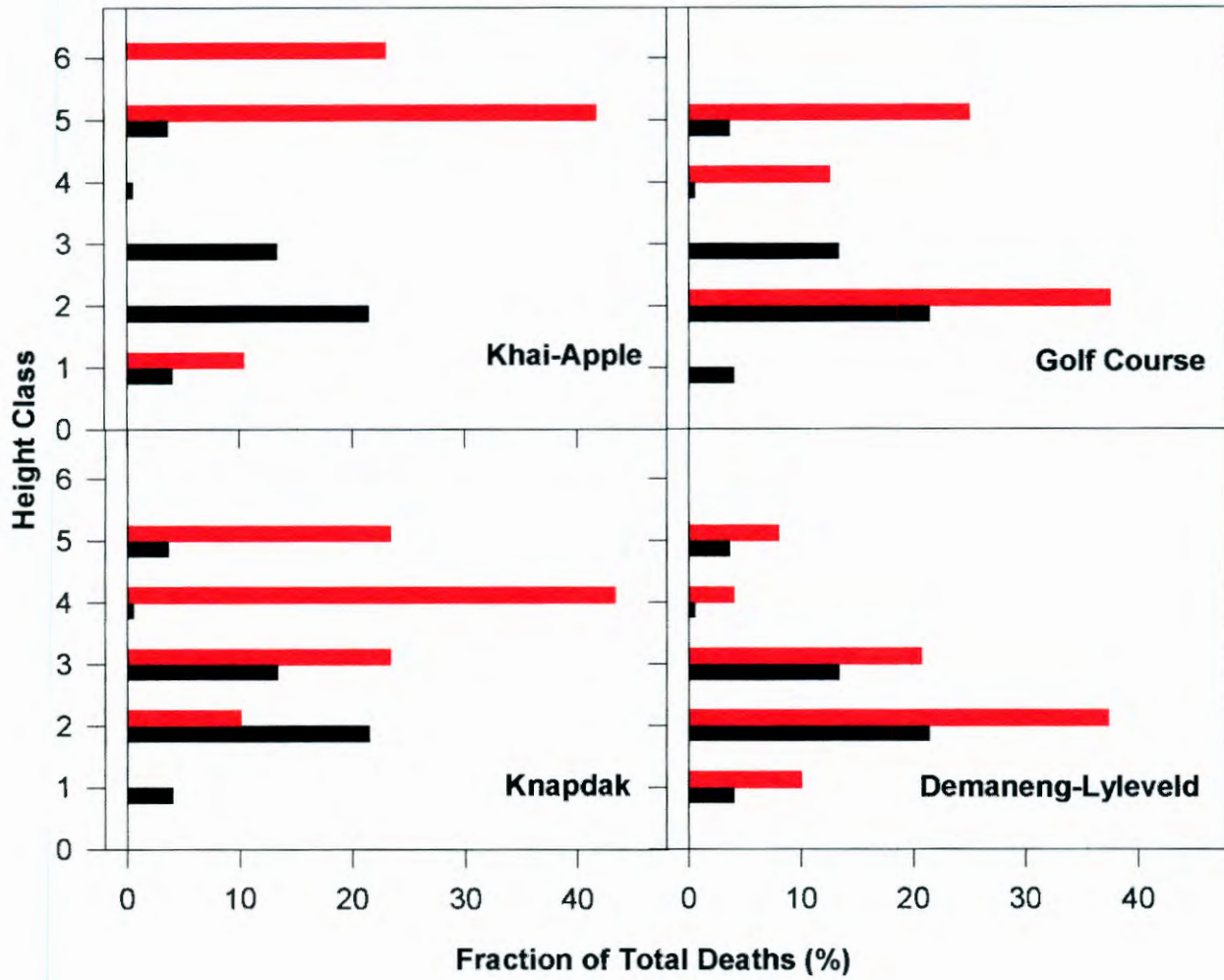
It is therefore not surprising that the second height class (1 m) of the Sandveld population contains a much smaller percentage of the population (6.30%) (Figure 2.3). A veld fire in the early 1990's was a major contributing factor in the relatively small size of this height class. This is confirmed by the results of the death structure study: a relatively high death rate occurred amongst individuals in height class two (Figure 2.4). These findings are in direct opposition to the findings of Ben-Shahar (1998), who stated that "*the structure of A. erioloba woodlands appeared to be influenced by factors other than ... the occurrence of fire*".

In the Sandveld Nature Reserve, the number of individuals in height classes two (1 m), three (2 m), four (3 m) and five (4 – 5 m) show a steady increase from 6.30% of the total population in the former, to 26.20% in the latter, giving rise to a typical bee hive-shaped height distribution graph (Figure 2.3). The height class containing the least individuals (2.70% of the population) is that of 5+ m (Figure 2.3). For the purpose of this study the control site is presumed as having a healthy *A. erioloba* population, and therefore its age demography will be regarded as the norm.

The largest percentage (65.20%) of the *A. erioloba* population of the Khai-Apple Nature Reserve falls within the first height class (0.50 m) (Figure 2.3). This figure is almost twice as high as that of the control area. This phenomenon cannot be explained by the climatic differences between the two areas, as the study area is both drier and hotter than the control area (Figures 1.3 & 1.4) – two factors that promote the desiccation of seedlings (Hoffman *et al.* 1989). The possibility that the presence of these two factors is in fact a prerequisite for the establishment of *A. erioloba* seedlings should, however, not be eliminated. Factors other than the climatic differences between the study and control areas that are potentially responsible for the irregularity in the height structure distribution of *A. erioloba* in the Khai-Apple Nature Reserve will be investigated in detail in the chapters that follow.

As is the case in the control area, the second height class (1 m) of the Khai-Apple Nature Reserve contains a considerably smaller number of individuals than the first, due to the susceptibility of seedlings to environmental adversities (Figure 2.3). It is interesting to note that a much smaller percentage of young individuals survive to reach the second height class (1m) in this area than in the Sandveld Nature Reserve, indicating the presence of fierce intra-specific competition and/or other adversities in the former. Higher mean temperatures and lower rainfall in the Kathu area (Figures 1.3 & 1.4) could be some of the factors that inhibit the successful establishment of seedlings.





**Figure 2.4.** The distribution of deaths within the different age classes of the *Acacia erioloba* populations of the Khai-Apple Nature Reserve (■), Knapdaar (■), Lylyveld-Demaneng (■), the Sandveld Nature Reserve (■) and the Sishen Golf Course (■). Both ■ and ■ indicate the fraction of the total deaths represented by each height class.

Instead of being bee-hive shaped, the age demography of the Khai-Apple Nature Reserve population exhibits a drop in that fraction of the population representing the middle height classes (1 m – 3 m) (Figure 2.3). At 5.00%, there is almost no increase in the fraction of the population representing the third (2 m) height class from that representing the first height class (1 m) (Figure 2.3). The fourth (3 m) height class is represented by the smallest fraction of the population, namely 3.90%. Compared to the control area (Sandveld Nature Reserve), this is irregular and could be indicative of some factor(s) that is either killing the trees in this height class, or preventing trees from reaching this height. Figure 2.4 indicates the latter assumption to be correct: none of the recorded deaths fall within the fourth (3 m) height class. The heartwood of *A. erioloba* is extremely hard, heavy and dense, making it resistant to termites, other wood-boring insects and fungi (Coates Palgrave 1984; Dudley 1999; Smit 1999; Van der Walt & Le Riche 1999). Dead trees therefore remain in position long after dying. If some factor was killing trees in this height class, at least some dead individuals would have been recorded. However, up until December 2000 dead trees were removed and sold as firewood in the Khai-Apple Nature Reserve, causing the full extent of deaths to be obscured. There is therefore a possibility that the number of deaths in the Khai-Apple Nature Reserve could have been underestimated by the present study. Height classes five (4 - 5 m) and six (5+ m) both represented larger fractions of the population than the same height classes in the Sandveld Nature Reserve (Figure 2.3).

The first height class (0.50 m) is well represented (26.60% of the total population) on the Sishen Golf Course (Figure 2.3). The age demography of this area follows the same basic trend as that of the Sandveld Nature Reserve, with one exception: one would expect the fourth height class (3 m) to be larger. This irregularity is indicative of some factor(s) that is negatively influencing the *A. erioloba* population of the Sishen Golf Course and will be investigated in the chapters that follow. The sixth height class (5+ m) is particularly well represented in this area (17.70% of the total population). This can be an indication of the high age of this population, or simply that growth conditions (e.g. the presence of deep Kalahari sands) are highly favourable.

Similar to the control site, the largest fraction (57.60%) of the *A. erioloba* population of Lylyveld-Demaneng consists of individuals from the first (0.50 m) height class (Figure 2.3). This figure is relatively high and can probably be attributed to the fact that cattle are fed with pods in times of food scarcity. Hard seededness is overcome during the digestive process, thus improving the chances of imbibition and subsequent germination (Sabiiti & Wein 1987; Hoffman *et al.* 1989;



Dudley 1999; Van der Walt & Le Riche 1999). Only 3.00% of the total population falls in the second height class (1 m) (Figure 2.3), which is once again indicative of the susceptibility of young individuals to environmental adversities. A bee-hive shaped age demography for the Lylyveld-Demaneng population is hindered by a conspicuously low percentage of the population (2.90%) representing the third (2 m) height class (Figure 2.3). This fraction of the population is clearly negatively influenced by some factor(s) and will be investigated in the chapters that follow. Height classes four (3 m) and five (4 - 5 m) exhibit a healthy age demography if compared to that of the Sandveld Nature Reserve (Figure 2.3). A relatively large fraction of the population (25.40%) represents the fifth (4 - 5 m) height class if compared to that of the Sandveld Nature Reserve. No individuals of 6+ m were found in the Lylyveld-Demaneng area (Figure 2.3). This may be indicative of a younger *A. erioloba* population on this farm, or the presence of a shallower form of the deep Kalahari sands preferred by the species (Smit 1999; Van der Walt & Le Riche 1999).

More than twice as many young individuals reach the second height class in the Sandveld Nature Reserve than in Knapdaar, indicating the effect of high temperatures and low rainfall (Figures 1.3 & 1.4) on the establishment of seedlings in the latter (Rohner & Ward 1999). The largest portion of the Knapdaar population is not represented by the first height class (0.50 m), as has been the case with all of the locations described in the paragraphs above (Figure 2.3). The rest of the age demography exhibits a trend similar to that of the Sandveld Nature Reserve, indicating a healthy population structure. One would, however, expect the third height class (2 m) to be better represented after the analogy of the control area (Figure 2.3). This irregularity in the Knapdaar-Swarthaak demography was probably caused by the use of non-specific poisons for the poisoning of *A. mellifera* in the early 1980's, killing many young individuals of *A. erioloba* (Engelbrecht, pers. comm.<sup>2</sup>) (See Chapter 5). The fifth height class (4 - 5 m) is particularly well represented (27.20% of the total population) in the Knapdaar-Swarthaak area (Figure 2.3), indicating an earlier boom in population growth.

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<sup>2</sup> Mrs. Marlene Engelbrecht. Owner: Knapdaar & Swarthaak. ☎: 0537910527.

## 2.4.2. TREE DENSITY AND PRODUCTION

### 2.4.2.1. Tree density

The Sandveld Nature Reserve has an *A. erioloba* density of 186 trees ha<sup>-1</sup>, which is, if compared to the densities measured in the study sites in the Kathu area, relatively high (Table 2.1).

The *A. erioloba* tree density in the Khai-Apple Nature Reserve was the lowest of all measured densities at 125 trees ha<sup>-1</sup> (Table 2.1). One would expect the density of this area, which contains the largest *A. erioloba* forest in the world, to be closer to that of the adjacent Sishen Golf Course (175 trees ha<sup>-1</sup>). The close proximity of the golf course and the reserve and the relatively large difference in their *A. erioloba* densities imply that some factor other than climatic or edaphic factors, which should be the same for these two areas, are responsible for this irregularity and will be investigated in the chapters that follow.

The *A. erioloba* density of Knapdaar was relatively low at 130 trees ha<sup>-1</sup> (Table 2.1). Assuming that the Sishen Iscor Iron Ore Mine influences the *A. erioloba* population of the Kathu area, one would expect a higher density at this location, seeing that it is situated up-wind from the mine and relatively far from it. This irregularity will be addressed in Chapter 8.

Lylyveld-Demaneng had the highest measured *A. erioloba* density at 200 trees ha<sup>-1</sup> (Table 2.1), which seems contradictory considering the location of this site. It should, however, be noted that the survey transects in this area bisected the occasional *A. erioloba* tree clump. These clumps are caused by one of two factors: the presence of cattle feeding troughs, where cattle are fed with Camel Thorn pods; and/or the death of an old *A. erioloba* tree, which creates opportunities for the establishment of new individuals of the same species (Van der Walt & Le Riche 1999). The density given for this area might therefore be an over-estimation.

### 2.4.2.2. Tree production

The leaf volume and mass of *A. erioloba* in the Sandveld Nature Reserve (394 m<sup>3</sup> ha<sup>-1</sup> and 182 kg dry mass ha<sup>-1</sup>, respectively) was low compared to that of the Kathu area (Table 2.1). This phenomenon can be explained by comparing the population structure of these areas: except for



Table 2.1. Density, leaf volume and leaf mass of *Acacia erioloba* in the study and control areas.

Location	Density (Plants ha <sup>-1</sup> )	Leaf Volume (m <sup>3</sup> ha <sup>-1</sup> )	Leaf Mass (kg Dry Mass ha <sup>-1</sup> )
Khai-Apple Nature Reserve	125	671	318
Knapdaar-Swarthaak	130	560	263
Lylyveld – Demaneng	200	536	226
Sandveld Nature Reserve	186	394	182
Sishen Golf Course	175	778	371

Lylyveld-Demaneng, the *A. erioloba* populations of all the study sites are well represented by individuals from height classes five and six. The Sandveld Nature Reserve, on the other hand, contains relatively few representatives from these height classes. This could be a result of the difference in environmental conditions of these two areas, e.g. climatic and edaphic factors. Secondly, the *A. erioloba* population of the Sandveld Nature Reserve could be younger than that of the Kathu area. It is believed that cattle and sheep farming practices had a definite influence in the present distribution of *A. erioloba* trees in the former area. After the occupation of the Sandveld Nature Reserve area by whites, animal-farming practices speedily developed. By 1880 the number of cattle in the area reached  $\pm 77\ 000$ , that of merino sheep  $\pm 583\ 000$ , Afrikaner sheep  $\pm 18\ 000$  and that of horses  $\pm 13\ 000$ . These animals concentrated in corals, water points and at salt licks, forming beds of seed-rich dung, which was the perfect germinating environment for *A. erioloba* seeds (Viljoen 1979). This population is therefore relatively young, if it is kept in mind that *A. erioloba* can reach ages of up to 300 years (Barnes *et al.* 1997; Milton & Dean 1999; Van der Walt & Le Riche 1999).

Despite its seemingly low tree density, the Khai-Apple Nature Reserve had a relatively large leaf volume and -mass at  $671\ \text{m}^3\ \text{ha}^{-1}$  and  $318\ \text{kg dry mass ha}^{-1}$ , respectively (Table 2.1). This phenomenon is a result of tree size: a large fraction of the *A. erioloba* population of the Khai-Apple Nature Reserve falls in height classes five and six (4 - 5 m and 5+ m) (Figure 2.3). Individuals from these height classes have wide, spreading crowns (Coates Palgrave 1984; Milton & Dean 1999; Van Wyk & Van Wyk 1997; Smit 1999), resulting in a relatively larger leaf volume and mass.

The same phenomenon occurs in the Sishen Golf Course area: the measured leaf volume ( $778\ \text{m}^3\ \text{ha}^{-1}$ ) and mass ( $371\ \text{kg dry mass ha}^{-1}$ ) of this area ranked highest overall, despite a relatively low tree density (Table 2.1). This is once again explained by the large fraction of this population in height classes five (4 - 5 m) and six (5+ m) (Figure 2.3).

Lylyveld-Demaneng and Knapdaar had similar *A. erioloba* leaf volumes ( $536\ \text{m}^3\ \text{ha}^{-1}$  and  $560\ \text{m}^3\ \text{ha}^{-1}$  respectively) and masses ( $226\ \text{kg ha}^{-1}$  and  $263\ \text{kg ha}^{-1}$  respectively), despite the marked difference in densities of these two areas (Table 2.1). This emphasises the height demography of the Lylyveld-Demaneng area (Figure 2.3): despite a large tree density, the largest part of this population fall in the lower height classes, resulting in a relatively low leaf density and mass. It



is, however, possible that some factor(s) could be inhibiting leaf production in the Lylyveld-Demaneng area. This possibility will be addressed in Chapter 4.

### 2.4.3. REPRODUCTIVE CAPACITY

#### 2.4.3.1. Optimal germination conditions

*Acacia erioloba* seeds germinate optimally in the dark at 30°C in 15 ml of distilled water (Table 2.2). Seeds incubated in these conditions had the highest germination success throughout. These conditions are similar to those found to be optimal for the germination of *A. erioloba* seeds by Burger (1988) and Hoffman *et al.* (1989). These optimal conditions were applied in all germination trials for the remainder of this study.

#### 2.4.3.2. Breaking seed dormancy

Hard seededness in *A. erioloba* may cause a seed to lie dormant for many years unless some form of treatment is conducted to improve permeability (Clemens *et al.* 1977; Hoffman *et al.* 1989). Digestive juices are one such treatment and will soften the testa (it may even fracture the lens), in this way facilitating imbibition. Germination success is improved in this way, but the survival rate of seeds after ingestion depends on its maturity, as well as the type of animal consuming the seed (Sabiiti & Wein 1987; Hoffman *et al.* 1989; Dudley 1999; Stuart-Hill 1999; Van der Walt & Le Riche 1999). Seeds are, however, exposed to digestive juices for a relatively long period of time (between 24.50 and 36.00 h; Dudley 1999), when compared to the scarification period of 90 minutes in concentrated sulfuric acid used in this study. Seed coat abrasion, on the other hand, mimics the mechanical scarring of seeds, e.g. being trodden on, and has previously appeared to be equally effective in ending seed dormancy (Hoffman *et al.* 1989).

Based on the work of Burger (1988) and Hoffman *et al.* (1989), a scarification period of 90 minutes with concentrated sulfuric acid at room temperature was selected for use in the present study. This scarification treatment proved most effective in breaking the dormancy of *A. erioloba* seeds in the studies mentioned.

Table 2.2. Germination potential of scarified, non-sterilised *Acacia erioloba* seeds incubated at different temperatures (°C) in different volumes (ml) of distilled water.

Incubation Time (h)	27°C			30°C			32°C		
	10 ml	12.5 ml	15 ml	10 ml	12.5 ml	15 ml	10 ml	12.5 ml	15 ml
16	15.00	0.00	5.00	20.00	0.00	20.00	0.00	15.00	5.00
20	20.00	10.00	15.00	30.00	15.00	43.30	0.00	15.00	15.00
24	20.00	10.00	25.00	35.00	25.00	65.00	5.00	40.00	15.00
40	50.00	35.00	60.00	65.00	55.00	80.00	25.00	60.00	40.00
44	60.00	40.00	60.00	65.00	55.00	80.00	35.00	75.00	45.00
48	60.00	40.00	65.00	65.00	65.00	81.67	35.00	75.00	60.00
64	60.00	45.00	65.00	70.00	70.00	81.67	45.00	75.00	60.00
72	65.00	55.00	65.00	70.00	70.00	81.67	50.00	75.00	60.00
88	70.00	55.00	65.00	70.00	75.00	81.67	50.00	75.00	60.00
96	70.00	55.00	65.00	70.00	75.00	81.67	50.00	75.00	60.00
168	70.00	60.00	65.00	75.00	75.00	81.67	50.00	75.00	60.00



Mechanically scarred seeds reached an average germination percentage of 66.67% after 88 h of incubation (Table 2.3). In contrast, seeds treated with concentrated sulfuric acid reached an average germination percentage of 81.67% within 48 h of incubation (Table 2.3). Acid treated seeds, therefore, not only rendered a higher germination percentage, but also completed germination sooner than mechanically scarified seeds. The control treatment, comprising non-scarified seeds, failed to germinate after 168 h of incubation (Table 2.3).

The success achieved through acid scarification can be explained by the fact that treatment with concentrated sulphuric acid mimics the natural process that takes place upon ingestion of seeds by ungulates. The seeds of various non-dehiscent *Acacia* species, e.g. *A. erioloba*, are adapted to endozoochory, which is dispersal and germination through the agency of large mammals (Hoffman *et al.* 1989). The seed coats of such seeds are tough and thick, preventing the passage of water and oxygen through the testa (Clemens *et al.* 1977; Hoffman *et al.* 1989), as well as allowing passage through animal guts without harm to either the seeds or animals (Lamprey 1967; Gwynne 1969; Hoffman *et al.* 1989).

#### 2.4.3.3. Comparison of seed viability

The mean germination potential of seeds collected from Kathu (81.67%) is higher than that of the Sandveld Nature Reserve (60.00%) after 168 h of incubation (Table 2.4). The rate of germination is also higher for *A. erioloba* seeds from the Kathu area: maximum germination potential was reached after only 48 h of incubation. Seeds from the Sandveld Nature Reserve only reached its maximum germination potential after 96 h of incubation (Table 2.4).

From the results of this investigation it is therefore clear that *A. erioloba* seeds from the Kathu area seem to have a higher germination potential than that of the Sandveld Nature Reserve. Another possible explanation may be that first instar Bruchidae larvae were overlooked in the latter case. As will be evident from Chapter 9, Bruchidae infestation inhibits the germination potential of *A. erioloba* seeds.

## 2.5. CONCLUSIONS

The population structure of the various study sites in Kathu show a number of irregularities if compared to that of the Sandveld Nature Reserve control site. These irregularities might be

Table 2.3. Germination potential of *Acacia erioloba* seeds after different scarifying treatments.

Incubation Time (h)	% Germination		
	Control	Mechanical Scarification	Concentrated H <sub>2</sub> SO <sub>4</sub>
16	0.00 ± 0.00	0.00 ± 0.00	20.00 ± 10.00
20	0.00 ± 0.00	0.00 ± 0.00	43.30 ± 2.89
24	0.00 ± 0.00	3.33 ± 2.89	65.00 ± 18.03
40	0.00 ± 0.00	18.33 ± 10.41	80.00 ± 18.03
44	0.00 ± 0.00	23.33 ± 15.28	80.00 ± 18.03
48	0.00 ± 0.00	26.67 ± 12.58	81.67 ± 15.28
64	0.00 ± 0.00	48.33 ± 24.66	81.67 ± 15.28
72	0.00 ± 0.00	58.33 ± 25.66	81.67 ± 15.28
88	0.00 ± 0.00	66.67 ± 15.28	81.67 ± 15.28
96	0.00 ± 0.00	66.67 ± 15.28	81.67 ± 15.28
168	0.00 ± 0.00	66.67 ± 15.28	81.67 ± 15.28



Table 2.4. Germination potential of *Acacia erioloba* seeds collected from the Kathu and Sandveld areas.

Incubation Time (h)	% Germination	
	Kathu Area	Sandveld Area
0	0.00 ± 0.00	0.00 ± 0.00
16	20.00 ± 10.00	0.00 ± 0.00
20	43.30 ± 2.89	0.00 ± 0.00
24	65.00 ± 18.03	0.00 ± 0.00
40	80.00 ± 18.03	0.00 ± 0.00
44	80.00 ± 18.03	30.00 ± 5.28
48	81.67 ± 15.28	30.00 ± 5.28
72	81.67 ± 15.28	30.00 ± 5.28
96	81.67 ± 15.28	60.00 ± 12.20
168	81.67 ± 15.28	60.00 ± 12.20

indicative of factors responsible for the decline of the *A. erioloba* population of the Kathu area and will be investigated in subsequent chapters.

*Acacia erioloba* density shows great variation between the various study areas and the control area. This could be indicative of the presence of factors that might be responsible for the decline of the *A. erioloba* population of the Kathu area and will be investigated in subsequent chapters.

Leaf volume and mass also showed great variation between sites, but this phenomenon was mostly ascribed to tree density and height.



**CHAPTER 3**

**THE VOICE OF THE PEOPLE**

### 3.1. INTRODUCTION

After having identified some irregularities in the *A. erioloba* population structure of the study area, the opinion of the local people, many of whom have been resident in the Kathu region for several decades, were gathered on factors that might be potentially harmful to this species. This was done through distributing questionnaires among residents of Kathu, Iscor employees, farmers, business people and housewives.

This opportunity doubled up as a chance to determine the attitude of locals toward the conservation of *A. erioloba*; the degree of awareness among locals regarding the ecology surrounding *A. erioloba* and the consequences of its extinction; and to obtain ideas on the effective conservation of this species for generations to come.

Due to a disappointing response, completed questionnaires were not regarded as a representative sample of the entire Kathu community and were therefore not treated as such. It was, however, felt that the responses received proved valuable insight in the attitude of the community towards the conservation of *A. erioloba*, as well as their knowledge regarding its ecology and the consequences of extinction. Excerpts from questionnaires were therefore included.

### 3.2. OBJECTIVES

The aims of this investigation were to:

- Identify areas in the Kathu region where a decrease in the *A. erioloba* population is conspicuous.
- Identify factors with a potentially harmful effect on the *A. erioloba* population of the Kathu area, upon which further investigations can be based.
- To determine the attitude of locals toward the conservation of *A. erioloba*.
- To determine the necessity of incorporating awareness programmes regarding the ecology surrounding *A. erioloba* and the possible consequences of its extinction.
- To obtain ideas on ways to conserve *A. erioloba*.



### 3.3. METHODOLOGY

Questionnaires were drawn up and distributed among as many as possible Kathu residents via e-mail, postal services or hand (Appendix B).

### 3.4. RESULTS AND DISCUSSION

#### 3.4.1. AREAS WHERE A DECLINE IN THE *ACACIA ERIOLOBA* POPULATION IS CONSPICUOUS

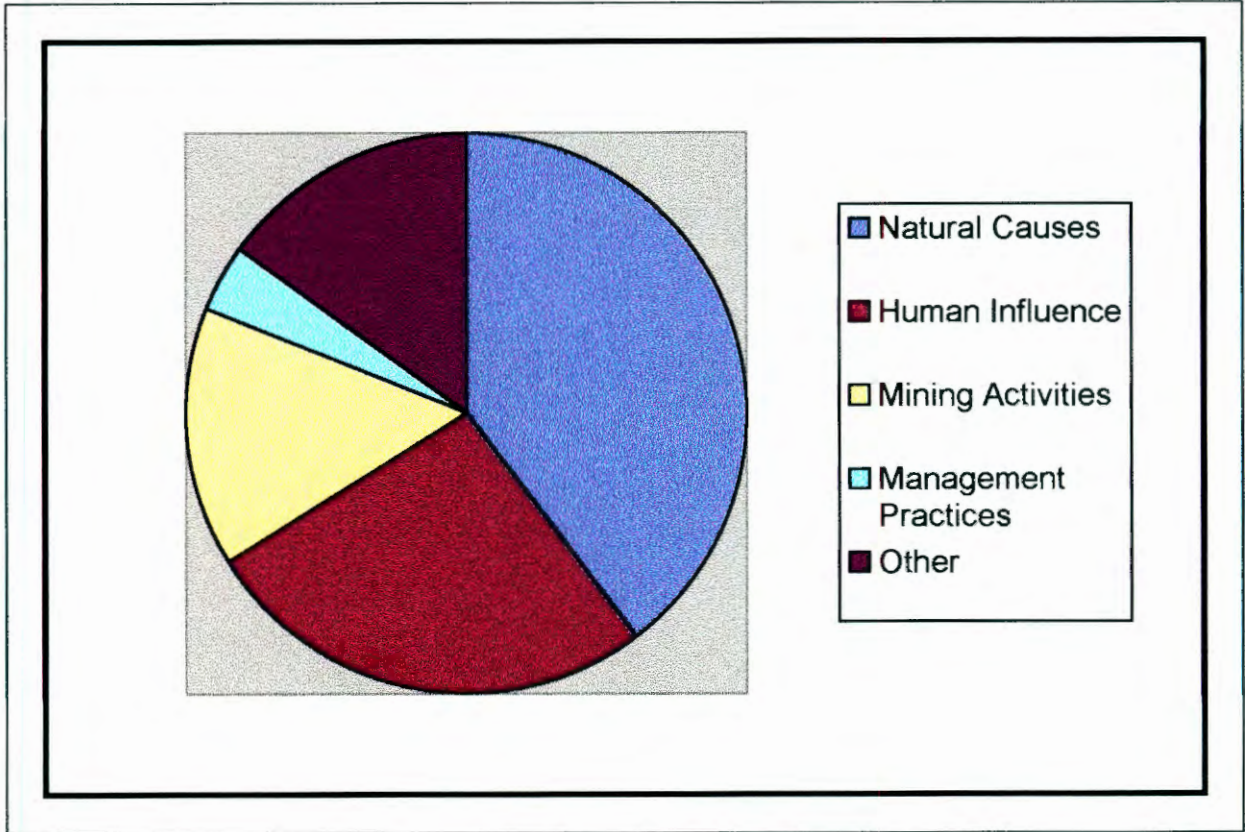
The following areas in the Kathu region were identified by locals as experiencing an appreciable decline in its *A. erioloba* population:

- The Sishen Golf Course;
- The Khai-Apple Nature Reserve;
- The roadside between Kuruman and Kathu (part of the Khai-Apple Nature Reserve); and
- Specified farms.

#### 3.4.2. FACTORS WITH A POTENTIALLY HARMFUL EFFECT ON THE *ACACIA ERIOLOBA* POPULATION OF KATHU

The following factors were identified by locals as being responsible for the decline in the *A. erioloba* population of the Kathu area (Figure 3.1):

- Natural causes, e.g. old age (39.62%);
- Human influence, e.g. deliberate poisoning or destruction (26.42%);
- Mining activities of the Sishen Iscor Iron Ore Mine (15.09%);
- Other, e.g. drought (15.09%); and
- Management practices (3.77%).



**Figure 3.1.** The possible causes of decline in the *Acacia erioloba* population of the Kathu area, according to residents of Kathu.



### 3.4.3. THE ATTITUDE OF LOCALS TOWARD THE CONSERVATION OF *ACACIA ERIOLOBA*

From the replies received, 36.56% participants indicated that the decline in the *A. erioloba* population of the Kathu area causes concern (Figure 3.2). Reasons provided were mostly aesthetic and sentimental. A small minority did, however, grasp the value of conserving this tree for generations to come because of its value to mankind in terms of e.g. dust deposition and providing shade (Chapter 1). An alarmingly large percentage of participants (18.61%) indicated that a decline in the population do not trouble them at all. Reasons provided included: "Too many thorns" and "Pods ferment on my roof". The rest of the participants (20.93%) had no opinion on the matter.

It is clear that there is a desperate need for environmental education among locals. Recommendations on the practical implementation of environmental education programmes, as well as on improving community involvement in *A. erioloba* conservation, are given in Chapter 11.

### 3.4.4. SUGGESTIONS ON WAYS TO CONSERVE *ACACIA ERIOLOBA*

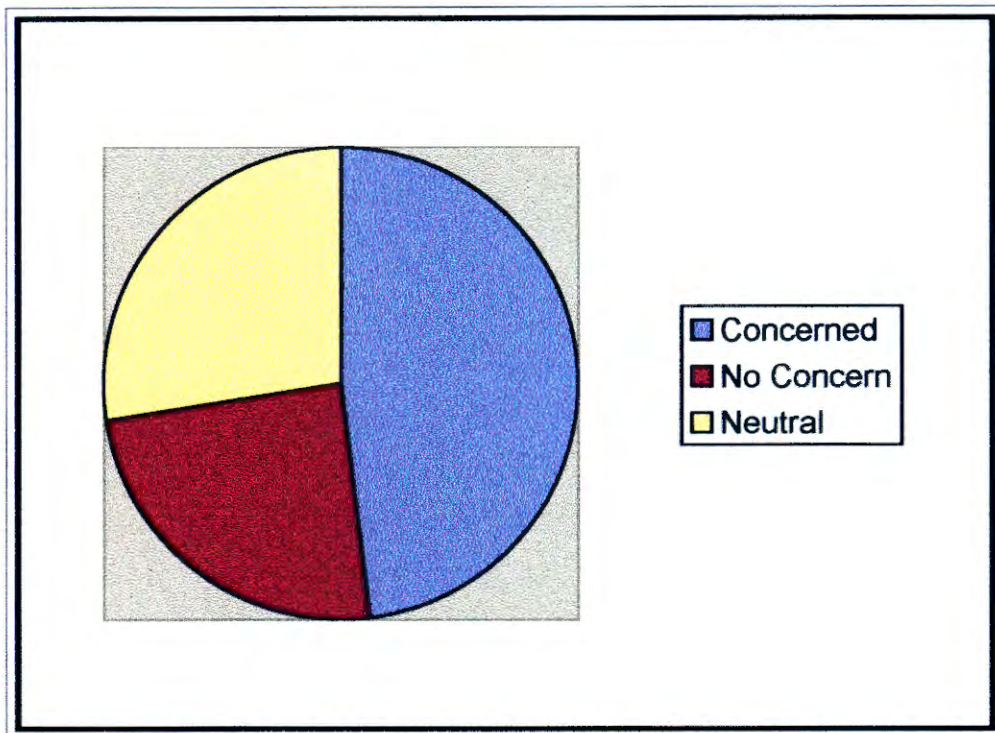
The following is an edited list of suggestions that were made on ways to conserve *A. erioloba*:

- Replace dying trees with young *A. erioloba* individuals.
- Ban the collection and selling of *A. erioloba* pods.
- Ban the use of *A. erioloba* as fire wood.
- Stricter enforcement of the legislation protecting *A. erioloba*.

### 3.5. CONCLUSIONS

The results of Chapter 2 and available information in the literature was used, in combination with the opinions of the locals gathered in this chapter, to identify the following three main areas of activities thought of as being potentially harmful to the *A. erioloba* population of the Kathu area:

- The mining activities of the Sishen Iscor Iron Ore Mine, with special focus on the mine dust emitted as a by-product of mining activities and the lowering of ground water levels;



**Figure 3.2.** The attitude of Kathu residents towards the decline in the *Acacia erioloba* population of the Kathu area.



- Management strategies, with special focus on the stocking rate of browsers and mixed feeders, pod removal, and the uninformed use of chemicals, and
- Natural phenomena, with special focus on Bruchidae seed predation.

## CHAPTER 4

THE INFLUENCE OF MINE DUST EMISSION BY  
THE SISHEN ISCOR IRON ORE MINE ON  
CERTAIN PHYSIOLOGICAL ASPECTS, GERMINATION,  
AND THE GROWTH POTENTIAL OF *ACACIA ERIOLOBA*



## 4.1. INTRODUCTION

Dust emission by the Sishen Iscor Iron Ore Mine was identified in the present study as one of the aspects of the mining activities in the Kathu region with a potentially harmful effect on the *A. erioloba* population. The influence of mine dust on various physiological processes, as well as the germination of *A. erioloba* seeds and the growth potential of seedlings, will therefore be thoroughly investigated in this chapter.

The main processes concerned with mineral extraction regularly cause problems in terms of dust pollution (Cresswell 1974; Farmer 1993). Dust is defined as "*solid matter in a minute and fine state of subdivision so that the particles are small enough to be raised and carried by the wind*" (Farmer 1993). The diameter of a dust particle varies from 1 - 75  $\mu\text{m}$  (Cresswell 1974).

A reddish dust, consisting of hematite, silica, alfaquartz, apatite, potassium-aluminate, manganese, iron salts, barium sulphate, chalcretes and diabase, is formed as a by-product of the mining activities of the Sishen Iscor Iron Ore Mine (Barnard & De Villiers, Unpublished). Mine dust emissions are mainly distributed in a south-eastern direction by the prevailing north-north-westerly winds (Strategic Environmental Focus CC, Unpublished) and are visible as a reddish layer on the vegetation, roads and electricity structures in the mine's proximity, as well as on vehicles frequenting the area. Mine dust even finds its way into homes and in the process, according to locals, colours curtains, carpets and furniture.

The potential effect of particulate deposits on vegetation can be damaging in various ways, i.e. chemical, physical and/or physiological (Cresswell 1974; Singh & Rao 1981; Lal & Ambasht 1982; Thompson *et al.* 1984; Shukla *et al.* 1990; Farmer 1993; Hegazy 1996). Affected plants may or may not exhibit visual symptoms of particulate deposition (Eveling 1969; Manning 1971; Lal & Ambasht 1982; Dixit 1988). Symptoms generally range from leaf injury to an overall reduction in vegetative growth and reproductive structures (Farmer 1993). Complete decimation of the vegetation of an area as a consequence of particulate pollutants is, however, a relatively infrequent occurrence (Brandt & Rhoades 1972).

The potential harmful effect of particulate deposits on vegetation can be summarised as follows:

#### 4.1.1. CHEMICAL EFFECTS

- Chemically active aerial pollutants may cause a chemical reaction upon physical contact with leaves and in this way have a toxic effect on plants (Mudd & Kozlowski 1975; Huttunen *et al.* 1981).
- The effect of dust on plants can occur via changes in soil chemistry (Turchenek *et al.* 1987; Shukla *et al.* 1990; Mayo *et al.* 1992; Farmer 1993), e.g. changes in soil pH (Mayo *et al.* 1992; Hegazy 1996).

#### 4.1.2. PHYSICAL EFFECTS

- Abrasion of the leaf surface by dust transported in wind and spray (Thompson *et al.* 1984);
- Blockage of stomata (Ruston 1921; Eller 1977; Borka 1980; Thompson *et al.* 1984; Farmer 1993);
- Shading through crust formation (Lal & Ambasht 1982; Thompson *et al.* 1984); and
- Smothering (Krajicková & Mejstrik 1984; Farmer 1993).

One or a combination of the above mentioned chemical and physical effects may have one (or a combination) of the following consequences:

- An overall reduction in size, as well as stunted growth, has been associated with plants treated with, or naturally covered in, dust (Parthasarthy *et al.* 1975; Singh & Rao 1981; Shukla *et al.* 1990; Sharifi *et al.* 1997).
- Relatively high levels of cement dust pollution may cause a decrease in the intensity of leaf growth and a reduction in seed weight in *Helianthus annuus* (Borka 1980).
- Beatley (1965) recorded plant defoliation and shoot death as a result of dust deposition on *Larrea tridentata* in Nevada.
- Hegazy (1996) reported a general pattern of decreased plant cover and density with decreased distance from a cement factory emitting cement-kiln particulates.
- Sree Rangasamy *et al.* (1973) observed changes in the composition and frequency of plant ecotypes in a cement dust polluted area.



- The partial occlusion of stomata may allow easier access to pathogenic fungal hyphae (Manning 1971; Ricks & Williams 1974).
- Bauxite and cement dusts cause extensive cellular and ultrastructural alterations in vegetation, indicating the activation of defence and/or wound repair mechanisms, premature senescence and stress (Dixit 1988).

A number of the above stated potential influences of dust on vegetation were subjectively chosen for investigation in the present study. In order to determine the extent of physical damage caused by mine dust to *A. erioloba* leaf surfaces, this parameter was investigated by means of scanning electron microscopy. Based on the work of Singh and Rao (1981) and Shukla *et al.* (1990), it was hypothesised in the present investigation that the accumulation of mine dust on *A. erioloba* leaf surfaces would cause a reduction in chlorophyll *a* and *b* content at all stages of growth. Based on the work of Horsfall and Harrison (1939), Beasley (1942), Eveling (1969), Eller (1977), Borka (1980), Singh and Rao (1981), Eveling and Bataillé (1984), Krajicková and Mejstrik (1984) and Sharifi *et al.* (1997), it was hypothesised in the present investigation that the accumulation of particulates in the form of mine dust on *A. erioloba* leaves will cause changes in transpiration rate. It was furthermore hypothesised in the present investigation that mine dust leached into the soil, as well as unalloyed mine dust solutions, will inhibit the germination capacity and growth potential of *A. erioloba* seeds/seedlings, as it was previously determined that the effect of dust on plants may occur via changes in soil chemistry (Turchenek *et al.* 1987; Shukla *et al.* 1990; Mayo *et al.* 1992; Farmer 1993).

## 4.2. OBJECTIVES

The aims of this investigation were:

- To determine the levels of mine dust deposition in the Kathu area.
- To determine the influence (if any) of mine dust on the structure of *A. erioloba* and other leaves.
- To determine the influence (if any) of mine dust on the chlorophyll *a* and *b* content, transpiration rate and protein content of *A. erioloba* leaves.
- To determine the influence (if any) of mine dust on the germination capacity of *A. erioloba* seeds.

- To determine the influence (if any) of mine dust on the growth potential of *A. erioloba* seedlings.

### 4.3. METHODOLOGY

#### 4.3.1. LEVELS OF DUST DEPOSITION IN THE KATHU AREA

Monthly mine dust deposition data was obtained from the dust monitoring stations of the Sishen Iscor Iron Ore Mine.

#### 4.3.2. THE INFLUENCE OF MINE DUST ON LEAF STRUCTURE

The leaf structure of *A. erioloba* was examined with the aid of a scanning electron microscope (SEM), as it provides the most accurate data on both the size and structure of dust particles, as well as on leaf surface morphology (Krajicková & Mejstrik 1984).

##### 4.3.2.1. Collection of leaf samples

*Acacia erioloba*, *A. mellifera* and *Ziziphus mucronata* leaf samples were randomly collected from the Sandveld Nature Reserve, the Khai-Apple Nature Reserve, the Sishen Golf Course, Demaneng-Lylyveld and Knapdaar-Swarthaak. No *A. mellifera* individuals could, however, be located in the Sandveld Nature Reserve and was therefore omitted.

Care was taken to collect leaves that were not concealed in any way, so as to ensure full (possible) contact with mine dust. Leaves were preserved in glutare aldehyde and refrigerated until prepared for the SEM. Leaf samples were collected at the end of the rainy season (Figures 1.3 & 1.4). According to Eveling (1969), the effect of dust on leaves cannot be reversed by merely washing off deposits. High rainfall will therefore have no marked effect on the level of dust deposition on vegetation.



#### 4.3.2.2. Preparation of leaf material for the SEM

Small squares (0.25 cm<sup>2</sup>) were clipped from *Z. mucronata* leaves between the tip and base and halfway between the margin and midrib (Yunus *et al.* 1985), while entire leaflets of *A. erioloba* and *A. mellifera* were removed from the rachii. Clipped squares and leaflets were dehydrated with the aid of an ethanol series (30% to absolute), whereafter it was dried in a critical point drier using liquid CO<sub>2</sub>. Two pieces of leaf material from each species, each with the opposite surface facing upwards, were mounted side by side on specimen stubs (Yunus *et al.* 1985). Leaf material was coated with a thin film of gold in an ion sputter coater (Krajicková & Mejstrik 1984; Yunus *et al.* 1985).

#### 4.3.2.3. Scanning electron microscopy

Coated specimens were examined with a JEOL WINSEM JSM 6400 Scanning Microscope. A magnification range of 200 to 5 000 was used and photographs were taken on Agfa 135 mm, 100 ASA film. Throughout the investigation care was taken to avoid any mechanical damage to the cuticle surface (Yunus *et al.* 1985).

#### 4.3.3. TREATMENT OF TREES FOR DETERMINING THE EFFECT OF MINE DUST ON CHLOROPHYLL A AND B AND PROTEIN CONTENT, AS WELL AS THE TRANSPIRATION RATE OF ACACIA ERIOLOBA LEAVES

In order to determine the effect of mine dust on the above mentioned processes, controlled dusting experiments were conducted where environmental variables (temperature, humidity, water provision, etc.) could be kept constant. In this way any irregularities regarding the above mentioned processes could be ascribed solely to the effect of mine dust on the plants.

Eighty young *A. erioloba* trees, all approximately 0.50 m tall, were obtained from the Worcester Botanical Gardens and housed in a green house for a six-month climatisation period. Temperature was kept constant at 25 °C. After the climatisation period, trees were randomly divided into four groups according to the treatments to be applied, namely CD (control, dry), CW (control, wet), DD (dust, dry), DW (dust, wet). Dry treatments mimicked natural windy conditions and wet treatments mimicked natural rainy conditions.

Trees from the CD group were treated with blasts of wind from a hand-held rotary duster for a pre-determined time period. Trees from the CW group were treated with a pre-determined volume of distilled water from a hand-held pressure applicator. Both these groups served as control groups.

Treatment of the DD group consisted of  $7.00 \text{ g m}^{-2}$  (a concentration used by Singh and Rao (1981)) of triturated, unalloyed mine dust applied to the trees by means of the hand-held rotary duster. Trees from the DW group were treated with a pre-determined volume of a solution of mine dust and distilled water ( $43.75 \text{ g l}^{-1}$ ), applied by means of the hand-held pressure applicator. The concentration of the mine dust solution used for DW treatments were chosen for the sake of uniformity with concentrations used in dry dust application: different methods of application necessitated different mine dust concentrations in order for application to be more or less uniform. Treatments were repeated twice a week, between 12:00 and 14:00, over a three-week period.

#### 4.3.4. THE EFFECT OF MINE DUST ON THE CHLOROPHYLL A AND B CONTENT OF *ACACIA ERIOLOBA* LEAVES

Chlorophyll determination was based on the absorption of light by aqueous acetone (80%) extracts of chlorophyll (Mackinney 1941; Arnon 1949; Singh & Rao 1981; Shukla *et al.* 1990; Gross 1991).

Chlorophyll was extracted by homogenizing  $\pm 0.10 \text{ g}$  of leaflets from each of the groups described above in 10 ml of cold acetone [80% (v/v)] containing 0.01 g  $\text{CaCO}_3$  and washed sea sand. Aliquots of the homogenate was centrifuged in a cooled bench centrifuge at 12 000 rpm for 10 min., after which the supernatant fractions were collected for further analysis. The optical densities of the chlorophyll extracts were determined at 645 nm and 663 nm wavelengths (Arnon 1949; Singh & Rao 1981) with a Hitachi U-2000 spectrophotometer, using cuvettes with a 1 cm light path.

Chlorophyll a and b content was determined using the following equations (Arnon 1949):

$$\text{Chlorophyll a (mg g}^{-1}\text{)} = 12.7 A_{663} - 2.69 A_{645} \times \frac{V}{1000 \times W}$$



$$\text{Chlorophyll } b \text{ (mg g}^{-1}\text{)} = 22.9 A_{645} - 4.68 A_{663} \times \frac{V}{1000 \times W},$$

Where V = Final volume of extract in milliliters, and

W = Fresh Mass in grams.

The absorption coefficients used in these equations were previously determined by Mackinney (1941).

The chlorophyll *a* and *b* content of *A. erioloba* leaves from every treatment group was determined weekly for a period of three weeks.

#### 4.3.5. THE EFFECT OF MINE DUST ON THE TRANSPIRATION RATE OF ACACIA *ERIOLOBA* LEAVES

Transpiration rate was determined by means of self-manufactured potometers, calibrated to the nearest millimeter. Thirty centimeter sections of *A. erioloba* branches from individuals from every group were inserted into air-tight systems, whereafter transpiration rate was determined over a 15 min. period. Transpiration rate was measured as the volume of water displaced through transpiration over this period. Trials were conducted in a green house, where environmental variables that could potentially influence transpiration rate (e.g. light intensity, temperature and relative humidity), could be controlled and monitored throughout. Light intensity was measured with the aid of a LICOR LI-185A photometer and temperature and relative humidity with the aid of a hand-held sling psychrometer (Unwin 1980).

Results were expressed as the volume of water lost per minute per gram of fresh leaf mass.

#### 4.3.7. THE EFFECT OF MINE DUST ON THE PROTEIN CONTENT OF ACACIA *ERIOLOBA* LEAVES

Thirty-five leaflets ( $\pm 0.10$  g) were homogenised in a precooled mortar and pestle in 2.50 cm<sup>3</sup> 12.50 mM Tris-HCl buffer (pH 6.8) containing 14 mM  $\beta$ -2-mercapto-ethanol, 2 mM EDTA and 1 mM PMSF (Laemmli 1970). EDTA and PMSF were added to the extraction buffer immediately before homogenisation. PMSF was dissolved in 500  $\mu$ l of ethanol prior to addition. The crude

extract was centrifuged in a cooled bench centrifuge at 12 000 rpm for 10 min., whereafter the water soluble protein content was determined from the clear supernatant.

Protein was assayed according to the method of Bradford (1976), using the Biorad colour agent and a BIO-RAD Model 3550 microplate reader. Bovine gamma globulin (0.50 mg ml<sup>-1</sup>) was used as standard. The mean of three assays was calculated.

The protein content of *A. erioloba* leaves from every treatment group was determined weekly over a period of three weeks.

#### 4.3.8. THE EFFECT OF SOIL- AND MINE DUST SOLUTIONS ON THE GERMINATION CAPACITY AND GROWTH POTENTIAL OF *ACACIA ERIOLOBA* SEEDS

The effect of mine dust, leached into and lying on topsoil, and of unalloyed mine dust on the germination capacity of *A. erioloba* seeds were determined by incubating sterilised, scarred, non-predated seeds in 15 ml of a soil/water solution or mine dust solution at optimal germination conditions (30°C, dark) (see Chapter 2). The soil/water solution was replaced with 15 ml of distilled water for the control treatment.

Soil/water solutions were prepared in a 1:2 ratio, i.e. 10 g of soil collected from the top 10 cm of the soil, dissolved in 20 ml of distilled water. Solutions were stirred with a magnetic stirrer for 90 min., after which the liquid phase was removed and used as incubation medium.

Mine dust incubation solutions were prepared by dissolving either 1 g or 10 g of mine dust in one litre of distilled water to render solutions of 1 g l<sup>-1</sup> and 10 g l<sup>-1</sup>, respectively. These solutions were used as incubation mediums in the required treatments.

For the purpose of this study germination capacity was defined as the ability of a seed to germinate. The capacity of the radicle to elongate after the completion of germination was taken to be representative of the growth potential of the seedling and was recorded to the nearest millimetre with the aid of a calibrated ruler.



## 4.4. RESULTS AND DISCUSSION

### 4.4.1. LEVELS OF DUST DEPOSITION IN THE KATHU AREA

The weekly dust deposition levels recorded at various locations in the Kathu area over a 20 week period is relatively low (Figure 4.1. Also see Figure 1.1.). Even the occasional upheaval in dust deposition levels (e.g. week 2 – Parsons and week 16 – Demaneng) is relatively low.

### 4.4.2. THE EFFECT OF MINE DUST ON LEAF STRUCTURE

The plant species to be included in this investigation were subjectively chosen. *Acacia erioloba* was included for obvious reasons. *Acacia mellifera* was included because of the similarity between its leaves and that of *A. erioloba*. The former appears, however, to be unaffected by whatever is causing the deaths of *A. erioloba* in the Kathu area. It was anticipated that the presence of possible protective mechanisms on the leaf surface of *A. mellifera* would be revealed by this investigation. *Ziziphus mucronata* was included in order to determine the degree of protection offered by the glossy wax-layer on its leaves (Van Wyk & Van Wyk 1997) against the effect of mine dust.

Figures 4.2A and 4.3A illustrate the anatomy of *A. erioloba* and *Z. mucronata* leaves collected from the Sandveld Nature Reserve. The surfaces of these leaves appear healthy and undamaged in any obvious way, and are generally free from adhering particles, except for the occasional sand grain or grass segment. The protective waxy layer on the surface of *Z. mucronata* is clearly visible (Figure 4.3A).

Figures 4.2B and 4.3B indicate the presence of mine dust crystals on the lamina of leaf samples collected from the Khai-Apple Nature Reserve site. It is clear that these crystals are imbedded in the laminae, covering a relatively large number of stomata. No crystals were, however, observed on the surface of *Z. mucronata* leaves (Figure 4.3B), suggesting that the protective waxy layer prevents crystals from penetrating the leaf surface.

Except for the odd sand grain or grass blade, no substances were found on the surface of the *A. erioloba* leaf samples collected from the Sishen Golf Club premises (Figure 4.2C). The absence of mine dust crystals from these leaves can probably be ascribed to the up-wind location of the

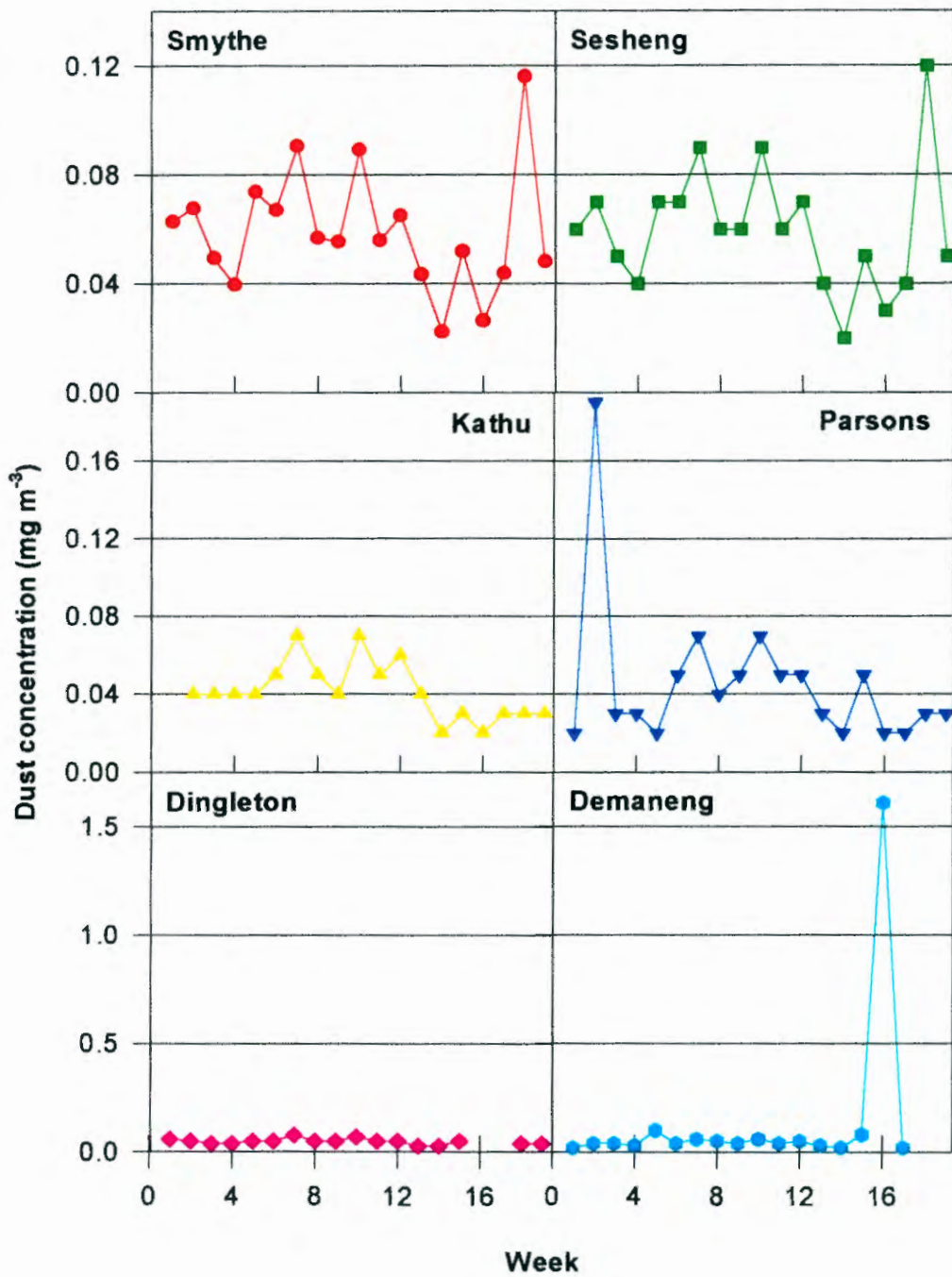


Figure 4.1. Weekly levels of dust deposition at various locations in the Kathu area over a 20 week period.



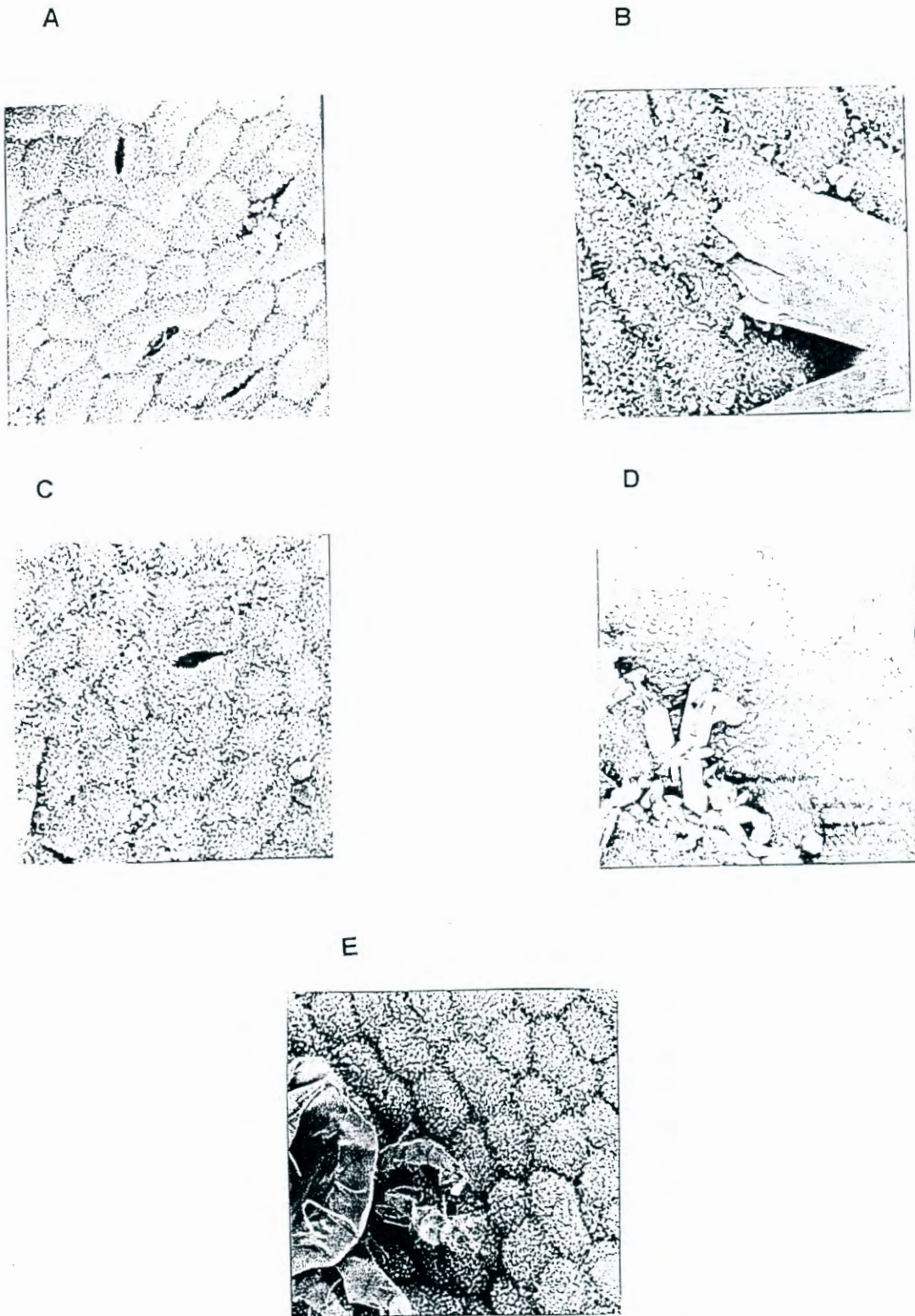
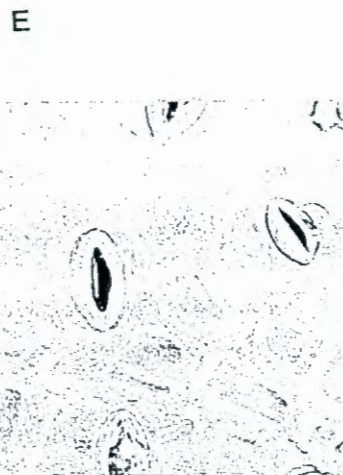
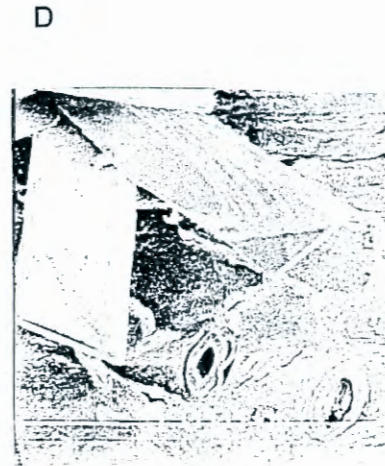
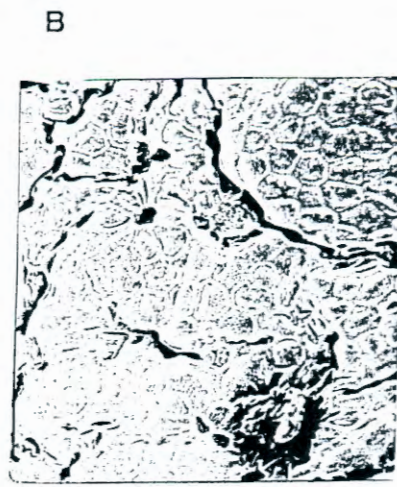
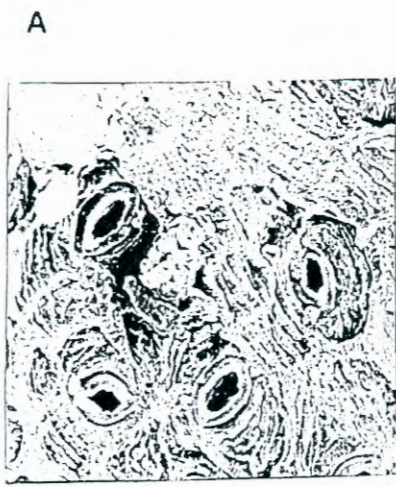


Figure 4.2. SEM photographs indicating the effect of mine dust on the leaf surfaces of *Acacia erioloba* leaves collected from the Sandveld Nature Reserve (A), the Khai-Apple Nature Reserve (B), the Sishen Golf Course (C), Lylyveld-Demaneng (D) and Knapdaar-Swarthaak (E).



**Figure 4.3.** SEM photographs indicating the effect of mine dust on the leaf surfaces of *Ziziphus mucronata* leaves collected from the Sandveld Nature Reserve (A), the Khai-Apple Nature Reserve (B), the Sishen Golf Course (C), Lylyveld-Demaneng (D) and Knapdaar-Swarthaak (E).



course with regard to the Sishen Iscor Iron Ore Mine. Crystals covering a relatively large portion of the leaf surfaces, were found on the *A. mellifera* and *Z. mucronata* samples from the Sishen Golf Course site (Figures 4.4C & 4.3C), suggesting that the absence of mine dust crystals from *A. erioloba* leaves in this area were mere chance.

The damage caused by mine dust to the leaves of *A. erioloba*, *A. mellifera* and even *Z. mucronata*, with its protective waxy layer, in the down-wind Lylyveld-Demaneng area, is obvious (Figures 4.2D, 4.3D & 4.4C). This damage can probably be ascribed to the down-wind location of these sites with regard to the Sishen Iscor Iron Ore Mine. Physical damage, visible as cracks around the mine dust crystals, is caused to the leaves as mine dust particles are thrust onto the laminae through wind and rain action. Abnormal growth occurs in the areas affected by crystal imbedding.

Except for sand grains and insect remains, the surfaces of leaf samples collected from the up-wind Knapdaar-Swarthaak site were free from foreign objects (Figures 4.2E, 4.3E & 4.4D). It is interesting to note that the *A. mellifera* sample had more trichomes than that collected from any other site (Figure 4.4D). It is also interesting to note that these trichomes appear to collect fine particles, rather than protect the leaf from it.

According to Yunus *et al.* (1985), a convincing relationship exists between inherited morphological traits (e.g. the presence of trichomes or a waxy layer) and the amount of dust captured on a leaf surface. This phenomenon was also apparent in the present study. Little or no particles of any kind were observed on the laminae of *Z. mucronata*, with its protective waxy layer. Trichomes seem to, on the one hand, protect the laminae of *A. mellifera* from larger particles, e.g. mine dust crystals, but, on the other hand, trap smaller particles such as sand grains. It is furthermore clear that *A. erioloba*, lacking both of these protective morphological traits, exhibits the greatest degree of damage caused by mine dust crystals.

According to Krajicková and Mejstrik (1984), plants with a pubescent leaf surface appear to be the most sensitive to damage caused by particles. However, the opposite appeared to be the case in the present study: *A. erioloba*, which lacks trichomes, exhibited the largest degree of lamina damage caused by mine dust particles. In addition to the lack of defensive morphological traits, the surface roughness of *A. erioloba* leaves may contribute to the accumulation of mine dust on its laminae. Particle damage on rough leaf surfaces is particularly

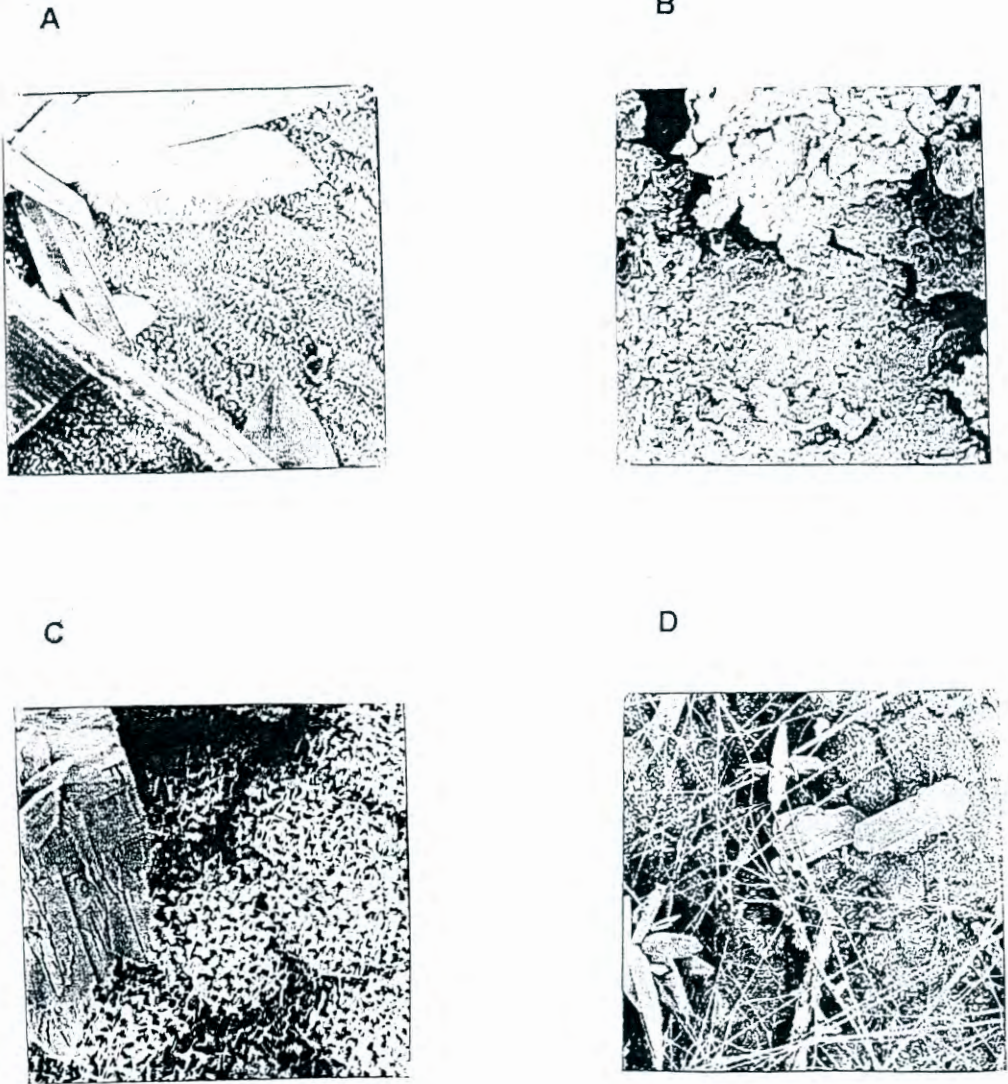


Figure 4.4. SEM photographs indicating the effect of mine dust on the leaf surfaces of *Acacia mellifera* leaves collected from the Khai-Apple Nature Reserve (A), Lylyveld-Demaneng (B), the Sishen Golf Course (C) and Knapdaar-Swarthaak (D).



important at high wind speeds and for particles greater than 10  $\mu\text{m}$  in diameter (Chamberlain 1967).

#### 4.4.3. THE EFFECT OF MINE DUST ON THE CHLOROPHYLL A AND B CONTENT OF ACACIA ERIOLOBA LEAVES

Wet mine dust application mimicked dust application to leaves under natural rainy conditions, while dry mine dust application mimicked dust application to leaves under natural windy conditions. The mine dust that is present in the atmosphere surrounding the Sishen Iscor Iron Ore Mine is deposited on *A. erioloba* leaves through rain and wind action, resulting in the damaging of leaf surfaces (Figures 4.2 – 4.4). It was postulated in this investigation that mine dust deposition on *A. erioloba* leaves, through the damaging or blockage of stomata, inhibits the metabolic processes of the leaves, e.g. photosynthesis. It was furthermore postulated in the present investigation that both wet and dry mine dust application inhibit chlorophyll *a* and *b* production in *A. erioloba* leaves – a criterion that can be used to confirm the postulated inhibition of photosynthesis.

Both the chlorophyll *a* and *b* content of CW (control, wet) leaves increased over the three week investigation period. The chlorophyll *b* content was, however, low if compared to the chlorophyll *a* content of control leaves (Table 4.1).

When *A. erioloba* leaves were exposed to mine dust dissolved in water (DW), which represented natural rainy conditions, both the chlorophyll *a* and *b* content increased over the investigation period (Table 4.1). This situation was similar to that found for control wet (CW) leaves. In addition, the increase in chlorophyll *a* and *b* content measured in dust treated leaves (DW) was higher than that of the control leaves (CW) (Table 4.1). From these results it appeared that exposure of *A. erioloba* leaves to mine dust dissolved in water ("rain") has no inhibitory effect on chlorophyll *a* and *b* content, as was postulated earlier.

Similar to the CW (control, wet) leaves, the chlorophyll *a* and *b* content of the CD (control, dry) leaves increased in concentration for the duration of the investigation period (Table 4.1). The chlorophyll *a* and *b* content of CD leaves also compared favourably to that of the CW leaves (Table 4.1).

Table 4.1. The effect of mine dust on the chlorophyll *a* and *b* content of *Acacia erioloba* leaves after 1, 2 and 3 weeks of application.

Time (Weeks)	Chlorophyll Content (mg g <sup>-1</sup> Fresh Leaf Mass)			
	CONTROL: WET	DUST: WET	CONTROL: DRY	DUST: DRY
	<b>Chlorophyll <i>a</i></b>			
0	0.7708 ± 0.1405	0.7708 ± 0.1405	0.7708 ± 0.1405	0.7708 ± 0.1405
1	0.8289 ± 0.0986	1.3873 ± 0.1109	1.0632 ± 0.0345	1.1029 ± 0.0603
2	1.1617 ± 0.0702	2.4597 ± 0.0204	1.7685 ± 0.1442	1.8784 ± 0.2051
3	1.9760 ± 0.2842	2.2426 ± 0.0117	1.6369 ± 0.1454	2.1868 ± 0.4318
	<b>Chlorophyll <i>b</i></b>			
0	0.2985 ± 0.1260	0.2985 ± 0.1260	0.2985 ± 0.1260	0.2985 ± 0.1260
1	0.2516 ± 0.0364	0.7049 ± 0.1773	0.4209 ± 0.0051	0.4912 ± 0.1279
2	0.4443 ± 0.0091	0.9625 ± 0.0190	0.6485 ± 0.0196	0.7842 ± 0.0582
3	0.8675 ± 0.0655	0.9103 ± 0.0004	0.6406 ± 0.1159	0.8581 ± 0.0782



The chlorophyll *a* and *b* content of *A. erioloba* leaves exposed to mine dust by means of wind action (DD) also increased during the three week investigation period (Table 4.1). This trend was similar to that obtained for the wet treated leaves (CW and DW), where the final content of the "dry" treated leaves (DD) exceeded that of the control dry leaves (CD). This is also in contrast to what was hypothesised earlier. In fact, it appeared as if the exposure of *A. erioloba* leaves to mine dust through both wet and dry treatments slightly stimulated an increase in chlorophyll *a* and *b* content.

From these results it was concluded that the exposure of *A. erioloba* leaves to mine dust does not affect chlorophyll *a* and *b* content, which was used as a parameter to investigate photosynthetic capacity, negatively. Furthermore, the mine dust concentration used in this investigation was substantially higher than that found under normal conditions (Figure 4.1). One could therefore postulate that the mine dust present in the atmosphere surrounding the Kathu area will affect *A. erioloba* plants to a lesser extent (if at all) than that measured in these controlled experiments.

#### 4.4.4. THE EFFECT OF MINE DUST ON THE TRANSPIRATION RATE OF ACACIA *ERIOLOBA* LEAVES

Wet mine dust application once again mimicked dust application to leaves under natural rainy conditions, while dry mine dust application mimicked dust application to leaves under natural windy conditions. It was hypothesised in this investigation that mine dust deposition, in both wet and dry states, inhibits the transpiration rate of *A. erioloba* leaves through the damaging or blockage of stomata.

The average rate of transpiration of CW (control, wet) leaves after three weeks of treatment was  $0.2210 \pm 0.0730 \text{ mm}^3 \text{ min}^{-1} \text{ g}^{-1}$  fresh leaf mass (Table 4.2). After exposure to mine dust dissolved in water (DW), which represented natural rainy conditions, the average transpiration rate of *A. erioloba* leaves was only slightly lower than that of CW (control, wet) leaves (Table 4.2). From these results it appeared that exposure of *A. erioloba* leaves to mine dust dissolved in water ("rain") has no inhibitory effect on transpiration rate, as was postulated earlier.

Table 4.2. Transpiration rate ( $\text{mm}^3 \text{min}^{-1} \text{g fresh leaf mass}^{-1}$ ) of *Acacia erioloba* leaves from different treatment groups (CW, CD, DW, and DD) after three weeks of exposure.

Transpiration Rate ( $\text{mm}^3 \text{min}^{-1} \text{g}^{-1}$ Fresh Leaf Mass)			
Control: Wet	Dust: Wet	Control: Dry	Dust: Dry
$0.2210 \pm 0.0730$	$0.2193 \pm 0.0937$	$0.3710 \pm 0.0923$	$0.3116 \pm 0.0783$



If compared to CW (control, wet) leaves, the average transpiration rate of CD (control, dry) leaves was slightly higher after the three week treatment period (Table 4.2). The average transpiration rate of *A. erioloba* leaves exposed to mine dust by means of wind action (DD) compared favourably to the value obtained for the latter treatment (Table 4.2).

It should, however, be kept in mind that the environmental variables that influence transpiration rate (temperature, relative humidity and light intensity) varied slightly during the 15 min. observation period (Table 4.3) and did therefore influence the values obtained. Another factor that might have influenced the rate of transpiration of leaves, is leaf age. Transpiration rate decreases with an increase in leaf age.

The average transpiration rate of "dry" treated leaves (CD and DD) was therefore slightly higher than that of "wet" treated leaves (CW and DW), but with no marked difference within "dry" and "wet" treatments. The results of the present investigation are therefore in contrast to what was hypothesised earlier, namely that mine dust, applied in both wet and dry states, inhibits the transpiration rate of *A. erioloba* leaves through the damaging or blockage of stomata. Furthermore, the mine dust concentration used in this investigation was substantially higher than that found under normal conditions (Figure 4.1). One could therefore postulate that the mine dust present in the atmosphere surrounding the Kathu area will affect *A. erioloba* plants to a lesser extent (if at all) than that measured in these controlled experiments.

#### 4.4.5. THE EFFECT OF MINE DUST ON THE PROTEIN CONTENT OF *ACACIA ERIOLOBA* LEAVES

As was mentioned earlier, wet mine dust application mimicked mine dust application to leaves under natural rainy conditions, while dry mine dust application mimicked mine dust application to leaves under natural windy conditions. It was postulated in this investigation that mine dust deposition on *A. erioloba* leaves, through the damaging or blockage of stomata, inhibits the metabolic processes of the leaves. It was furthermore postulated in the present investigation that both wet and dry mine dust application inhibit the protein production of *A. erioloba* leaves – a criterion that can be used to confirm the postulated inhibition of metabolic processes.

Table 4.3. Values of environmental variables during the determination of the transpiration rate of *Acacia erioloba* leaves.

Mean Temperature (°C)	Relative Humidity (%)	Light Intensity ( $\mu\text{E cm}^{-2} \text{s}^{-1}$ )
28.23 $\pm$ 3.08	52.73 $\pm$ 7.17	4.28 $\times 10^4$ $\pm$ 2.38 $\times 10^4$



The protein content of *A. erioloba* leaves from the CW group steadily decreased from week zero ( $5.1077 \mu\text{g g}^{-1} \pm 0.1754$ ) to week three ( $0.2562 \mu\text{g g}^{-1} \pm 0.1072$ ). This decrease in protein content became less severe over time (Table 4.4).

When *A. erioloba* leaves were exposed to mine dust dissolved in water (DW), which represented rainy conditions in nature, a similar trend to that found for CW was noted: the protein content steadily decreased from week zero to week three (Table 4.4). From these results it appeared that exposure of *A. erioloba* leaves to mine dust in a wet state ("rain") have no inhibitory effect on protein content, as was postulated earlier.

Similar to the CW (control, wet) leaves, the protein content of the CD (control, dry) leaves also steadily decreased over the investigation period (Table 4.4).

The protein content of *A. erioloba* leaves that were exposed to mine dust by means of wind action (DD) also showed a steady decrease over the three week investigation period. This trend is similar to that which was observed for the wet treated leaves (CW and DW). This is also in contrast to what was hypothesised earlier, namely that mine dust deposition would have a negative impact on the protein content of *A. erioloba* leaves.

From the results of this investigation it was concluded that the exposure of *A. erioloba* leaves to mine dust in both a wet and dry state does not negatively affect protein content and therefore metabolic activity. Furthermore, the dust concentration used in this investigation was substantially higher than that which naturally occurs in the Kathu area (Figure 4.1). One could therefore further postulate that the dust present in the atmosphere surrounding the Kathu area will affect *A. erioloba* plants to a lesser extent than was measured in this investigation.

A possible explanation for the decrease in protein content over time noted for leaves in all four groups is that trials were conducted early in the new growth season. It is well-known that young leaves have a higher metabolic rate and more available energy than mature leaves (Styles 1993). This goes hand in hand with a higher protein content, as metabolic rate is dependent on protein enzymes. It is also well known that browsers often prefer younger plants because the nutritional quality of some leaves decrease with age (Schroeder 1986; Styles 1993). The decrease in protein content over time is therefore probably a growth-related phenomenon. This

Table 4.4. Protein content (in  $\mu\text{g g}^{-1}$  fresh mass leaf material) of mine dust treated *Acacia erioloba* leaves after 1, 2 and 3 weeks of exposure.

Time (Weeks)	Protein Content ( $\mu\text{g g}^{-1}$ Fresh Mass Leaf Material)			
	Control: Wet	Dust: Wet	Control: Dry	Dust: Dry
0	$6.8771 \pm 0.1481$	$6.8771 \pm 0.1481$	$6.8771 \pm 0.1481$	$6.8771 \pm 0.1481$
1	$1.3371 \pm 0.8289$	$2.0835 \pm 0.2501$	$2.4920 \pm 0.4150$	$1.2885 \pm 0.3617$
2	$0.4039 \pm 0.0602$	$1.5920 \pm 0.9475$	$0.2867 \pm 0.1774$	$0.3220 \pm 0.0697$
3	$0.2562 \pm 0.1072$	$0.4333 \pm 0.2477$	$0.1692 \pm 0.0652$	$0.2785 \pm 0.0256$



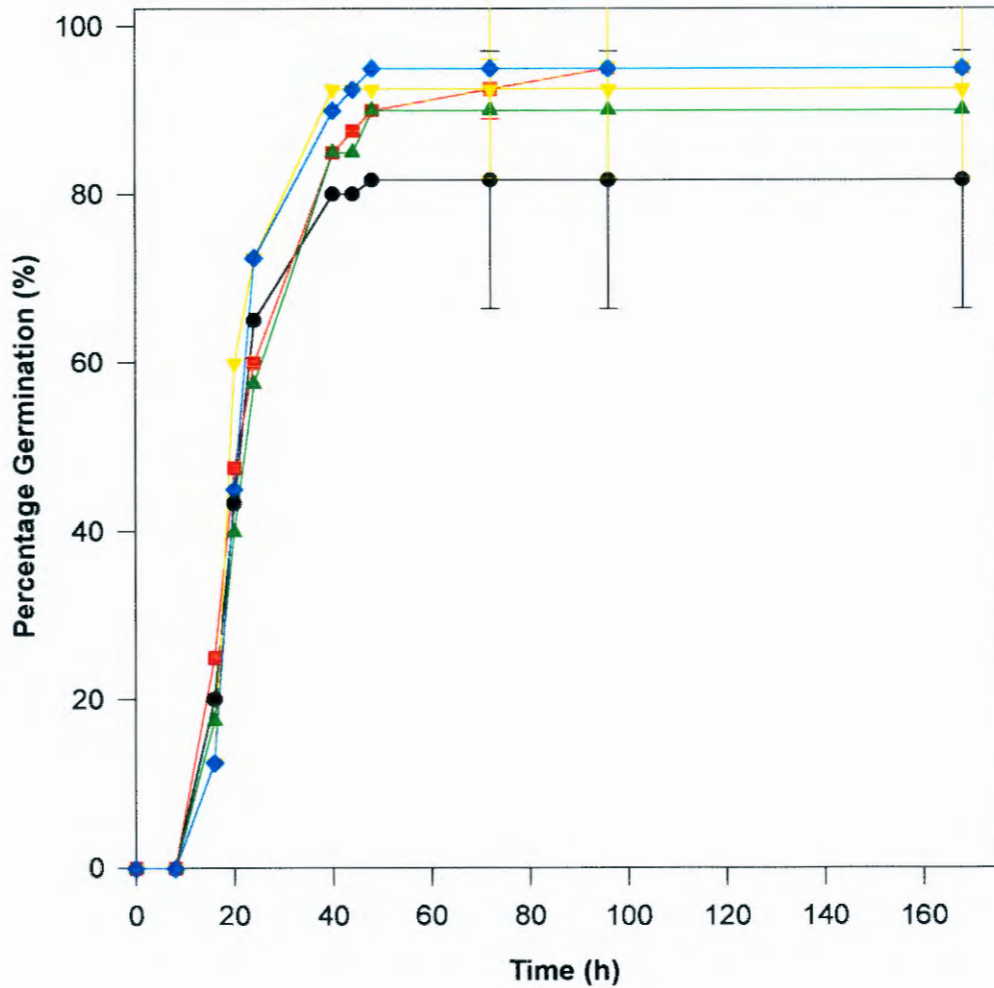
is clearly visible from the data in Table 4.4, where both control treatments show a decrease in protein content over time.

#### 4.4.6. THE EFFECT OF SOIL- AND MINE DUST SOLUTIONS ON THE GERMINATION CAPACITY OF *ACACIA ERIOLOBA* SEEDS

Seeds incubated in distilled water (control treatment) reached a maximum germination percentage of 81.67% after 48 h of incubation. The soil/water solutions (10 g/20 ml) of none of the sites had an inhibitive effect on germination; in fact, germination seemed to be stimulated by all the soil/water solutions (Figure 4.5). After 40 h of incubation, all soil/water-incubated seeds had a germination percentage higher than that of the control treatment (Figure 4.5), which lasted until the end of the investigation period. It is therefore concluded in this study that mine dust leached into the soil does not inhibit the germination of *A. erioloba* seeds.

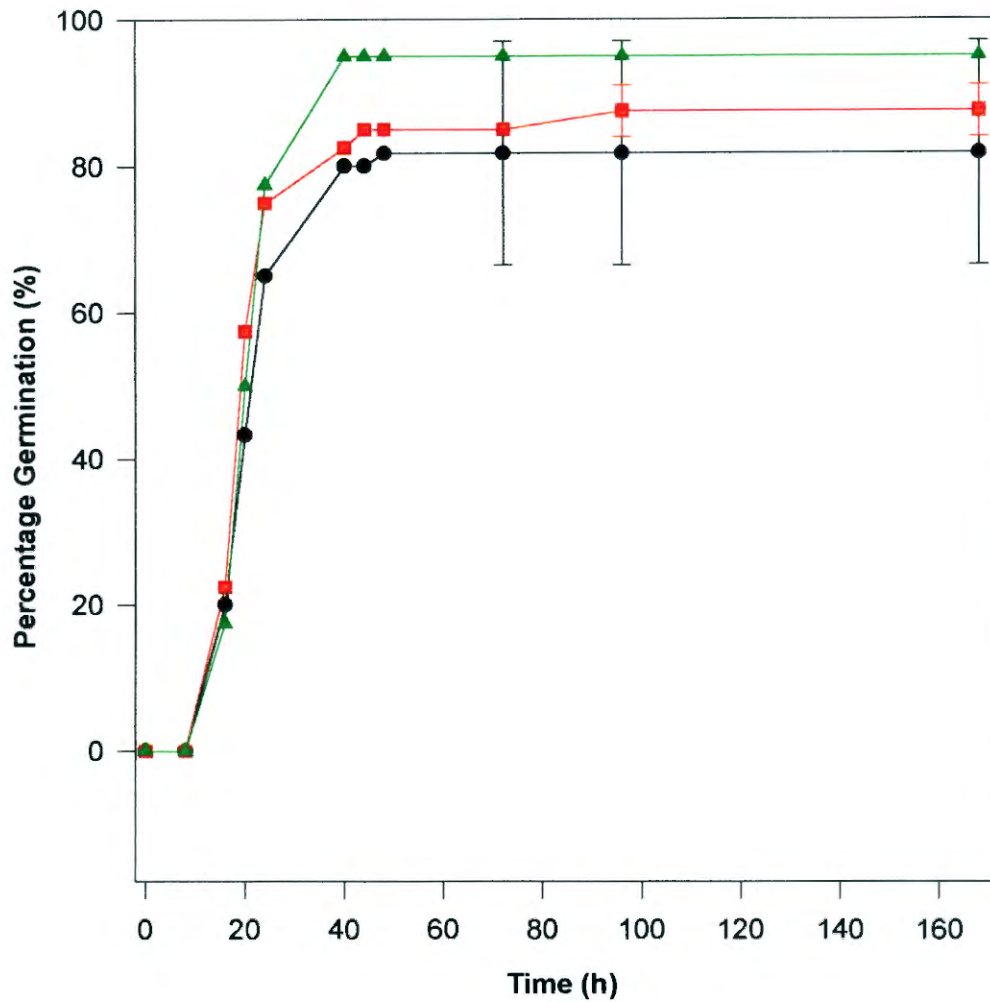
None of the mine dust solutions used ( $1 \text{ g l}^{-1}$  and  $10 \text{ g l}^{-1}$ ), had an inhibitive effect on the germination capacity of *A. erioloba* seeds (Figure 4.6). In fact, seeds germinated in mine dust solutions had a germination rate equal to, or even higher than that of the control seeds. Seeds germinated in the murky  $10 \text{ g l}^{-1}$  solution had the highest average germination percentage (95.00%) after 168 h of incubation (Figure 4.6). These results can probably be explained by considering the composition of mine dust. Mine dust contains silica (Barnard & De Villiers, Unpublished) which plays a vital role in limiting fungal infections by accumulating in epidermal cell walls (Salisbury & Ross 1992). Through visual inspection it was determined that fungal infestation was only present in the control treatments, despite treatment with Panacide. Fungal infestation could therefore be responsible for the lower germination rate of control seeds.

It should be emphasised that the mine dust solutions occurring in nature (solutions of rain water and mine dust) normally have a much lower concentration than that of the solutions used in the present investigation. It was argued that, if the high concentrations used in the present investigation do not have an inhibitive effect on the germination rate of *A. erioloba* seeds, a possible effect by the more diluted solutions could be excluded. It is therefore concluded from the findings of this investigation that the presence of mine dust from the Sishen Iscor Iron Ore



**Figure 4.5.** The germination capacity of *Acacia erioloba* seeds collected from the Kathu area in soil/water solutions from various locations (Khai-Apple Nature Reserve ■; Knapdaar-Swarthaak ■; Lylyveld-Demaneng ■; Sandveld Nature Reserve ■; Control treatment ■).





**Figure 4.6.** The effect of different concentrations of mine dust on the germination capacity of *Acacia erioloba* seeds collected from the Kathu area (Control treatment ■; 1 g l<sup>-1</sup> Mine dust solution ■; 10 g l<sup>-1</sup> Mine dust solution ■).

Mine in the soil does not have an inhibitory effect on the germination capacity of *A. erioloba* seeds.

#### 4.4.6. THE EFFECT OF DIFFERENT SOIL- AND MINE DUST SOLUTIONS ON THE GROWTH POTENTIAL OF *ACACIA ERIOLOBA* SEEDLINGS

No marked differences occurred between the growth rate of the radicle, which was used as a parameter of growth potential, in any of the soil/water treatments (10 g/20 ml) used for the first 72 h of incubation (Figure 4.7). Following this, seeds incubated in the soil/water solution collected from both the Sandveld Nature Reserve and Knapdaar sites exhibited an increase in growth potential of the radicle that could not be matched by any of the other treatments. Seeds incubated in the Lylyveld soil/water solution had a growth potential lower than that of seeds incubated in the Sandveld and Knapdaar solutions, but better than that of the Kathu and control treatments.

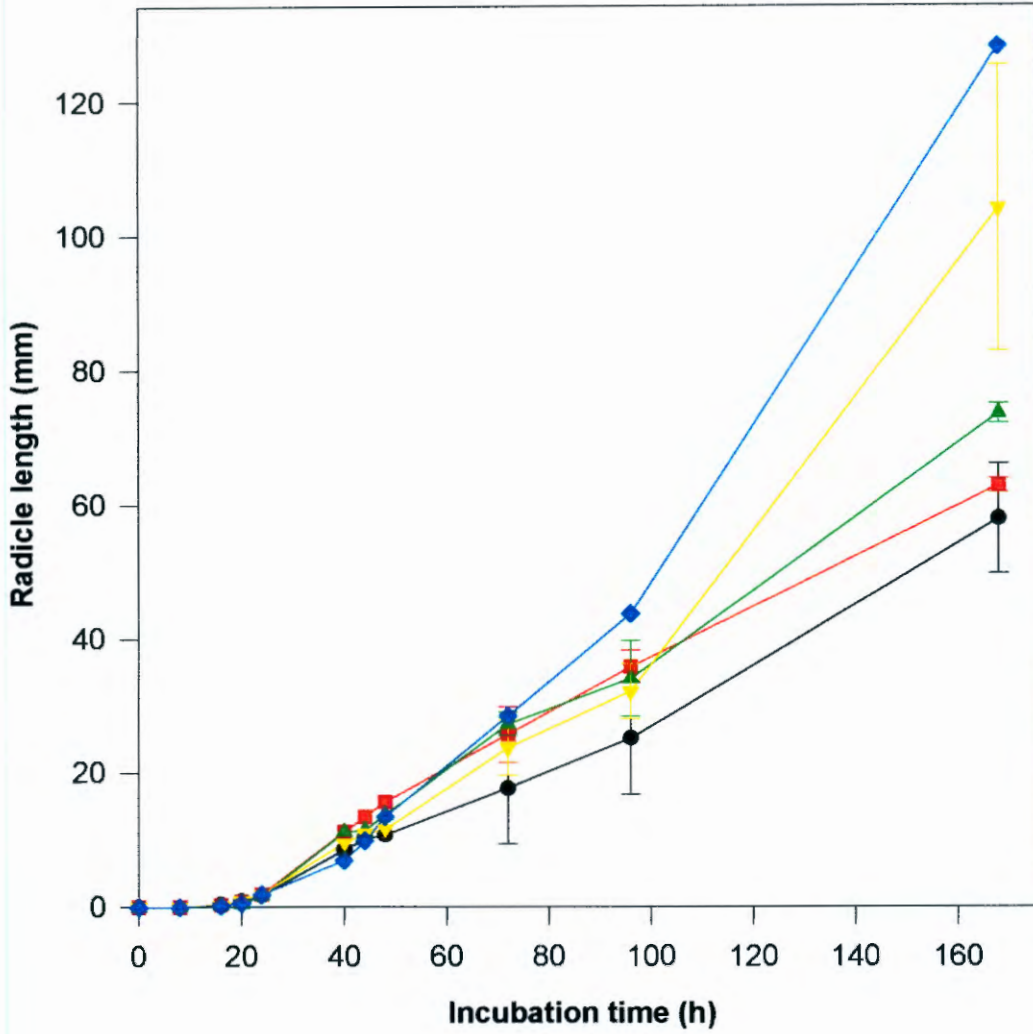
Seeds incubated in distilled water (control treatment) and the Kathu solution had the lowest measured growth potential (Figure 4.7).

Figure 4.8 represents the growth potential of the radicle of seeds incubated in unalloyed mine dust solutions ( $1 \text{ g l}^{-1}$  and  $10 \text{ g l}^{-1}$ ), clearly illustrating that mine dust does not have an inhibitive effect on the growth potential of the radicle, as was previously hypothesised. The growth potential of the radicle of seeds incubated in mine dust solutions was higher than that of seeds of the control treatment throughout. Mine dust therefore seems to have a stimulating, rather than an inhibitive effect on growth potential. The soil solutions containing traces of mine dust, as well as the unalloyed mine dust solutions, did not have any inhibitive effect on the growth potential of *A. erioloba* seedlings. In fact, both the soil solutions and unalloyed mine dust solutions stimulated radicle growth and this is in contrast to what was initially hypothesised.

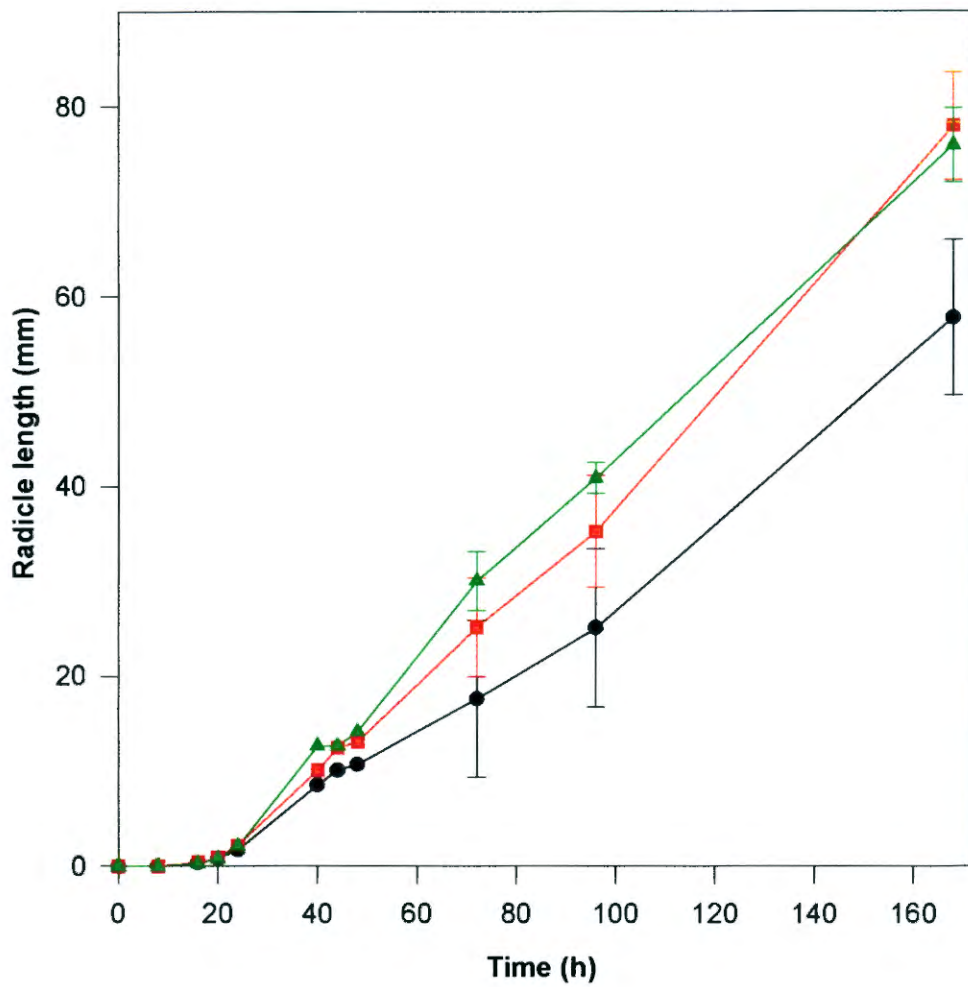
#### 4.5. CONCLUSIONS

Scanning electron microscopy revealed that mine dust in the Kathu area appears to have an impact on the surface of *A. erioloba* leaves. To confirm this, the impact of mine dust on the following physiological processes were determined: the chlorophyll *a* and *b* content of leaves,





**Figure 4.7.** The influence of different soil/water solutions on the growth potential of *Acacia erioloba* seedlings (Khai-Apple Nature Reserve ■; Knapdaar-Swarthaak ▼; Lylyveld-Demaneng ▲; Sandveld Nature Reserve ◆; Control treatment ●).



**Figure 4.8.** The influence of different concentrations of a mine dust solution on the growth potential of *Acacia erioloba* seedlings (Control treatment ■; 1 g l<sup>-1</sup> Mine dust solution ■; 10 g l<sup>-1</sup> Mine dust solution ■).



the transpiration rate and the protein content of leaves. From the results of this investigation it was concluded that the mine dust emitted by the Sishen Iscor Iron Ore Mine has no marked influence on any of these parameters.

The impact of mine dust on the germination capacity of *A. erioloba* seeds and the growth potential of seedlings were also determined. No inhibitive effect on any one of these parameters could be detected. In fact, mine dust seemed to have a stimulating effect on both the germination capacity and growth potential of *A. erioloba*.

Except for the structural damage caused to *A. erioloba* leaf surfaces by mine dust, the results of the present investigation was therefore in contrast to the results obtained in the literature that was stated in the beginning of this chapter: no detrimental effect of mine dust on the physiological processes of *A. erioloba* could be found.

CHAPTER 5

THE INFLUENCE OF THE LOWERING OF UNDERGROUND  
WATER LEVELS BY THE SISHEN ISCOR IRON ORE MINE  
ON THE POPULATION STRUCTURE OF  
*ACACIA ERIOLOBA*



## 5.1. INTRODUCTION

The lowering of underground water levels by the Sishen Iscor Iron Ore Mine was identified as one of the aspects of the mining activities in the Kathu region with a potentially harmful effect on the *A. erioloba* population. The influence of the lowering of water table levels on the population structure *A. erioloba* will therefore be thoroughly investigated in this chapter.

### 5.1.1. GEOLOGY

The Kathu area is geologically well described (Lynch 1982). Geological surveys conducted in the area include those of Rogers and Du Toit (1909), Van der Merwe (1973), Moen (1977), Beukes (1978) and Van der Merwe *et al.* (1981).

Dolomites of the Campbell Group form the base of the geological structure of the Kathu region. Jaspillites, banded ironstones and shales of the Griqualand Group concordantly overlie the Campbell group (Strategic Environmental Focus CC 1999), with the Gamagara Formation, consisting of hematite, shales, siltstones and quartzites, discordantly overlaying the Griqualand Group (Lynch 1982; Strategic Environmental Focus CC 1999). Rocks of the Makganyene Formation, consisting of dolomite, banded lydite, sandstone, mudstone, subordinate grit stone and diamictite, discordantly overlie the Gamagara Formation (Lynch 1982; Strategic Environmental Focus CC 1999). The former is, in turn, overlain by rocks of the Ongeluk Formation (Lynch 1982; Strategic Environmental Focus CC 1999), which is, in turn, discordantly overlain by rocks of the Dwyka Formation (Strategic Environmental Focus CC 1999) (Figure 5.1).

The tertiary-aged Kalahari Group, consisting of aeolian sand, calcrete, clays and Precambrian rocks, covers the entire Kathu area discordantly (Lynch 1982; Heystek 1985; Rossouw 1999) (Figure 5.1). The Kalahari layers are relatively thin (up to 100 m thick), but increase in width in a northerly direction (Lynch 1982; Strategic Environmental Focus CC 1999). The Precambrian rocks are cut by diabase<sup>4</sup> dykes and a Dwyka (early Karoo) Valley, of which the former has an important influence on the occurrence of underground water (Rossouw 1999).

## STRATIGRAPHY

## LITHOLOGY

KALAHARI GROUP

DWYKA FORMATION

ONGELUK FORMATION

MAKGANYENE FORMATION

PALING FORMATION

MARTHASPOORT

SISHEN FORMATION

KURUMAN FORMATION

TSINENG FORMATION

GAMOHAAAN FORMATION

CALCRETE, CLAY AND BOULDERS

TALUTE AND SHALE

LAVA

GLACIAL DIAMICTITE

UPPER TECH SHALE

QUARTZITE

TECH SHALE

FERRUGINOUS FLAGSTONE

SHALE

BANDED IRONSTONE

CONGLOMERATE

SHALE

CONGLOMERATIC AND GRITTY IRON ORE

SHALE

GAMAGARA LAMINATED AND MASSIVE IRON ORE

THABAZIMBI TYPE IRON ORE

BANDED IRON FORMATION

CHERT BRECCIA

DOLOMITE

U = UNCONFORMITY

Figure 5.1. A typical stratigraphic section of the geology of the Kathu area (adopted from Rossouw (1999)).

\*A type of basalt commonly known as greenstone.



The general strike of rocks in the Kathu area is north-south, with a regional dip of  $\pm 11^\circ$  to the west. Faulting, folding and subsidence does, however, cause local variations in both the direction and angle of dip (Heystek 1985; Rossouw 1999; Strategic Environmental Focus CC 1999). These variations, as well as Graben-type structures, are common in the Kathu region. Several phases of folding resulted in the development of local anticlines, synclines, domes and basins, as well as localised normal and trough faults. Structurally the Kathu area resembles a synclinorium that has been affected by normal faulting (Strategic Environmental Focus CC 1999).

High grade hematite sediments are present in two geological units, namely the Gamagara formation, which is correlated with the Etagé Timeball Hill, and in the Etagé Under-Griekwastad, which is correlated to the banded ironstones of the Dolomite Serie of the Transvaal System (Heystek 1985).

#### 5.1.2. AQUIFERS

An aquifer can be defined as "*a stratum which contains intergranular interstices, or a fissure/fracture (as such) or a system of interconnected fissures/fractures (as such) capable of transmitting groundwater rapidly enough to directly supply a borehole or spring. These fissures/fractures are generally bound by either aquiclude/aquitard or aquifuge*" (Vegter 1995). Simply put, an aquifer is a layer of rock containing water (Ramsar Bureau 2001).

The aquifers present in the study area are typically that which is encountered over most parts of South Africa: virtually impermeable, with a potentially significant storage coefficient and with fractures and fracture zones serving as pathways for ground water flow (Strategic Environmental Focus CC 1999). Structural features such as joints, fractures and dykes are of importance both in the transmission and the storage of ground water (Partridge 1967), as the permeability of fracture zones can be high (Strategic Environmental Focus CC 1999). Two important fracture zones occur in the study area: the chert breccia and banded iron formations of the Tshineng Formation, which serve as water transmitters; and the Kuruman Hills Subgroup (Strategic Environmental Focus CC 1999).

Two aquifers occur in the Kathu catchment area (Anderson 1992; Laan 1998; Strategic Environmental Focus CC 1999). The primary aquifer is situated in the Kalahari Formation,



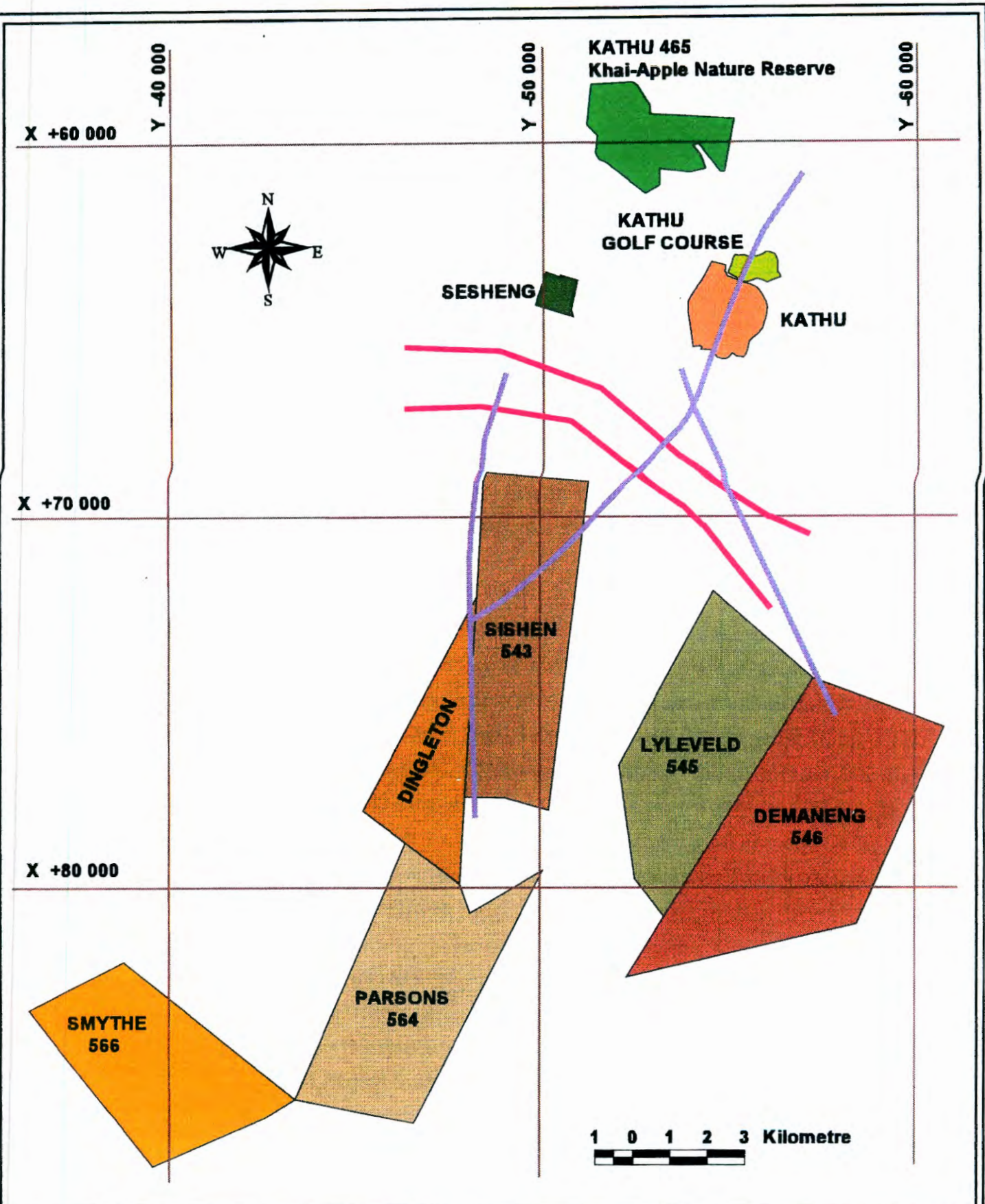
which consists of upper and lower water holding Kalahari gravel layers. These layers are separated by an impermeable layer of red clay and consist of argillaceous clay overlain by limestone and calcrete. The secondary aquifer occurs in the pre-Kalahari Formation and acts as the main ground water source in the area. It consists of the following (Strategic Environmental Focus CC 1999):

- **Dolomite.** Dolomite is relatively impermeable and can be regarded as the floor of the ground water compartments.
- **Banded ironstone.** This rock-type possesses a well-defined jointing system. A high rate of water supply is caused by brecciation along its fault zones.
- **Gamagara strata.** These strata occur in a north-south running belt. Folding and well-defined jointing ensures a good supply of ground water from the south.
- **Ongeluk lava.** This lava is generally impermeable and separates the primary and secondary aquifers to the west of the mine.

In the study area, dolerite dykes serve as subsurface boundaries for lateral water flow (Anderson 1992; Strategic Environmental Focus CC 1999, Goussard, pers. comm.<sup>1</sup>). Dykes, especially where it forms an intersecting network, tend to divide the host rock into discrete hydrological compartments, since the rocks of which it is composed are generally impermeable (Partridge 1967). Dolerite dykes divide the mine area into three ground water compartments: a northern, southern and western compartment (Compartments 1, 2 and 3); plus another two compartments in the area, namely the Kathu and the Khai-Apple compartments (Compartments 4 and 5) (Anderson 1992; Strategic Environmental Focus CC 1999) (Figure 5.2). According to Strategic Environmental Focus CC (1999) these compartments, stretching over an area of 20 000 ha, with a catchment area of 60 000 ha, do not have a significant effect on each other.

The southern mine compartment (Compartment 1) includes both the current and planned south mine mining areas. Its boundaries are formed by the Makganyene diamictite or Dwyka Valley to the east and the north-south trending dolerite dyke to the west (Figure 5.2). The dolerite dyke separating the southern mine from the northern mine can be classified as quartz monsonite. Clay minerals, which form as a result of the weathering process in this dyke, make it impermeable to water (Lynch 1982). It is important to note, however, that parts of the dolerite





**LEGEND**



Dolorite dyke

**Figure 5.2.** The location of impermeable dolerite dykes in and around the mining area.



dykes in the quarry area are currently being removed as part of the mining process, thus making it partly permeable to water (Goussard, pers. comm.<sup>1</sup>). Compartment 1 is open to the south, up to the Gamagara River (Figure 5.2) and has the highest transmissivity, storativity and most effective recharge of all five compartments in the area (Strategic Environmental Focus CC 1999).

The northern mine compartment (Compartment 2) lies in a V-shaped area between two prominent dolerite dykes (Figure 5.2). The western leg of these dykes lies virtually north and the eastern leg points north-east. The Makganyene diamictite or Dwyka Valley forms the northern boundary of this compartment (Strategic Environmental Focus CC 1999) (Figure 5.2).

The western mine compartment (Compartment 3) has a prominent eastern boundary in the form of a dolerite dyke. The compartment is open to the south, west and north (Strategic Environmental Focus CC 1999) (Figure 5.2).

As mining activities intensified and excavations became deeper after the commencing of iron ore export in 1977, large quantities of ground water started entering the mining area. Twenty-eight pumps, pumping water from the Kathu aquifers full-time to prevent the mine from flooding, were installed as a counteracting measure (Lynch 1982). The water that is pumped from the mining area, is used to supply the Kalahari East and Vaal-Gamagara Pipeline Water Schemes, as well as the towns of Hotazel and Olifantshoek, with water (Anderson 1992; Laan 1998). The Sishen Iscor Iron Ore Mine is furthermore the main water source of the town of Kathu, except in times of high water demand. At such times water is supplemented with water pumped from Compartment 4 (Anderson 1992; Laan 1998).

The direct removal of water from aquifers for agricultural and household purposes is common practice worldwide. Groundwater deficits have, however, become a significant problem in India, China, the USA and the Arabian Peninsula. This causes great concern – not only because of the role groundwater plays in irrigation and supplying drinking water to thousands, but also because of the role it plays in sustaining lakes, rivers and other ecosystems (Ramsar Bureau 2001). As mature *A. erioloba* trees survive on subsurface water during the dry season (Van Wyk & Gericke 2000), concern about the effect of fluctuating water table levels (caused by both mining activities and the pumping of water from aquifers below the Khai-Apple Nature Reserve



and Kathu (Lynch 1982; Laan 1998)) on the *A. erioloba* population of the Kathu area grew in recent years. This matter was subsequently thoroughly investigated.

## 5.2. OBJECTIVES

The aims of this investigation were:

- To determine the effect of ground water pumped from the Sishen Iscor Iron Ore Mine area on the underground water levels of the same area.
- To determine the effect of ground water pumped from the Sishen Iscor Iron Ore Mine area on the underground water levels of the Kathu- and Khai-Apple areas.
- To determine the effect of ground water pumped from the Kathu- and Khai-Apple areas on the underground water levels of the same areas.

## 5.3. METHODOLOGY

Data on variations in water levels of bore holes in the Kathu area, as well as the pumping rates of the various mining compartments, were obtained from the Sishen Iscor Iron Ore Mine. Data for the 48 month-period from January 1994 to January 1998 were used for the present investigation, as these records were most complete.

The water pumping rates of the southern mining compartment were plotted against the water levels of bore holes in the same compartment, as well as bore holes in the Khai-Apple and Kathu areas, with the purpose of identifying possible patterns that could indicate a relationship between these two variables. Bore holes and mining compartments used in this investigation were randomly selected, as complete data sets could not be used due to a lack of space.

Rainfall figures for the period January 1994 to January 1998 for Kathu and the various mining compartments were also obtained from the Sishen Iscor Iron Ore Mine, as the aquifers in the Kathu region are recharged by annual rainfall (Anderson 1992; Laan 1998; Strategic Environmental Focus CC 1999). The potential influence of rainfall on bore hole levels was considered throughout the present investigation.

## 5.4. RESULTS AND DISCUSSION

### 5.4.1. THE EFFECT OF THE PUMPING OF GROUND WATER FROM THE SISHEN ISCOR IRON ORE MINE AQUIFERS ON ITS WATER LEVELS

The pumping rate of water from the southern compartment of the Sishen Iscor Iron Ore Mine was firstly compared to the water level of a bore hole in the same compartment to verify that the pumping of water does indeed influence bore hole water levels. For the remainder of this chapter the trend that emerges here will then be used as a control against which other trends (e.g. the pumping rate of the southern mining compartment vs. the water level of a bore hole in the Kathu aquifer) can be compared.

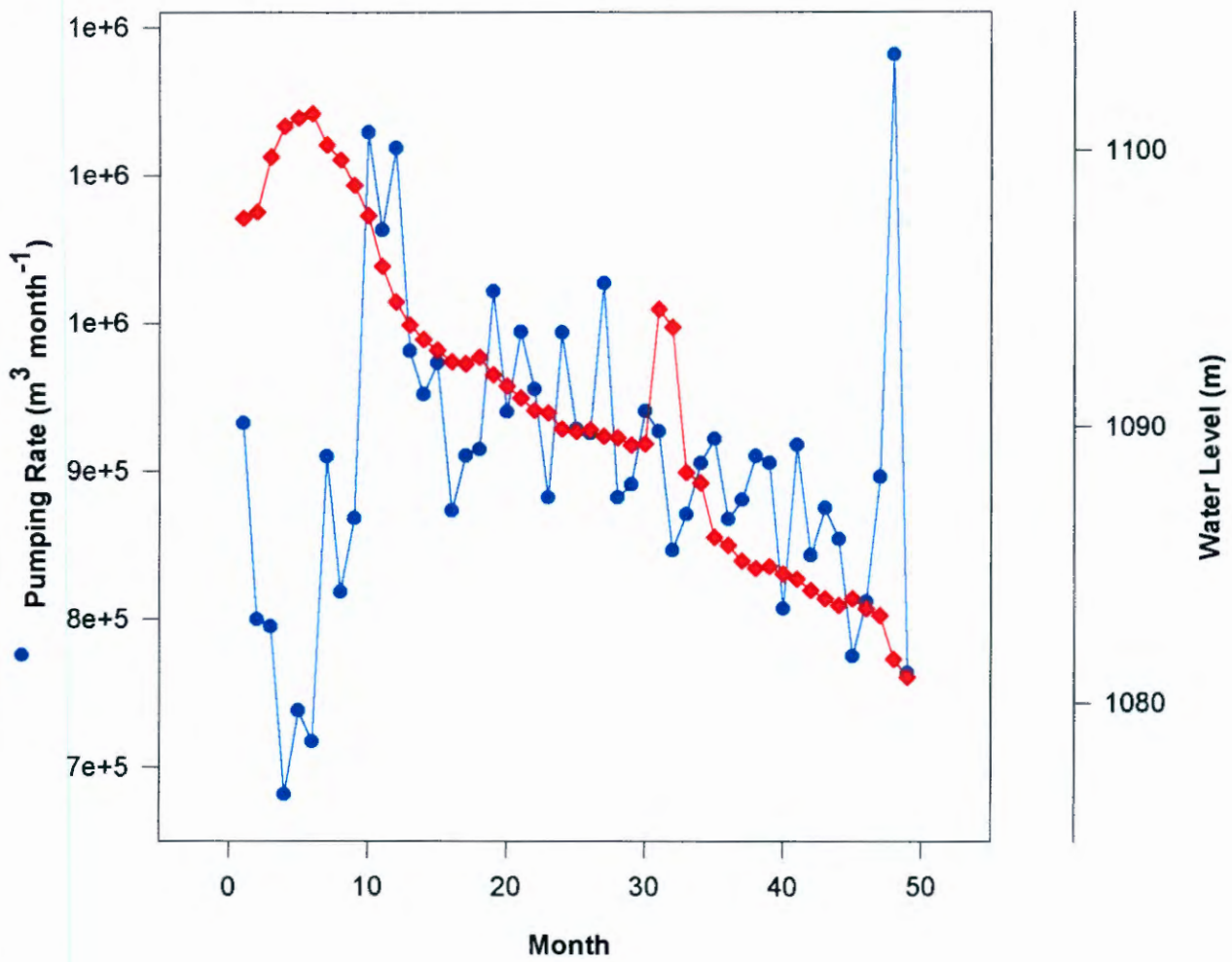
The effect of pumping water from the south mine mining compartment on the water level of a bore hole in the same compartment is evident from Figure 5.3. An inversely proportional relationship between pumping rate and water level was evident from month one to 12, after which the water level showed a slight but steady decrease despite variations in pumping rate. Not even the relatively high rainfall received in months 23 to 26 (Figure 5.4) prevented water levels from decreasing over this period. An inversely proportional relationship between water level and pumping rate was once again evident in months 31 and 32, after which water levels once again steadily decreased despite variation in pumping rates (Figure 5.3). This steady decrease in water level was once again unhindered by the relatively high rainfall received in months 35 to 37 (Figure 5.4).

It should be kept in mind that the steady decrease in bore hole level that is evident from Figure 5.3 is a result of the combined pumping of water from all three mining compartments, which are not completely separated by means of dolerite dykes.

### 5.4.2. THE EFFECT OF GROUND WATER PUMPED FROM THE SISHEN ISCOR IRON ORE MINE AREA ON THE UNDERGROUND WATER LEVELS OF THE KATHU AND KHAI-APPLE AREAS

It is hypothesised in the present investigation that if the water levels of any one of the bore holes from the Kathu or Khai-Apple aquifers have an inversely proportional relationship to the





**Figure 5.3.** The water pumping rate of the southern mining compartment plotted against the water level of a bore hole in the same compartment (Pumping rate ■; Bore hole level ◆).

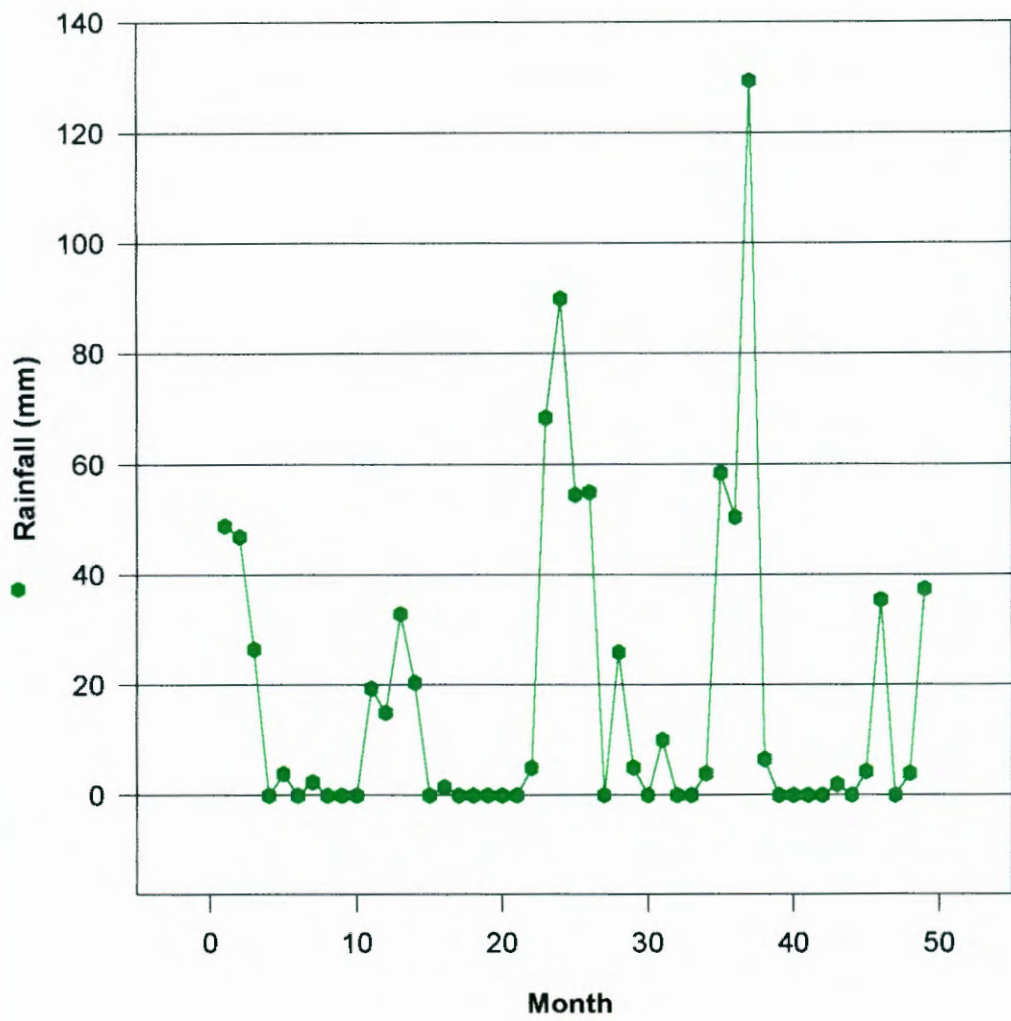


Figure 5.4. Rainfall figures for the south mine mining area of the Sishen Iscor Iron Ore mine for the period January 1994 to January 1998.



pumping rate of one of the mining compartments, it would be clear that water extraction by the mine does indeed have an influence on Compartments 4 and 5.

An approximately inversely proportional relationship between the water level of a bore hole in the Kathu aquifer and the pumping rate of water from the south mine mining compartment was evident over the entire investigation period, except months 40 – 41 and 45 - 46 (Figure 5.5). This relationship occurred despite relatively high rainfall in months one and two, 23 – 26, 28, 35 – 37, 39 and 49 (Figure 5.6).

A Dwyka Tillite Valley forms a watershed between the two north-eastern compartments, namely Compartments 4 and 5, and the three compartments (Compartments 1 - 3) found in the mining area (Anderson 1992; Strategic Environmental Focus CC 1999). Tillite is generally non-permeable to water, causing Compartments 4 and 5 to be water-tight and uninfluenced by the pumping of water from Compartments 1 - 3 (Anderson 1992; Strategic Environmental Focus CC 1999; Goussard, pers. comm.<sup>2</sup>). It was therefore hypothesised in the present study that the pumping of water from any of the mining compartments of the Sishen Iscor Iron Ore Mine would not influence the bore hole water levels of bore holes in the Kathu and Khai-Apple aquifers. This hypothesis is in line with the findings of Laan (1998), who concluded that the mining activities of the Sishen Iscor Iron Ore Mine has no effect on the underground water levels of Kathu and the Khai-Apple Nature Reserve areas. In opposition to this, Lynch (1982) estimated the total area affected by the extraction of underground water by the Sishen Iscor Iron Ore Mine to be 1 700 km<sup>2</sup>.

From Figure 5.5 it is, however, in contrast to what was hypothesised, clear that there is a relationship between the pumping rate of water from the southern mining compartment and the water level of a bore hole in the Kathu aquifer, albeit a relatively small one. It can therefore not be concluded from the results of the present investigation that the lowering of water table levels as a result of the mining activities of the Sishen Iscor Iron Ore Mine does not negatively impact the *A. erioloba* population of the Kathu area.

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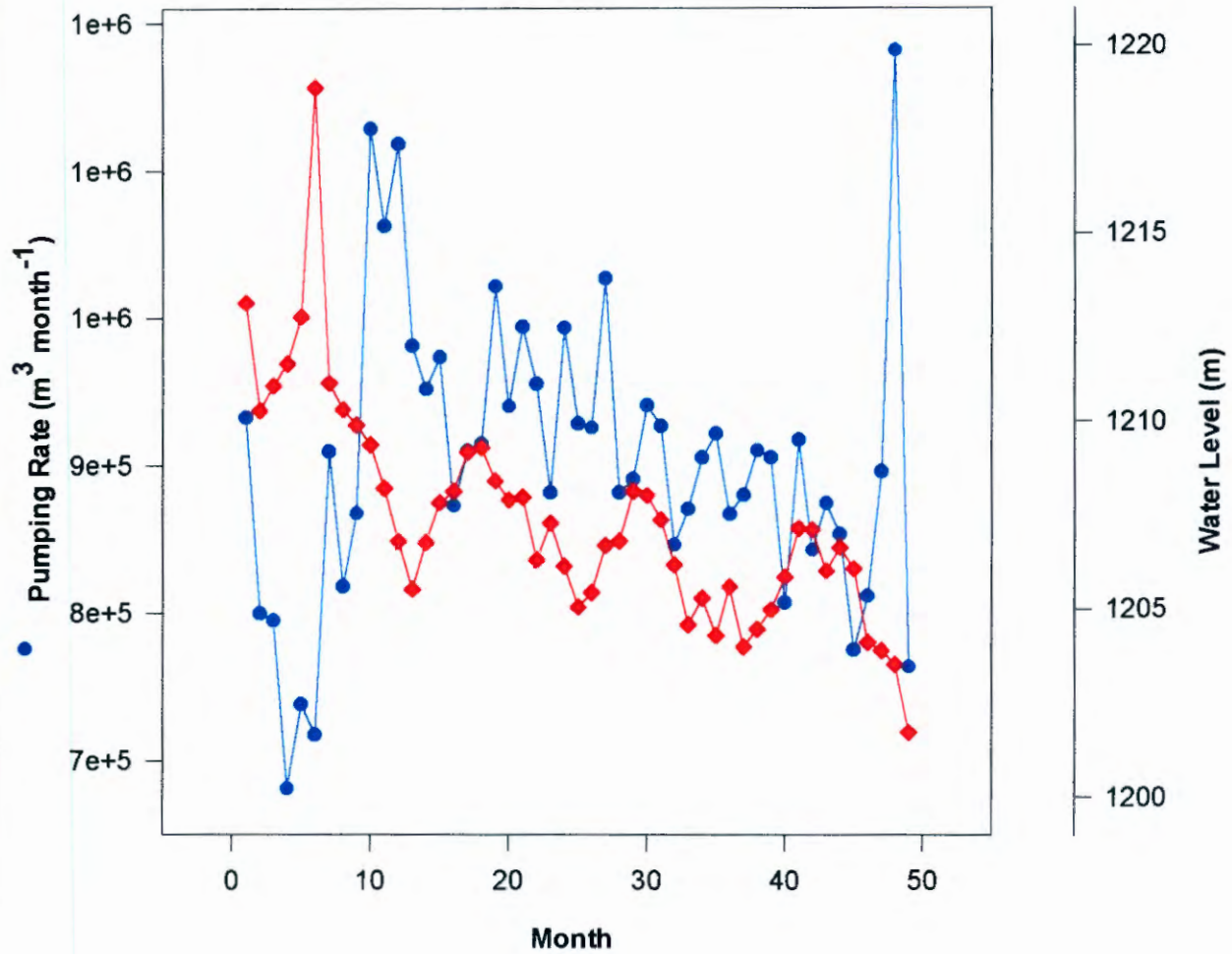


Figure 5.5. The water pumping rate of the southern mining compartment plotted against the water level of a bore hole in the Kathu aquifer (Pumping rate ■; Bore hole level ■).



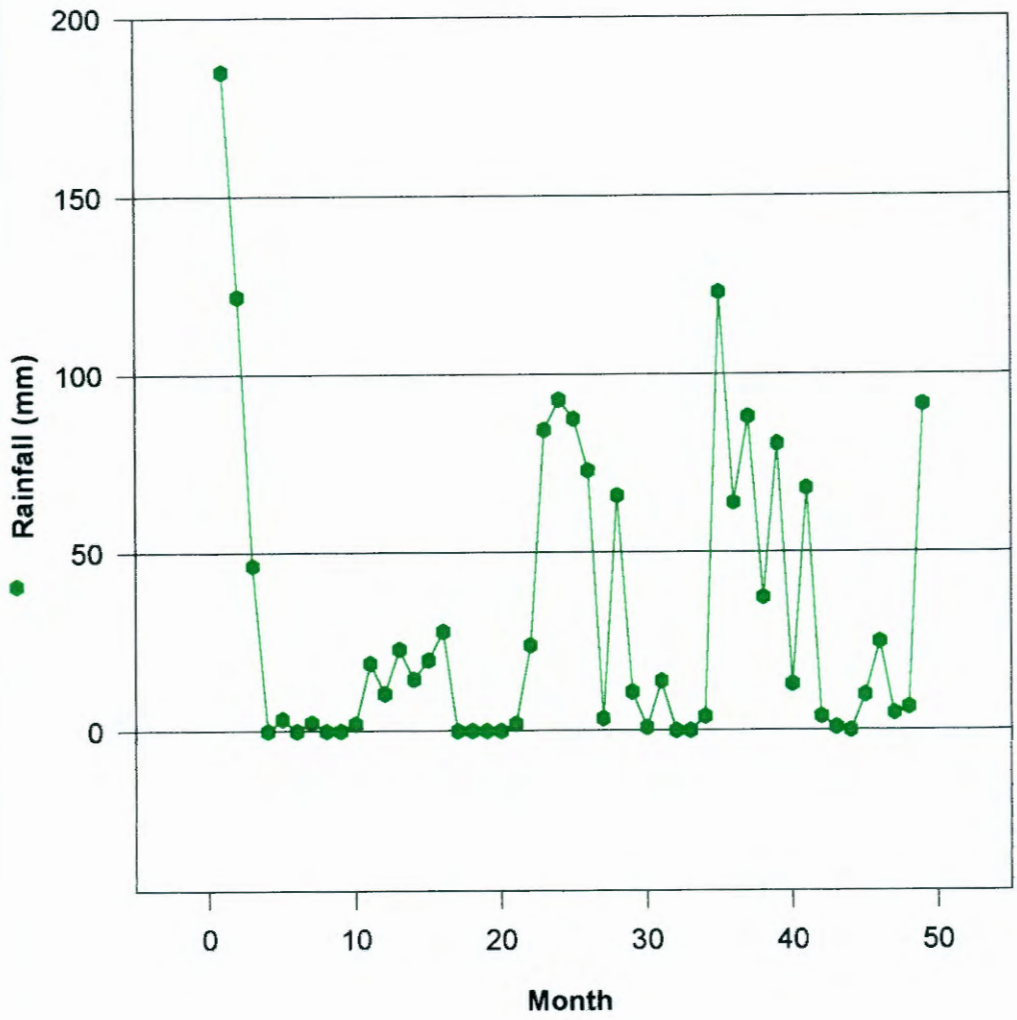


Figure 5.6. Rainfall figures for the Kathu area for the period January 1994 to January 1998.

## 5.5. CONCLUSIONS

The influence of the Sishen Iscor Iron Ore Mine on underground water levels were determined by comparing the pumping rate of water in the different mining compartments to the level of various bore holes in the region. In contrast to what was hypothesised, it is concluded from the results of this study that the pumping of water in the different mining compartments does have a slight influence on the water levels of bore holes in the Kathu aquifer.



CHAPTER 6

THE INFLUENCE OF HIGH BROWSE PRESSURE ON THE  
POPULATION STRUCTURE AND ABOVE-GROUND BIOMASS OF  
*ACACIA ERIOLOBA*, AND ON THE BEHAVIOUR OF ITS  
POLLINATORS

## 6.1. INTRODUCTION

The response of woody plants to browsing is still poorly understood (Bryant *et al.* 1983). The effect of browsing can, however, be described as either positive or negative (Kay 1984; Coe & Coe 1987; Sabiiti *et al.* 1991; Paige 1992; Kay 1993; White *et al.* 1998; Stuart-Hill 1999), as was reviewed by Belsky (1986). The level of expression of either depends on the intensity, season and frequency of browsing (Stuart-Hill 1999).

Advantages of herbivory include:

- The ingestion of pods by ungulates facilitates seed dispersal and increases germination of hard seeded species by scarifying the seed coat (Gwynne 1969; Miller & Coe 1993).
- By frequently eating pods while they are still on the trees, ungulates significantly reduce the negative effect of insect seed predators (mostly Bruchidae beetles) on seeds (Halevy 1974; Miller 1994b).
- Browsed plants produce significantly more flowers and fruits than non-browsed plants (Paige 1992).
- Both above- (Danell & Huss-Danell 1985; Coe & Coe 1987; Paige 1992; Gowda 1997; Hurt & Tainton 1999) and below-ground biomass is significantly greater for naturally browsed plants following regrowth (Paige 1992).
- Increases in leaf palatability due to severe browsing have been reported, although such effects are short-lived (Styles 1993).

High levels of secondary herbivory are, however, detrimental in most cases (Paige 1992; Hurt & Tainton 1999).

Disadvantages of herbivory include:

- Large numbers of seed-feeding animals may consume so much seed that potential safe-sites remain unfilled or are filled by competing plant species, thus limiting seedling recruitment (Crawley 1983).
- Seedling establishment may be rare under high ungulate browsing pressures and may depend on temporary declines of herbivore populations (Sinclair 1995).
- Herbivory may restrict the growth and survival of young trees (Dublin *et al.* 1990; Mwalyosi 1990).



- Pollinators visit plants damaged by herbivores less frequently and for shorter periods of time compared to unbrowsed plants (Strauss *et al.* 1999).
- Records of defoliation having a significantly negative effect on pollen grain size, pollen tube growth and rates of pollen tube attrition have been documented for hermaphroditic plants. Herbivory may also impair pollen performance by decreasing carbon provisioning during pollen development (Aizen & Raffaele 1998).
- Both the mean tree biomass and the mean density of trees can be decreased by browsing (McInnes *et al.* 1992).
- Unbrowsed areas produce more tree and shrub litter than browsed areas, which is likely to increase the organic content of soils (McInnes *et al.* 1992).

Detrimental effects of both concentrated and normal levels of browsing on woody plant regeneration are well documented (Kay 1984; Coe & Coe 1987; Sabiiti *et al.* 1991; Kay 1993; White *et al.* 1998), especially for arid and semi-arid areas (Chesterfield & Parsons 1985; Smart *et al.* 1985; Auld 1990). Management intervention is often necessary to protect seedlings and sprouts from browsers (Baker *et al.* 1999). Introduced animal species, such as goats, are often major culprits (Auld 1990) and need careful management.

Early stages of seedling growth are generally associated with high mortality rates (Crawley 1983; Fenner 1985; Auld 1995), as the plant is most vulnerable to suppression and defoliation when it starts to rely on the products of its own photosynthesis for the first time (Crawley 1983). Utilisation by browsers is often the cause of these high seedling mortalities (Fenner 1985; Hjältén *et al.* 1994; Auld 1995; García *et al.* 1999; Rohner & Ward 1999). Browsers often prefer younger plants because the nutritional quality of some leaves decrease with age (Schroeder 1986; Styles 1993) and young leaves have a high available energy- and moisture content (Styles 1993). Every plant species has a specific stage after which normal levels of herbivore feeding is not likely to kill it (Crawley 1983). Once this stage is reached, individuals are likely to have tenure over a specific site for a long time (Crawley 1983; Auld 1995). The browsing of seedlings can be problematic in terms of reproduction, as many *Acacia* species rely on seedling recruitment as the only manner of maintaining populations (McInnes *et al.* 1992).

Mature *A. erioloba* individuals are also utilised by browsers (Van Wyk & Van Wyk 1997; Van der Walt & Le Riche 1999). In heavily browsed areas, larger herbivores may change the biomass,

structure, production, density and species composition of woodlands (Naiman 1988; McInnes *et al.* 1992; Ben-Shahar 1998).

#### 6.1.1. BROWSING CAPACITY

Browsing capacity is a habitat characteristic and can be defined as "*the number of browsers that can be supported by a given habitat over the long term, without any detrimental effects on either the game or the habitat*" (Trollope *et al.* 1990; Bothma 1996a). Browsing capacity is calculated in Browse Units (BU's), which is normally expressed per unit area of land. Smit (Unpublished) and Peel *et al.* (Unpublished) defined a BU as "*the metabolic equivalent of a kudu (100% browser) with a mean body mass of 140 kg*".

Although it is at best only speculative as to how much browsable material is necessary to sustain any browsing animal, it is possible to estimate the available browse of an area by determining the browsable volume which is contributed per hectare by the woody species present (Van Essen 1997). The following factors influence browse capacity and potential (Aucamp 1979):

- The density of the woody plants.
- The amount of leaf material within the reach of an animal (e.g. due to the presence of structural defence mechanisms such as spines (Cooper & Owen-Smith 1986; Van Rooyen *et al.* 1996; Hurt & Tainton 1999); the height of browsers; and/or the density of a specific plant).
- The species composition of the woody vegetation.
- The palatability of the woody species.
- The digestibility of the woody species.
- The growth potential of the woody species.

Another factor that may influence the amount of available browse is the presence of chemical defence mechanisms (e.g. the concentration of secondary metabolites such as condensed tannins) (Bryant *et al.* 1983; Cooper & Owen-Smith 1985; Danell & Huss-Danell 1985; Cooper *et al.* 1988; Bemarks *et al.* 1989; Paige 1992; Hurt & Tainton 1999), and other deterring mechanisms, e.g. symbiotic ants (Hölldobler & Wilson 1990; Madden & Young 1992) in some woody plants (Bryant *et al.* 1983; McNaughton 1983; Van der Meijden *et al.* 1988). These



defence mechanisms may act as feeding deterrents (Bernays *et al.* 1989), or simply slow down the rate of plant consumption (Cooper & Owen-Smith 1986; Coe & Coe 1987).

The first three factors listed by Aucamp (1979), namely the density of woody plants, the amount of available leaf material within reach of browsers and species composition, were recorded in the present investigation. It is, however, difficult to measure the palatability, digestibility, growth potential and the amount of condensed tannins in the leaves of woody species (Schmidt 1992) and these factors were therefore omitted from the present study. It is, however, logical to accept a correlation between the latter three factors (Van Essen 1997).

The aim of browsing management is, for as far as it is economically and technically feasible, the improvement or maintenance of the present veld condition for the benefit of browsing animals (Barnes 1982; Trollope 1990; Van Rooyen *et al.* 1996). This involves the modification of the ecosystem in order to guarantee, as far as is possible, ideal conditions for plant growth (Barnes 1982). Smaller areas, such as the Khai-Apple Nature Reserve (2 312.50 ha), require intensive management, as such areas are not self-regulating ecological units (Trollope 1990).

## 6.2. OBJECTIVES

The aims of this investigation were to:

- Calculate the current stocking rate of the Khai-Apple Nature Reserve.
- Calculate the current short term browsing capacity of the Khai-Apple Nature Reserve.
- To determine the influence (if any) of the browse pressure of ungulates on the post-fertilisation regeneration of *A. erioloba*.
- To determine the influence (if any) of the browse pressure of ungulates on the occurrence and/or behavior of the insect pollinators of *A. erioloba* in the Khai-Apple Nature Reserve.
- To determine the influence (if any) of the browse pressure of ungulates on the above ground biomass and density of *A. erioloba* in the Khai-Apple Nature Reserve.

### 6.3. METHODOLOGY

#### 6.3.1. CURRENT STOCKING RATES

Game species present and game numbers were determined by the reserve management by means of an aerial game count in January 2000 (Mostert, pers. comm.<sup>1</sup>). The method for conducting an aerial game count is described in detail by Young (1992) and Bothma (1996b).

The current stocking rate of the Khai-Apple Nature Reserve was calculated from the game count data with the aid of the ECOCAP<sup>2</sup> programme. Large Stock Unit and Browse Unit equivalents, as well as the percentage graze and browse in the diet of ungulates used in this programme were taken as correct, unless otherwise indicated.

#### 6.3.2. CURRENT SHORT-TERM BROWSING CAPACITY

The current short-term browsing capacity was determined with the aid of the BECVOL transect method of Smit (1989). This method is described in detail in Chapter 2. An additional motivation for using this method in calculating browse capacity specifically, is the fact that it enables the calculation of available browse at different height levels (Von Holdt 1999).

A total of 50 BECVOL surveys were conducted at random in the Khai-Apple Nature Reserve (Figure 6.1) during September 2000, prior to the spring rains. None of the other study sites (Lylyveld-Demaneng, Knapdaar-Swarthaak and the Sishen Golf Course) sustain large herds of ungulates, and were therefore omitted from this investigation.

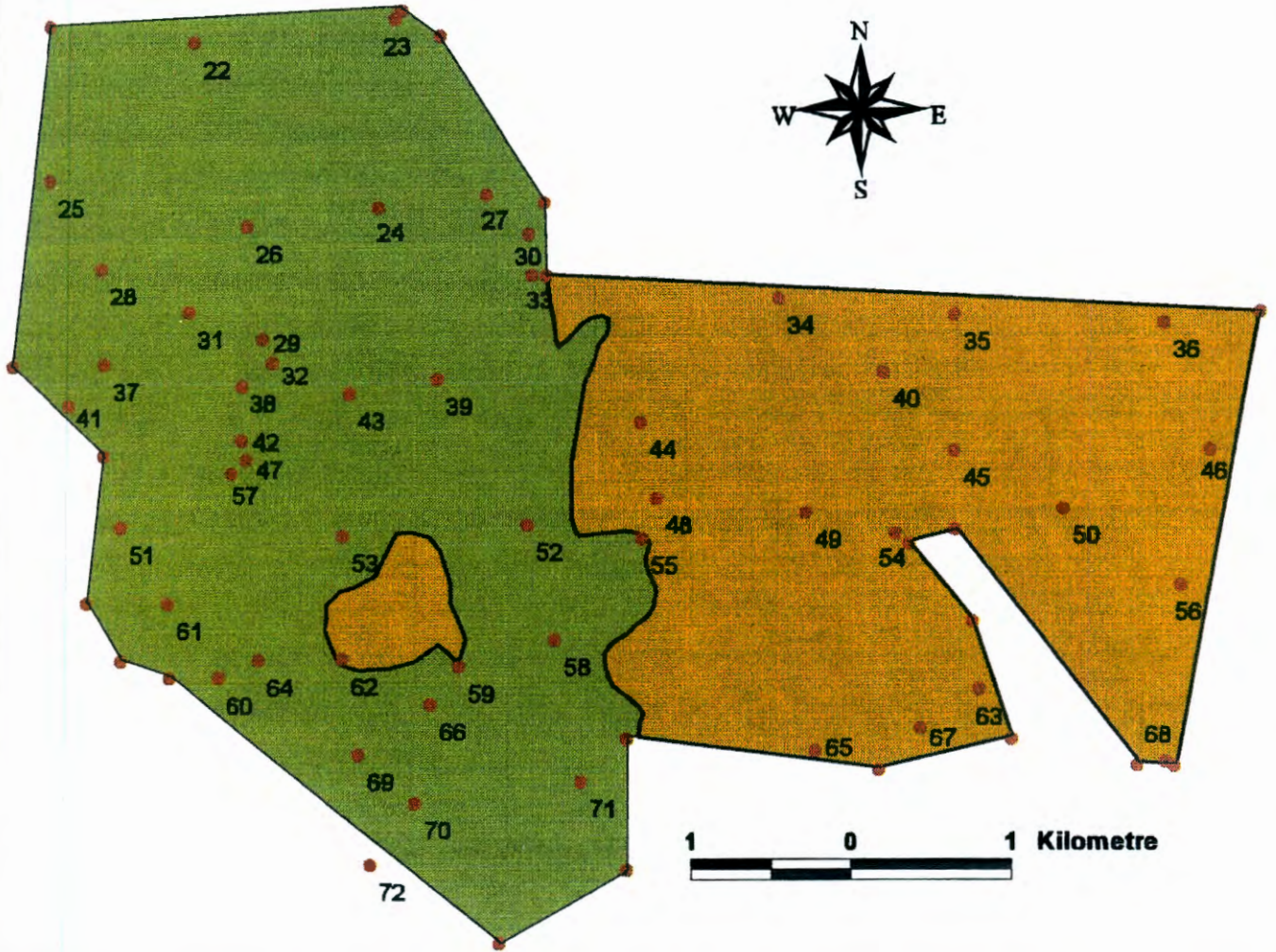
#### 6.3.3. THE INFLUENCE OF BROWSE PRESSURE ON THE BEHAVIOUR OF *ACACIA ERIOLOBA* POLLINATORS

Pollination ecology involves consistent observation of the plant under investigation in its original, natural habitat (Faegri & Van der Pijl 1966; Kearns & Inouye 1993). Variations of this technique have been successfully applied by various authors (Snow 1982; Spears 1983; Hainsworth *et al.*

<sup>1</sup> Mr. André Mostert, Reserve Manager. ☎: 0537232261.

<sup>2</sup> Developed and distributed by Mr. B. Orban. ☎: Centre for Wildlife Management, University of Pretoria, Pretoria.





**LEGEND**

- Acacia mellifera* Shrubland community
- Acacia erioloba* Woodland community
- Plots for BECVOL surveys

**Figure 6.1.** Random distribution of plots identified for BECVOL surveys in the Khai-Apple Nature Reserve.

1984; Zietsman 1988; Tybirk 1993; Bosch & Waser 1999; Krupnick *et al.* 1999; Strauss *et al.* 1999; Yi-Bo & Zhen-Yu 1999).

#### 6.3.3.1. Choice of branches to be studied

Branch height was standardised at 2.5 – 3.5 m from the ground, as visitation has been shown to increase with branch height (Larson & Larson 1990). Trees from height classes four and five (Chapter 2) were selected as far as possible, as visitation has also been shown to decrease with plant size (Andersson 1988).

*Acacia erioloba* individuals surrounded by subjectively judged equal distributions of flowering plants were investigated, as the density of flowering plants (both conspecific and non-conspecific) can affect the foraging behavior of pollinators by competing for attention, thus influencing pollination (Nilsson & Wästljung 1987; Kearns & Inouye 1993; Willems & Lahtinen 1997).

Areas with subjectively judged equal densities of *A. erioloba*, were selected to be included in this study as seed production is influenced by the distance between the pollen source and -recipient (Kearns & Inouye 1993).

Trees from both the early and late flowering groups were included in this study, as suggested by Zietsman (1988).

Thirty-centimeter-sections of selected north facing branches were marked with yellow plastic identification flags (Hainsworth *et al.* 1984).

#### 6.3.3.2. Observation technique

Observation and subsequent notation of all potential flower pollinators (Faegri & Van der Pijl 1966; Zietsman 1988; Potgieter *et al.* 1999; Strauss *et al.* 1999) of four randomly chosen trees per selected site were made for a 180 second period once every two hours. Observations were made in random order. Care was taken to correctly identify all potential pollinators. Unknown insect visitors were collected and preserved in ethanol for later identification (Tybirk 1993).



Insect visitations were expressed as the number of insects per hour per 30 cm of length of flower-bearing twig.

To give an indication of the importance of various insect visitors, visitation frequency was calculated by using the proportion of observed visits made by each insect species (Tybirk 1993; Potgieter *et al.* 1999).

A behavioural analysis of potential floral pollinators (Tybirk 1993; Potgieter *et al.* 1999; Yi-Bo & Zhen-Yu 1999) was also carried out. This comprised of an observation period of 180 seconds once every two hours. The time spent per flower by a single flower visitor for the stated period was recorded (Zietsman 1988; Tybirk 1993; Strauss *et al.* 1999).

Observations were made for a total of three non-consecutive days per site during the flowering season from two hours before sunrise to two hours after sunset. In this way both potential diurnal and nocturnal pollinators were accommodated (Kearns & Innouye 1993).

Because both plants and pollinator activities are affected by environmental variables (Molano-Flores *et al.* 1999), the most important of these parameters were standardised by collecting meteorological data along with the data on flower visitation (Kearns & Innouye 1993). In this way the effects of environmental variables on visitation in different areas could be quantified. Meteorological measurements included ambient temperature, relative humidity, wind speed and direction, as well as light intensity (Kearns & Innouye 1993). A hand-held sling psychrometer (Unwin 1980) was used for determining relative humidity. Wind speed and direction was measured with a cup anemometer, while light intensity was measured with a LICOR LI-185A photometer. Environmental variables were determined prior to every two-hourly observation period.

#### 6.3.4. THE INFLUENCE OF BROWSERS ON THE ABOVE GROUND BIOMASS AND DENSITY OF *ACACIA ERIOLOBA*

The tree density and leaf dry mass of *A. erioloba* were determined with the aid of the BECVOL belt transect method of Smit (1989). This technique is described in detail in Chapter 2.

A total of 11 transects were surveyed in the *Acacia erioloba* Woodland community of the Khai-Apple Nature Reserve (Figure 2.1), 10 in the Sandveld Nature Reserve, four on the Sishen Golf Course, five in the Lylyveld-Demaneng area and five in the Knapdaar area.

## 6.4. RESULTS AND DISCUSSION

### 6.4.1. CURRENT STOCKING RATE

The current stocking rate of browsers and mixed feeders in the Khai-Apple Nature Reserve, excluding the exotic camel, adds up to 252.17 BU's (Browse Units) and 63.25 LSU's (Large Stock Units) (Table 6.1). The bulk of these figures (223,04 BU and 63.25 LSU) are contributed by mixed feeders, with the contribution of eland (71.76 BU) and springbok (79.56 BU) being the highest. Selective browsers contribute only 29.13 BU to the current stocking rate, with giraffe being the highest contributor at 22.80 BU (Table 6.1).

### 6.4.2. CURRENT SHORT-TERM BROWSING CAPACITY

The total calculated browsing capacity of the Khai-Apple Nature Reserve for the nutritional bottleneck period, is 15.87 BU. The *Acacia erioloba* Woodland contributes slightly more than half of this (8.40 BU), while the *Acacia mellifera* Shrubland contributes 7.47 BU (Table 6.2).

The idea of fixed ecological capacity figures for specific regions, read from predetermined tables, has little or no use in practice, as browsing capacity is not a constant (Trollope 1990; Bothma 1996a). It is influenced by variables such as habitat diversity, management strategy, plant composition, rainfall, veld type, veld condition and utilisation pressure (Trollope 1990; Young 1992; Bothma 1996a; Liversidge & Berry 1996; Van Hoven 1996; Van Rooyen & Du Toit 1996, Van Essen 1997). Browsing capacity figures should therefore be based on intensive and continuing vegetation studies (Trollope 1990; Bothma 1996a), as was done in the present study.

Only leaf material was taken into consideration for the calculation of the current browsing capacity, although other plant parts such as flowers, fruit, twigs and bark also form a part of the diet of many browsers (Barnes 1982; Smit 1989; Young 1992). *Acacia erioloba* pods, especially, are highly nutritious (Coates Palgrave 1984; Gubb 1988; Hoffman *et al.* 1989; Miller & Coe 1993; Van der Walt 1993; Fagg & Stewart 1994; Van Wyk & Van Wyk 1997; Smit 1999),



Table 6.1. Current stocking rate of browsers and mixed feeders of the Khai-Apple Nature Reserve.

Animal Type	Number	LSU Equivalent	BU Equivalent	Percentage Grass in Diet <sup>3</sup>	Percentage Browse in Diet <sup>4</sup>	LSU's	BU's
<b>Mixed Feeders</b>							
Eland	46	0.43	1.56	30	70	19.78	71.76
Gemsbok	40	0.39 <sup>4</sup>	0.41 <sup>5</sup>	75	25	15.60	16.40
Impala	91	0.12	0.18	60	40	10.92	16.38
Kudu	33	0.05	1.18	18	72	1.65	38.94
Springbok	306	0.05	0.26	30	70	15.30	79.56
<b>Sub-total</b>						<b>63.25</b>	<b>223.04</b>
<b>Browse Feeders</b>							
Duiker	24	0.00	0.22	2	98	0.00	5.28
Giraffe	6	0.00	3.80	1	99	0.00	22.80
Steenbok	7	0.00	0.15	0 <sup>5</sup>	100 <sup>5</sup>	0.00	1.05
<b>Sub-total</b>						<b>0.00</b>	<b>29.13</b>
<b>TOTAL</b>						<b>63.25</b>	<b>252.17</b>

<sup>3</sup> Van Hoven (1996).

<sup>4</sup> For game in the Mopanielveld north of the Soutpansberg (Snyman 1991).

<sup>5</sup> According to ECOCAP Programme.

Table 6.2. *Current short-term browsing capacity of the Khai-Apple Nature Reserve.*

Plant Community <sup>6</sup>	Browsing Capacity (BU)
<i>Acacia erioloba</i> Woodland	8.40
<i>Acacia mellifera</i> Shrubland	7.47
TOTAL	15.87

<sup>6</sup> As identified by Van Hoven and Guldmond (1992).



containing 27 - 33% crude protein (Dudley 1999; Van der Walt & Le Riche 1999), and are therefore attractive to mammals (Pellew & Southgate 1984). Fallen foliage and the consumption thereof were not considered in the calculation of browsing capacity, due to the impracticality of such measurements (Von Holdt 1999). The calculated browsing capacity (Table 6.2) will therefore be somewhat conservative.

The browsing capacity of the Khai-Apple Nature Reserve was calculated at a maximum browsing height of 2 m because plant material above this height is out of reach for most wild ungulates. This height represents the mean browsing height of kudu (Wentzel 1990) and is a mean maximum height, and not an absolute maximum browsing height (Van Essen 1997). It is known that large individuals are able to reach higher than this mean height (Dayton 1978) and that breaking off branches may also enable browsers to utilise browse at even higher levels (Styles 1993). These are, however, exceptions and should not influence results meaningfully (Van Essen 1997).

Browsing capacity was determined during early spring, as the actual browsing capacity of an area is at its minimum prior to the spring rains, before the commencing of the new season's growth (Smit, pers. comm.<sup>7</sup>). Stocking rates should be based on figures calculated during this period, rather than on the abundance of mid-summer. The latter should be used for improving the condition of game and not for increasing game numbers (Trollope 1990; Bothma 1996a; Smit, pers. comm.<sup>8</sup>).

Previously recommended stocking rates for browsers in the Khai-Apple Nature Reserve were based on Large Stock Units (LSU's) (Van Hoven & Guldemond 1992), which is not desirable because a LSU provides, by definition, a measure of the stocking rate of grazers. As both the feeding patterns and the digestive systems of grazers and browsers differ remarkably, the LSU is of less value to browsers (Breebaart 1995).

If the current short-term browsing capacity of the Khai-Apple Nature Reserve (15.87 BU) is compared to the current stocking rate of browsers and mixed feeders (252.17 BU), it is clear that the reserve is grossly overstocked (Tables 6.1 & 6.2). Grazing capacity and the stocking rate of grazers fall outside the scope of this study and was therefore omitted.

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#### 6.4.3. THE INFLUENCE OF A HIGH BROWSE PRESSURE ON POST-FERTILISATION REGENERATION

It is clear from the results of the Khai-Apple Nature Reserve age structure surveys (Chapter 2) that over-stocking may already have a detrimental effect on the growth and survival of young *A. erioloba* trees. Trees from height classes three (2 m) and four (3 m) are relatively scarce (Figure 2.3), which might be an indication that the high browse pressure is preventing seedlings from reaching these heights. This can happen in one of the following ways:

- Young seedlings rarely recover from being browsed back to near ground level (Auld 1995). Death of seedlings may also be caused by trampling (García *et al.* 1999), complete uprooting (<http://www.fwprdc.org.au/projects/completed/p706/pn97604.htm>) and intense foliage removal when seedlings have not yet passed the stage where normal levels of herbivore feeding is likely to kill it (Crawley 1983).
- There exists a finely balanced and complex interrelationship between seed production, infestation of seeds by bruchid beetles, ingestion of seeds by mammals and germination. Alteration to any one component of this system could have a significant effect upon seed germination rates, and thus ultimately upon the continuity of woodlands (Pellew & Southgate 1984). There is currently an imbalance in the Khai-Apple Nature Reserve system because of the high browse pressure present; even unripe pods are stripped from trees at an alarming rate (also see Chapter 7). This eliminates the advantages of ungulate digestion on the germination, dispersal and bruchid infestation of seeds and may ultimately have a negative impact on the reproduction of *A. erioloba*.
- When plant growth is slow because of intense utilisation, seed production may be substantially reduced, resulting in insufficient seeds to fill the available microsites (Crawley 1983). According to Crawley (1983), such seed-limited recruitment is only likely in species that neither maintain a seedbank nor are supported by immigration of seed from other habitats. This description perfectly fits the *A. erioloba* population of the Khai-Apple Nature Reserve: an *A. erioloba* seed bank is absent from the area (Chapter 7) and ungulates are prevented from entering or leaving the area, thus limiting seed emigration and immigration. Recruitment of *A. erioloba* seedlings in the Khai-Apple Nature Reserve may therefore be seed-limited.



#### 6.4.4. THE INFLUENCE OF A HIGH BROWSE PRESSURE ON THE BEHAVIOUR OF *ACACIA ERIOLOBA* POLLINATORS

Table 6.3 gives an indication of the importance of various insect visitors in the pollination of *A. erioloba* by stating the proportion of observed visits made by each insect species (Tybirk 1993; Potgieter *et al.* 1999). It should be kept in mind that every insect visit to a flower does not necessarily imply pollination. Reasons for this include that the flower may be pollinated by another, less conspicuous pollinator (Faegri & Van der Pijl 1966); or that nectar or pollen may be removed illegitimately by nectar robbers. In the latter instance the flower visitor extracts nectar without contacting the reproductive parts of the flower and therefore does not pollinate it (Kearns & Inouye 1993). To ensure that a flower visitor is in actual fact a pollinator, pollen must be transferred from the visitor to the stigma and pollen must be transferred between flowers on a plant or among plants (Kearns & Inouye 1993). The latter observations fall outside the scope of the present investigation and were therefore omitted.

Ants (male; winged) most frequently visited *A. erioloba* in all locations, with visitation frequencies ranging from 63.64% (Knapdaar) to 100.00% (Khai-Apple Nature Reserve) (Table 6.3). Flies had a markedly lower visitation rate, varying from 9.09% to 12.50%, and were only observed in two of the five locations (Sishen Golf Course and Knapdaar). Honeybees also visited *A. erioloba* in two locations only (the Sishen Golf Course and Knapdaar), with both visitation frequencies below 10.00%. Only the flowers of Knapdaar were visited by beetles. The latter visitation frequency was relatively low at 18.18% (Table 6.3).

Ants (male; winged) had the highest average visitation time per flower in all locations, varying from  $35.00 \pm 7.07$  s (Khai-Apple Nature Reserve) to  $46.00 \pm 37.86$  s (Knapdaar) (Table 6.3). All other flower visitors spent notably less time per flower. Both bees and flies spent approximately 5 s per flower (an average of  $5.00 \pm 0.00$  s for bees at the Sishen Golf Course and  $5.33 \pm 1.53$  s at Knapdaar; and  $5.00 \pm 1.00$  s for flies at the Sishen Golf Course and  $4.33 \pm 2.52$  s at Knapdaar) (Table 6.3).

As was stated previously, pollinators visit plants damaged by herbivores for shorter periods of time compared to unbrowsed plants (Strauss *et al.* 1999). If the visitation times of the Sandveld Nature Reserve, with its correct stocking rates, are compared to that of the grossly overstocked Khai-Apple Nature Reserve, it is clear that there is no appreciable difference between that of the

Table 6.3. *Acacia erioloba* flower visitors, visitation frequencies and behaviour.

Location	Flower Visitors	Visitation Frequency (%)	Average Time Spent per Flower (s)	Average Number of Visits per Day
Sandveld Nature Reserve	Ant (male; winged)	100.00	36.67 ± 20.82	2.67 ± 1.53
Khai-Apple Nature Reserve	Ant (male; winged)	100.00	35.00 ± 7.07	1.5 ± 0.71
Sishen Golf Course	Ant (male; winged)	80.95	37.00 ± 20.42	5.67 ± 4.11
	Bee	9.52	5.00 ± 0.00	0.67 ± 1.16
	Fly	9.52	5.00 ± 1.00	1.00 ± 1.73
Knapdaar	Ant (male, winged)	63.64	46.67 ± 37.86	2.33 ± 2.31
	Bee	9.09	5.33 ± 1.53	0.33 ± 0.58
	Beetle	18.18	8.00 ± 5.66	0.67 ± 1.16
	Fly	9.09	4.33 ± 2.52	0.67 ± 0.58



former ( $36.67 \pm 20.82$  s) and the latter ( $35.00 \pm 7.07$  s) (Table 6.3). The high browse pressure present in the Khai-Apple Nature Reserve therefore does not seem to have a marked influence on the visitation times of flower visitors.

Ants (male; winged) also had the highest average number of flower visits per day in all locations (Table 6.3). The Sishen Golf Course had the highest visitation rate ( $5.67 \pm 4.11$  visits per day) of ants. The Sandveld Nature Reserve and Knapdaar had slightly lower visitation rates by ants at  $2.67 \pm 1.53$  and  $2.33 \pm 2.31$  visits per day, respectively. The Khai-Apple Nature Reserve had the lowest visitation rate by ants ( $1.5 \pm 0.71$  visits per day). All other insect visitation rates were comparatively low. Bees had an average visitation rate of  $0.67 \pm 1.16$  visits per day at the Sishen Golf Course and  $0.33 \pm 0.58$  at Knapdaar. Flies made an average of  $1.00 \pm 1.73$  visits per day at the Sishen Golf Course and  $0.67 \pm 0.58$  visits per day at Knapdaar. Beetles had an average daily visitation rate of  $0.67 \pm 1.16$  at Knapdaar. As was previously mentioned, pollinators visit plants damaged by herbivores less frequently compared to unbrowsed plants (Strauss *et al.* 1999). There is, however, no marked difference between the average daily number of visits in the correctly stocked Sandveld Nature Reserve ( $2.67 \pm 1.53$ ) and the grossly overstocked Khai-Apple Nature Reserve ( $1.50 \pm 0.71$ ) (Table 6.3). The presence of the high browse pressure in the latter does therefore not have a marked effect on the behaviour of the flower visitors of *A. erioloba*.

It should be kept in mind that environmental variables might have an influence on the number of visits per day. It can, e.g. be expected that less insect visits will take place on a windy day. In the present investigation, no definite pattern regarding environmental conditions and insect visitation frequency or behaviour could, however, be detected and average figures are therefore given in Table 6.4. It did, however, appear that visitation frequency declined on cold and windy days. Substantial variation in environmental variables occurred during the investigation period (Table 6.4).

Although Table 6.3 indicates that ants (male; winged), by having the highest average daily visitation rate and time spent per flower, are the main pollinators of *A. erioloba*, it should be kept in mind that even plants that exhibit characteristics of a one pollinator syndrome may rely on other organisms for an appreciable amount of its pollination (Waser 1978). This is especially true in plant species with a wide geographical range (Miller 1981). As was mentioned in Chapter 1, *A. erioloba* is widespread in Africa and occurs throughout most of the drier southern

Table 6.4. Average temperature, relative humidity, light intensity and wind speed during pollination trials.

Time	Temperature (°C)	Relative Humidity (%)	Light Intensity ( $\mu\text{E cm}^{-2} \text{s}^{-1}$ )	Wind Speed ( $\text{km h}^{-1}$ )
06:00	15.85 ± 5.38	50.21 ± 10.42	1071 ± 314.30	7.31 ± 3.45
08:00	19.80 ± 5.87	46.60 ± 18.88	2535 ± 81.79	8.78 ± 7.10
10:00	25.96 ± 5.70	32.05 ± 15.50	5290 ± 1207.80	7.82 ± 3.87
12:00	28.82 ± 5.65	28.36 ± 13.50	6750 ± 371.93	8.09 ± 3.21
14:00	30.82 ± 5.47	23.45 ± 8.88	5940 ± 1246.51	7.90 ± 3.57
16:00	31.15 ± 5.22	28.20 ± 9.78	4080 ± 1085.05	7.63 ± 4.21
18:00	29.37 ± 5.49	31.54 ± 7.46	2431 ± 1308.08	6.32 ± 5.41



African savannas, including Botswana; Mozambique; the southern parts of Angola; Namibia; South Africa; south-western Zambia; and Zimbabwe (Hoffman *et al.* 1989; Smit 1999; Van der Walt & Le Riche 1999) (Figure 6.2) and may therefore show great plasticity in pollinator species (Miller 1981).

Kearns and Inouye (1993) advised that the possibility of pollination and seed predation by the same insect species should be investigated in cases of substantial predispersal seed predation (see Chapter 9). No Bruchidae beetles were observed on *A. erioloba* flowers in any of the five locations, implying that this phenomenon is not present in *A. erioloba*.

Records of defoliation having a significantly negative effect on pollen grain size, pollen tube growth and rates of pollen tube attrition have been documented for hermaphroditic plants. Herbivory may also impair pollen performance by decreasing carbon provisioning during pollen development. Flowering and seed production is therefore determined, in part, by pollinator activity (Aizen & Raffaele 1998). Due to the practical difficulty of quantifying the allotment of pollinator success in seed production (Kearns & Inouye 1993), the latter was omitted from the present investigation.

#### 6.4.5. THE INFLUENCE OF BROWSERS ON THE DENSITY OF *ACACIA ERIOLOBA*

The data in Table 6.5 indicates that Lylyveld-Demaneng has the highest *A. erioloba* density of all sites, at 200 trees ha<sup>-1</sup>. This may seem contradictory, considering the history of land-use of these areas (Chapter 1), but can be explained as follows:

- Both Lylyveld and Demaneng have a history of cattle farming and therefore contain numerous *A. erioloba* "clumps" where water troughs, feeding cribs (where animals are fed with *A. erioloba* pods) and salt licks have been placed in the past. Large numbers of animals gather in these areas for extended periods of time, resulting in high concentrations of cattle dung in a relatively small surface area. This, in turn, results in clumps of young trees growing together in close proximity (Van der Walt & Le Riche 1999). A transect passing through one or more tree clumps will inevitably lead to an over-estimation of the tree density of an area.
- The distribution of *A. erioloba* is determined by the presence of deep Kalahari sands (Smit 1999; Van der Walt & Le Riche 1999). It furthermore often occurs in alluvial soils along

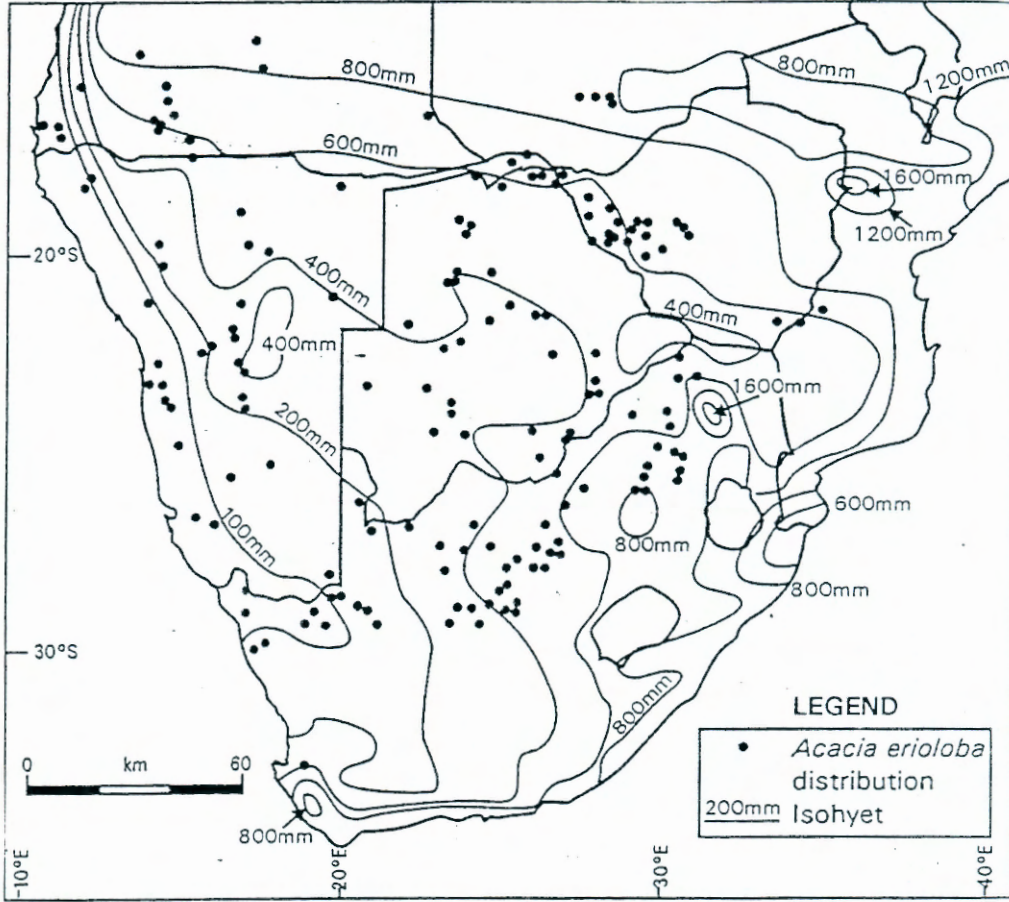


Figure 6.2. Distribution of *Acacia erioloba* in Africa (adopted from Steenkamp (2000)).



Table 6.5. Tree density and leaf mass of *Acacia erioloba*, indicating differences in above ground biomass.

Location	Density (plants ha <sup>-1</sup> )	Leaf Mass (kg dry mass ha <sup>-1</sup> )
Demaneng – Lylyveld	200	226
Sandveld Nature Reserve	186	182
Sishen Golf Course	175	371
Knapdaar	130	263
Khai-Apple Nature Reserve	125	318

- watercourses in arid areas (Van Wyk & Van Wyk 1997; Smit 1999). Part of the bed of the Gamagara River wanders through Lylyveld-Demaneng and transects passing through the riverbed may therefore be responsible for an over-estimation of the *A. erioloba* density of the area.
- The absence of sizeable herds of large ungulates from these areas may also be a contributing factor to its high *A. erioloba* density, as the establishment of seedlings takes place relatively fast in the absence of browsers (Hoffman *et al.* 1989; McInnes *et al.* 1992; Van der Walt & Le Riche 1999). Small numbers of blesbok, gemsbok and springbok are present in these areas (Van Rensburg, pers. comm.<sup>8</sup>), but are prevented from roaming the entire area by camp fences. Certain areas are therefore protected from browse pressure for extended periods of time, giving seedlings a chance to establish.

Of the sites surveyed, the Sandveld Nature Reserve has the second highest *A. erioloba* density at 186 trees ha<sup>-1</sup> (Table 6.5). This relatively high *A. erioloba* density can be attributed to one or a combination of any of the the following factors: the presence of deep sands and the presence of *A. erioloba* clumps (which, if included in a survey might give an over-estimation of density).

The Sishen Golf Course has a relatively high *A. erioloba* density of 175 trees ha<sup>-1</sup> (Table 6.5). This can be attributed to one (or a combination of) the following reasons:

- Large ungulates are prevented from entering the area, therefore giving seedlings a chance to establish.
- Survey plots were situated in the rough. These relatively untouched areas coincide with naturally denser areas, while the areas with a naturally spaced-out tree distribution were cleared for construction of the fairway. The surveys could therefore give an over-estimation of the tree density of the area.

Knapdaar had a relatively low *A. erioloba* density (130 trees ha<sup>-1</sup> – Table 6.5). This may seem contradictory, if the presence of deep Kalahari sands, the absence of sizeable herds of large ungulates and the presence of tree clumps, caused by previous placement of feeding cribs, drinking troughs and salt licks, are taken into account. After careful analysis of previous management practices, the following reason for a low *A. erioloba* density was, however, discovered: Previous owners used non-specific chemical substances for eradicating *A. mellifera*

<sup>8</sup> Dihan van Rensburg. Owner: Demaneng. ☒: P.O. Box 678, Kathu, 8446.



(Engelbrecht, pers. comm.<sup>9</sup>). These substances caused large-scale *A. erioloba* deaths (also see Chapter 8).

The Khai-Apple Nature Reserve, being the area with the largest closed canopy *A. erioloba* forest in the world, ironically had the lowest measured tree density at 125 trees ha<sup>-1</sup> (Table 6.5). If it is taken into consideration that this area is situated on deep Kalahari sands; it contains tree clumps since it was previously a cattle farm; and that no non-specific poisons have ever been used in the centre of the Kathu Forest, it is logical to assume that a correlation exists between the low *A. erioloba* density of the area and its high stocking rates.

In light of the discussion above, this study confirms the statement of McInnes *et al.* (1992), namely that browsing decreases the mean density of trees.

#### 6.4.6. THE INFLUENCE OF BROWSERS ON THE ABOVE-GROUND BIOMASS OF ACACIA ERIOLOBA

The data in Table 6.5 gives an estimate of above-ground biomass based on dry leaf mass only, as BECVOL provides an estimate of the leaf mass of individual trees, excluding branches and twigs (Smit 1996). This method was chosen for use despite this shortcoming, because of its non-destructive nature (Von Holdt 1999).

A correlation between tree height, tree density and leaf mass was clear throughout. The Sishen Golf Course had the highest calculated leaf mass at 371 kg ha<sup>-1</sup> (Table 6.5). This is, however, also the site with the highest occurrence of trees in height class six (5+ m) (Figure 2.3). The Khai-Apple Nature Reserve has a relatively high occurrence of trees in height classes five (4 - 5 m) and six (5 m+), coinciding with a relatively high leaf mass of 318 kg ha<sup>-1</sup>. This is despite a relatively low tree density (125 trees ha<sup>-1</sup>), indicating that tree density has a less profound impact on leaf mass than tree height. Knapdaar had a leaf mass of 263 kg ha<sup>-1</sup> (Table 6.5). This coincided with a large fraction of the population falling in height classes four (3 m), five (4 - 5 m) and six (5+ m), but a relatively low tree density of 130 trees ha<sup>-1</sup> (Figure 2.3). Lylyveld had a leaf mass of 226 kg ha<sup>-1</sup>, with a high fraction of the population falling in height class five (4 - 5 m) (Figure 2.3) and a relatively high tree density of 200 trees ha<sup>-1</sup>. Sandveld had the lowest leaf

<sup>9</sup> Mrs. Marlene Engelbrecht. Owner: Knapdaar and Swarthaak. ☎: 0537910527.

mass of all sites ( $182 \text{ kg ha}^{-1}$ ), despite a relatively high tree density (Table 6.5). This can be attributed to the small fraction of the population higher than 4 m (Figure 2.3).

No relationship could be found between browse pressure and leaf mass. The Sandveld Nature Reserve has a low mean leaf mass ( $182 \text{ kg ha}^{-1}$ ), while the grossly overstocked Khai-Apple Nature Reserve has a relatively high leaf mass at  $318 \text{ kg ha}^{-1}$  (Table 6.5). This phenomenon can be ascribed to the differences in structure of the investigated areas.

## 6.5. CONCLUSIONS

By comparing the current stocking rate of browsers and mixed feeders of the Khai-Apple Nature Reserve with its current short term browsing capacity, it was determined that the reserve is currently grossly over-stocked. The high browse pressure appeared not to have a marked influence on the behaviour of *A. erioloba* pollinators or the above-ground biomass of *A. erioloba* trees. It was, however, found that the density of *A. erioloba* is decreased by the high browse pressure.



**CHAPTER 7**

**THE INFLUENCE OF POD REMOVAL ON THE SOIL  
SEED BANK OF *ACACIA ERIOLOBA***

## 7.1. INTRODUCTION

Viable but dormant *Acacia* seeds accumulate in the upper soil layers in the vicinity of pod-bearing trees, which seems to act as a general survival strategy (Sabiiti & Wein 1987). These seeds seem well adapted to a strategy of seed dispersal over time: it has hard seed coats, and it is both long-lived and dormant upon pod-bearing (Coe & Coe 1987).

A persistent seed bank has the following advantages:

- It can be drawn upon over long periods of time and is likely to contribute to the future of a species in case of changes in safe site abundance or environmental conditions (Templeton & Levin 1979; Keddy & Reznicek 1982; Fenner 1985; Graham & Hutchings 1988; Andersen 1989; Diemont 1990; Hulme 1998).
- Seed banks have important genetic implications for individual species. Dormant seeds are laid down by many generations over many decades, forming an 'evolutionary memory'. Disturbances may bring a mixture of these seeds to the surface, resulting in a progeny of parents that existed at different times, under completely different circumstances. The crossing of this generation could have an important buffering effect against genetic changes (Raven *et al.* 1999).
- Changes in management can have dramatic effects on vegetation. The impact of such changes may, however, be buffered by the resilience of a soil seed bank (Akinola *et al.* 1998; Meissner & Facelli 1999).

The decline of a seed bank usually occurs with an increase in the intensity of disturbance, a decrease in seed production, the loss of viability of buried seeds, limited longevity and predation pressure (Thompson 1978). The seed bank of African *Acacia* species is influenced mainly by annual seed production, dispersal, seed predation and germination (Tybirk *et al.* 1992). Soil seed bank dynamics are important in the consideration of the degradation and resilience of African savannas (Tybirk *et al.* 1992).

There is often a marked fluctuation in the annual seed production of polycarpic plant populations (Herrera *et al.* 1998). Mast seeding can be defined as "*the periodic synchronous production of large seed crops*" (Nilsson & Wästljung 1987). Plant species whose seeds are subject to both vertebrate and insect predation and are dispersed only by vertebrates often adjust seed



production over evolutionary time so as to reduce seed loss to predators and satiate dispersal agents (Nilsson 1985).

## 7.2. OBJECTIVE

The aim of this investigation was:

- To determine the size of the *A. erioloba* seed bank at different study sites.

## 7.3. METHODOLOGY

### 7.3.1. THE SIZE OF THE ACACIA ERIOLOBA SEED BANK OF THE DIFFERENT STUDY SITES

Different methods can be used to estimate the composition of a seed bank, namely seed separation methods and seedling emergence methods (Fay & Olson 1978; Roberts 1981; Brown 1992). Seed separation methods, like chemical flotation (Malone 1967; Meissner & Facelli 1999), sifting (Roberts 1981; Miller 1994b) and airflow separation utilise differences in size or density to separate seeds from the soil. This is followed by the manual sorting of seeds (Brown 1992; Ter Heerd *et al.* 1996; Meissner & Facelli 1999). Emergence methods, on the other hand, are based on the identification and enumeration of seedlings that emerged from soils incubated either in a greenhouse or *in situ* (Malone 1967; Grice & Westoby 1987; Brown 1992; Hegazy 1996; Ter Heerd *et al.* 1996; Bekker *et al.* 1999).

Despite a tendency to over-estimate seed banks because of the detection of all readily germinable, dormant and nonviable seeds (Brown 1992), and its labour intensity (Meissner & Facelli 1999), the seed separation method was chosen for use in the present study. Reasons include effectiveness in finding large-seeded species (Malone 1967; Fay & Olson 1978; Brown 1992; Ter Heerd *et al.* 1996), such as *A. erioloba*; effectiveness in detecting the presence of tree species (Olmsted & Curtis 1947; Kramer & Johnson 1987); economy in terms of time and space; its suitability for use in single species population studies; as well as for seeds, like that of *A. erioloba*, in a state of natural dormancy (Hoffman *et al.* 1989; Brown 1992; Meissner & Facelli 1999).

Three locations for the sampling of 1 m x 1 m x 0.25 m soil profiles were randomly chosen at each of the identified study and control sites. Soil profiles were dug in the vicinity of mature *A. erioloba* trees (Tybirk *et al.* 1992). The soil from each profile was meticulously sifted (Tybirk *et al.* 1992), whereafter it was hand sorted in search of *A. erioloba* seeds.

## 7.4. RESULTS AND DISCUSSION

### 7.4.1. THE SIZE OF THE ACACIA *ERIOLOBA* SEED BANK AT DIFFERENT STUDY SITES

No seeds were recovered from any of the soil samples in any of the locations (Table 7.1). Even though *A. erioloba* cannot be classified as small-seeded, these results are in stark contrast to the 125-250 million seeds ha<sup>-1</sup> found in the top 10 cm of soil by Sabiiti and Wein (1987) for small seeded *Acacia* species in South Africa.

It is unlikely that the absence of seeds from the soil samples was a result of inadequate profile size. The profiles used were ten times deeper than those dug by Meissner and Facelli (1999) (depth: 2 cm) and five times deeper than those dug by Tybirk *et al.* (1992) (depth: 3-5 cm). According to Meissner and Facelli (1999), a sample strategy of 10 cm x 10 cm x 2 cm retrieved 85.00% of species in the soil bank and therefore the profile size used in this study would have been adequate for the retrieval of *A. erioloba* seeds.

The low numbers of seeds occurring in the soil seed banks of plant species, like *A. erioloba*, dispersed by ungulates, may be the result of high utilization pressure (Tybirk *et al.* 1992). It is clear from the data in Chapter 6 that the Khai-Apple Nature Reserve is currently grossly overstocked with both browsers and mixed feeders. It is therefore highly probable that this high utilization pressure is one of the main causes of the absence of a soil seed bank of *A. erioloba* in this specific area.

To test the latter assumption, four flower-bearing branches in the Khai-Apple Nature Reserve, all approximately 2 m above the ground, were marked and pod formation monitored over a six week period. Branches at this specific height were monitored because plant material above this height, which represents the mean browsing height of kudu (Wentzel 1990), is out of reach for most wild ungulates. No pods from the marked branches survived to full ripeness (Table 7.2),



Table 7.1. The size of the *Acacia erioloba* seedbank of different study sites.

Location	Seeds ha <sup>-1</sup>
Khai-Apple Nature Reserve	0
Knapdaar-Swarthaak	0
Demaneng-Lylyveld	0
Sishen Golf Course	0
Sandveld Nature Reserve	0

Table 7.2. Number of *Acacia erioloba* pods reaching ripeness in selected locations (A - D) in the Khai-Apple Nature Reserve.

Weeks After Pollination	Number of Pods per 30 cm Portion of Branch			
	A	B	C	D
1	4	5	3	1
2	0	7	3	1
3	0	7	3	0
4	0	5	4	0
5	0	5	2	0
6	0	5	2	0
7	0	3	0	0
8	0	2	0	0
9	0	0	0	0



confirming the assumption stated earlier, namely that the high browsing pressure in this area inhibits the formation of an *A. erioloba* seed bank. Pods of a similar age than those under investigation were collected from closeby sites throughout. These pods were opened and revealed that seeds were not yet ripe at 6 weeks. It is therefore clear that ungulates consume unripe pods, and, in so doing, destroy unripe seeds, as it do not yet posses a hard seed coat. These seeds can therefore make no valuable contribution to the seed bank.

Due to practical constraints, the Sandveld Nature Reserve control site could not be visited once a week for the entire six-week observation period and were visited only intermittently. A situation similar to that encountered in the Khai-Apple Nature Reserve was encountered in the Sandveld Nature Reserve. No marked pods survived to ripeness, indicating the role of ungulates in preventing *A. erioloba* seeds from making a valuable contribution to the seed bank (Table 7.3).

It should be added that trails were conducted in a year of sub-optimal pod production for the *A. erioloba* trees of both the Khai-Apple Nature Reserve and the Sandveld Nature Reserve. It is highly possible that more pods would have survived to ripeness in a year of high pod production.

The absence of an *A. erioloba* seed bank in the Sishen Golf Course, Knapdaar-Swarthaak and Lylyveld-Demaneng areas (Table 7.1) cannot be ascribed to high mammalian utilisation, as none of these areas support large herds of ungulates. Possible explanations of the absence of *A. erioloba* seed banks in these three areas are given in the paragraphs that follow.

A contractor from Thabazimbi collects pods from the Sishen Golf Course premises to be sold as cattle fodder. As much as 60 tons of pods are collected in years of optimal pod production (Bosch, pers. comm.<sup>1</sup>). Pod collection, combined with low pod production in some years, could be responsible for the absence of *A. erioloba* from the seed bank of this area. Pod production varies from year to year (Van der Walt & Le Riche 1999), but it is not clear from the literature whether climatic or evolutionary factors (masting) are responsible for this phenomenon. This aspect falls outside the scope of the present study, but necessitates further investigation.

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<sup>1</sup> Gert Bosch. Environmental manager: Sishen Iscor Iron Ore Mine. ☎ : 083 461 5734.

Table 7.3. Number of *Acacia erioloba* pods reaching ripeness in selected locations (A - D) in the Sandveld Nature Reserve control site.

Weeks After Pollination	Number of Pods per 30 cm Portion of Branch			
	A	B	C	D
1	1	4	3	8
7	0	0	0	0



Sub-optimal pod development in the down-wind Lylyveld-Demaneng area could be responsible for the absence of *A. erioloba* in the seed bank in this area. Based on visual inspection, it was found that pods from Lylyveld-Demaneng appeared smaller and generally less healthy than that of other areas. In order to verify this, the development of pods of subjectively chosen branches, approximately 3 m from the ground, were monitored weekly over a 3 month period and compared to the development of pods from the Knapdaar-Swarthaak area. Pods from the control area could not be used in this comparison, as practical constraints prevented this site from being visited weekly. The *A. erioloba* pods of Lylyveld-Demaneng exhibited a slower growth rate in terms of pod length than that of Knapdaar-Swarthaak. The latter reached its maximum pod length, which was higher than that of Lylyveld-Demaneng, sooner (Table 7.4). Visual inspection furthermore confirmed that pods from the Lylyveld-Demaneng were generally in a worse condition than that of Knapdaar-Swarthaak: Pods from the former area were thin, short and covered in mine dust. Pod weight could not be used as a second parameter of pod development, as exceptionally low pod production in the Lylyveld-Demaneng area over the investigation period prevented the removal and weighing of pods on a weekly basis. The cause of the retarded growth of *A. erioloba* pods of the Lylyveld-Demaneng area is unknown and falls outside the parameter of the present investigation. Pod development in Lylyveld-Demaneng is, however, sub-optimal and could be a contributing factor to the absence of *A. erioloba* from the seed bank of this area.

The absence of *A. erioloba* seeds from Knapdaar-Swarthaak could possibly be ascribed to pod removal, as pods are collected and used as fodder in times of food scarcity (Table 7.4).

## 7.5. CONCLUSIONS

Through seed separation it was determined in the present investigation that *A. erioloba* is absent from the seed bank of the Kathu area (Table 7.1). This can be ascribed to various factors, including the presence of a high browse pressure in the Khai-Apple and Sandveld Nature Reserves, pod collection on the Sishen Golf Course premises and sub-optimal pod development in Lylyveld-Demaneng.

Table 7.4. *Acacia erioloba* pod development in Lylyveld-Demaneng and Knapdaar-Swarthaak.

Weeks After Pollination	Mean Pod Size (cm)	
	Lylyveld-Demaneng	Knapdaar-Swarthaak
1	1.75 ± 0.50	1.61 ± 0.56
2	1.95 ± 0.50	2.12 ± 0.94
3	1.95 ± 0.50	2.20 ± 0.83
4	3.00 ± 0.71	2.92 ± 0.66
5	3.00 ± 0.71	3.51 ± 1.12
6	3.20 ± 0.84	4.61 ± 1.39
7	3.80 ± 1.10	5.89 ± 1.44
8	4.20 ± 1.10	6.21 ± 1.29
9	6.10 ± 0.71	8.24 ± 1.56
10	8.00 ± 2.07	8.58 ± 1.44
11	8.00 ± 2.07	8.69 ± 1.56



The absence of an *A. erioloba* seed bank can be catastrophic in terms of the long-term survival of *A. erioloba*. Counteracting suggestions are given in Chapter 11, which deals with management recommendations.

**CHAPTER 8**

**THE INFLUENCE OF THE UNINFORMED USE  
OF CHEMICALS ON THE POPULATION STRUCTURE  
OF *ACACIA ERIOLOBA***



## 8.1. INTRODUCTION

Anonymous questionnaires brought to light that a relatively large percentage of Kathu residents are eager to remove *A. erioloba* trees from their gardens (Chapter 3). Numerous reasons were provided, including that fallen pods decompose on roofs, causing an unpleasant odor; kids and pets step in thorns, causing pain and discomfort; and thorns puncture car tires. The survey furthermore indicated that the law protecting *A. erioloba* (Appendix A) does not prevent residents from attempting to kill the Camel Thorn trees on their properties. Various methods are applied, including drilling holes in the stems of mature trees and filling it with diesel, petrol and/or paraffin; or simply chopping down unwanted trees.

The survey also brought to light that the divisional council of Kuruman applied hazardous chemicals at the side of the Kuruman-Kathu highway approximately 25 years ago, causing the death of a number of *A. erioloba* trees. This could, however, not be confirmed.

The bushveld areas of South Africa are subject to invasion by *A. mellifera* (Van Rooyen *et al.* 1996), as is evident in the study area. Incorrect grazing practices, e.g. over-utilisation, decreases both the vigour and the water utilisation abilities of graminoids close to the soil surface and in this manner increases the competitive ability of woody species like *A. mellifera* (Barnes 1982; Van Rooyen *et al.* 1996). Bush encroachment causes a decrease in the grass cover and the grass production per hectare, thus also decreasing grazing capacity (Barnes 1982; Van Rooyen *et al.* 1996). Bush encroachment furthermore limits the area grazed by livestock by inhibiting the free movement of grazers (Okello & Young 2000). The thinning of encroachers will therefore generally cause an increase in the production of the herbaceous layer (mainly grasses) (Barnes 1982) and thus be advantageous in the study area in terms of both game and livestock farming. Various methods are incorporated in the eradication of *A. mellifera*, including labourous mechanical removal and the use of chemicals, e.g. Molopo® 20 GG. Unfortunately, many of the chemicals used are non-specific, killing other plants (including *A. erioloba*) along with the problematic *A. mellifera*.

## 8.2. OBJECTIVE

The aim of this investigation was:

- To determine the influence (if any) of the uninformed use of chemicals on the population structure of *A. erioloba*.

## 8.3. METHODOLOGY

Enquiries about the use of (especially non-specific) poisons for the eradication of *A. mellifera* were made in the Kathu region. One site (Knapdaar) where non-specific chemicals were previously used to combat bush encroachment was identified. The *A. erioloba* population structure of this site was determined with the aid of the Variable Quadrat method of Coetzee and Gertenbach (1977) (discussed in detail in Chapter 2) and compared to that of the control site to identify irregularities that were potentially caused by the uninformed use of chemicals.

## 8.4. RESULTS AND DISCUSSION

Due to the wish of most farmers to remain anonymous, only one farm was identified where non-specific chemicals have been previously used in combatting bush encroachment. Non-specific chemicals were used in combatting *A. mellifera* encroachment on Knapdaar under previous ownership (Engelbrecht, pers. comm.<sup>1</sup>).

The effect of the use of non-specific poisons on the population structure of *A. erioloba* is clear from Figure 2.3 (Knapdaar) as an irregularity in height class 3. Instead of showing an increase in the fraction of the population representing this height class, as is the case in the control area, a decrease in tree numbers is evident (Figure 2.3).

The death structure of Knapdaar clearly indicates that it is the young *A. erioloba* individuals (height classes 1, 2 and 3) that are killed by non-specific poisons (Figure 2.4). Only a small fraction of young *A. erioloba* individuals therefore survive poisoning to reach mature height classes. It is clear that the uninformed use of chemicals can cause irregularities in the *A.*



*erioloba* age structure, which can, in the long run, impede optimal regeneration and the survival of the species in the long run.

Recommendations on the safe application of chemicals for the purpose of bush eradication are given in Chapter 11, which deals with management recommendations.

## 8.5. CONCLUSIONS

It was concluded from the results of this investigation that the uninformed use of chemical substances in the vicinity of *A. erioloba* can have a decreasing effect on its population size.

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<sup>1</sup> Mrs. Marlene Engelbrecht. Owner: Knapdaar. ☎: 0537910527.

**CHAPTER 9**

**THE INFLUENCE OF BRUCHIDAE SEED  
PREDATION ON THE GERMINATION POTENTIAL  
OF *ACACIA ERIOLOBA* SEEDS**



## 9.1. INTRODUCTION

### 9.1.1. GENERAL

Both the intensity and pattern of seed predation may have a variety of effects on the population biology and dynamics of host plants by influencing regeneration (Ross 1965; Janzen 1970; Harper 1977; Crawley 1989; Ernst *et al.* 1990b). In most cases the impact of insects on plant seeds is purely destructive (Nilsson & Wästljung 1987). In *Acacia* species, specifically, insect damage is one of the major factors that negatively influences seed germination (Ross 1965; Ernst *et al.* 1990a; Mucunguzi 1995).

Bruchidae beetles attack the seeds of a wide variety of flowering plants (Howe & Currie 1964; Janzen 1969; Taylor 1981; Van Tonder 1981), including members of the Convolvulaceae, Compositae, Malvaceae, Anacardiaceae and Leguminosae (Cushman 1911; Howe & Currie 1964; Arora *et al.* 1969). Bruchid predation is mostly host-specific (Skaife 1926; Peake 1953; Howe & Currie 1964; Center & Johnson 1974; Halevy 1974; Lamprey *et al.* 1974; Johnson 1981b; Pellew & Southgate 1984; Auld 1986; Sabiiti & Wein 1987; Ernst *et al.* 1989). Members of the Leguminosae predated by bruchids include various African *Acacia* spp. (Halevy 1974; Lamprey *et al.* 1974; Southgate 1978, 1979 & 1983b; Pellew & Southgate 1984; Coe & Coe 1987; Ernst *et al.* 1989, 1990a & 1990b; Tybirk *et al.* 1992; Abdullah & Abulfatih 1995), e.g. *A. erioloba* (Van Tonder 1985; Hoffman *et al.* 1989; Van der Walt & Le Riche 1999). The seeds of the Leguminosae are attractive to bruchids due to their high nutritious value and nitrogen content (Halevy 1974; Southgate 1979; Johnson 1981b).

### 9.1.2. BRUCHIDAE

The Bruchidae is a cosmopolitan family comprising nearly 1 400 described species of chrysomeloid beetles (Taylor 1981; Van Tonder 1981), consisting of 56 genera, of which only 10 (at least seven, according to Taylor (1981)) occur in the Old World (Southgate 1983b; Van Tonder 1985). This comparatively small family of beetles forms one of the most natural groups of the order Coleoptera (Skaife 1926).

Bruchids are generally small in size (Skaife 1926; Van Tonder 1981; Southgate 1983b), with compact, robust bodies that are ovoid in shape (Peake 1953; Van Tonder 1981; Southgate

1983b). A complete anatomical description of bruchid beetles in general was given by Van Tonder (1981).

*Bruchidius senegalensis* (Genus *Bruchidius* Schilsky) and *Caryedon multinotatus* (Genus *Caryedon* Schönherr) are dominant *A. erioloba* seed predators (Van Tonder 1981, 1985; Hoffman *et al.* 1989; Ernst *et al.* 1990b). Other bruchid seed predators of *A. erioloba* include *Bruchidius uberatus* (Ernst *et al.* 1990a), *Pygobruchidius acaciae* (Van Tonder 1981) and *Pygobruchidius cavithorax* (Van Tonder 1981).

Bruchid eggs are generally oviposited in and/or on developing pods (Howe & Currie 1964; Wilson & Janzen 1972; Van Tonder 1981, 1985; Miller 1994a; Mucunguzi 1995) and are, in most cases, protected by a white, ovoid shield. The latter shield is firmly fastened to the pod or seed surface by means of a gummy substance extruded prior to oviposition (Skaife 1926; Southgate 1983c). Upon emergence from the egg, the larva enters the seed either directly, or through the pod wall, at the same time discarding the tannin-laden raspings from the testa wall (Southgate 1983c).

The larva excavates a cell in the seed (Skaife 1926; Southgate 1983b; Miller 1994a), in which it consumes parts of the endosperm and embryo (Skaife 1926; Wilson & Janzen 1972; Lamprey *et al.* 1974; Southgate 1983b; Miller 1994a). Bruchidae larvae generally consume 9 - 100% of seed cotyledons (Miller 1994a). Being hard-seeded, it was hypothesised before, as it is in the present investigation, that this mechanical scarifying of the *A. erioloba* testa would stimulate germination by facilitating imbibition (Lamprey *et al.* 1974; Louda 1982; Hoffman *et al.* 1989; Sabiiti *et al.* 1991; Miller 1994a; Mucunguzi 1995; Van der Walt & Le Riche 1999). (The larva of *C. multinotatus*, which is commonly found on *A. erioloba*, differs from bruchids in general in that it pupates in a cell in the soil or among fallen leaf litter, and not in a seed (Van Tonder 1981)).

Upon eclosion, the adult bruchid beetle chews a circular disk (the emergence cap) out of the seed coat, pushes it upward and crawls out of the seed (Peake 1953; Ross 1965; Ernst *et al.* 1989). The life-span of adult bruchids after emergence from field-collected pods varies between 22 and 57 days (Ernst *et al.* 1990b).

A number of factors limit bruchid population growth. These include temperature, desiccation, predation, plant phenology and migration, disease, hardness of the endocarp, intense



cannibalism and deficient amounts of food (Janzen 1971a; Mitchell 1977; Janzen 1985; Traveset 1991). Such losses are compensated for by the fact that the adults of some species of bruchids can complete more than one generation during a single fruiting season (Southgate 1981; Abdullah & Abulfatih 1995). In the presence of high animal populations, where seeds are not left below the trees for long periods as they are eaten rapidly, the possibility of more than one bruchid generation developing in a single season, is, however, remote (Southgate 1980).

Insect infestation generally reduces the attractiveness of fruits and seeds to dispersers (Manzur & Courtney 1984; Courtney & Manzur 1985). Bruchid-damaged seeds are, however, not completely avoided by ungulates (Miller 1994a). It has previously been suggested that the stomach acids of animals decrease Bruchidae infestation (Halevy 1974; Lamprey *et al.* 1974; Pellew & Southgate 1984; Coe & Coe 1987; Miller 1994a; Leistner 1996) by killing bruchids that are at an early stage of their development (Halevy 1974; Lamprey *et al.* 1974; Coe & Coe 1987). Passage through the gut may furthermore remove the olfactory cues needed by the beetles for seed location (Coe & Coe 1987). In areas where seeds are preferentially defecated under trees, re-infestation by bruchids may, however, take place in the feces of ungulates, thus eliminating the benefit gained by seed scarification during digestion (Rohner & Ward 1999).

A complex and finely balanced inter-relationship has evolved between seed production, bruchid infestation, browser ingestion and germination. Alteration to any one of these components could have a significant effect upon seed germination rates, and therefore on the continuity of a woodland (Pellew & Southgate 1984).

## 9.2. OBJECTIVES

The aims of this investigation were:

- To determine the levels of Bruchidae infestation of *A. erioloba* seeds.
- To determine the influence of bruchid beetle predation on the germination capacity of *A. erioloba* seeds.
- To review literature on the possible influence of bruchid seed predation on the population dynamics of *A. erioloba*.

### 9.3. METHODOLOGY

#### 9.3.1. THE EXTENT OF INSECT PREDATION OF *ACACIA ERIOLOBA* SEEDS

Insect infestation rates can be determined by any one of the following methods: X-ray photographic scanning (Milner *et al.* 1950; Pellew & Southgate 1984), flotation (Janzen 1971b), differential staining of crushed dead seed (Boyce 1934), rearing (Keiser 1959) and visual inspection (Halevy 1974; Coe & Coe 1987; Nilsson & Wästljung 1987; Sabiiti & Wein 1988; Ernst *et al.* 1989; Mucunguzi 1995; Rohner & Ward 1999).

Visual inspection was used for determining bruchid infestation rates in the present study because of the simplicity and practicality of this method. Pods were collected from the ground after an unknown lying period. Seeds were mechanically removed from the pods, whereafter randomly selected seeds were, after a brief storage period, inspected for characteristic exit holes in the testa or in-the-hole arrested beetles, as suggested by Coe and Coe (1987), Sabiiti and Wein (1988), Ernst *et al.* (1990a) and Mucunguzi (1995).

Mean seed mass was determined with the aid of a Mettler AJ100 scale.

#### 9.3.2. THE INFLUENCE OF INSECT PREDATION ON THE GERMINATION CAPACITY OF *ACACIA ERIOLOBA* SEEDS

Sterilised, predated seeds were incubated at previously determined optimal germination conditions (30°C, dark, 15 ml of distilled water). For a detailed description of the optimum germination conditions, see Chapter 2. The control treatment consisted of scarified non-predated seeds incubated in identical conditions.

Percentage germination was calculated from the total number of seeds that germinated out of those incubated from the start, as was done by Mucunguzi (1995), at predetermined incubation times. A seed was classified as germinated when part of the embryo (radicle) protruded through the testa.

Unless otherwise stated, all germination studies were carried out at least in triplicate.



## 9.4. RESULTS AND DISCUSSION

### 9.4.1. THE EXTENT OF INSECT PREDATION OF *ACACIA ERIOLOBA* SEEDS

Thirty-five percent of the seeds collected from the Kathu area showed visual signs of bruchid predation, while seeds from the control area had a higher predation level at 46.00% (Table 9.1). A higher predation level coincided with smaller mean seed mass ( $0.2654 \pm 0.019$  for the Sandveld Nature Reserve compared to  $0.3448 \pm 0.036$  obtained for the Kathu area), as greater predation levels imply the removal of more of the seed contents (Table 9.1).

These results compared well to the 28.90% predation rate found for *A. erioloba* pods collected from the ground by Coe and Coe (1987) (Table 9.1). Considerably higher infestation rates (up to 99.00%) were, however, recorded for different *Acacia* spp. elsewhere in Africa (Lamprey *et al.* 1974; Southgate 1979; Miller 1994a; Miller & Coe 1993). Many of these high predation levels were obtained from counts made on seeds that had been stored for extended periods, when the emerging beetles were able to pass through many generations in the presence of such a super-abundant food source (Coe & Coe 1987). This explains the comparatively low predation rates obtained in the present study: inspection was carried out shortly after pod collection, thus eliminating a long storage period and the consequences thereof.

Infestation rates lower than the above mentioned are more common (Miller 1994a). Inspection of fresh seeds, i.e. seeds that have not undergone a storage period, demonstrate relatively low predation figures, e.g. 21.40% for *A. caffra* in South Africa (Janzen 1970); 5.10 – 8.40% for *A. tortilis* subsp. *spirocarpa* in Tanzania (Pellew & Southgate 1984) and between 4.10 and 7.60% for a number of *Acacia* spp. in Zimbabwe, South Africa and Kenya (Coe & Coe 1987).

Ernst *et al.* (1989) cautions that Bruchidae infestation may vary strongly between years and between trees. It is therefore risky to attribute the higher bruchid predation levels of the control area to any factor associated with the mining activities in the study area. These higher predation levels could indicate:

- Lower levels of insect activity in the study area due to the presence of mine dust.
- Variation in predation levels between trees (Ernst *et al.* 1989).

Table 9.1. *Extent of Bruchidae infestation of Acacia erioloba seeds.*

Area	% Predation	Average Mass (g)
Kathu area	35	0.3448 ± 0.036
Sandveld Nature Reserve	46	0.2645 ± 0.019



- A compensatory response to high stocking rates in the case of the study area. Pellew and Southgate (1984) stated that a reduction in seed parasitism as seed production declines could be regarded as a compensatory response by the ecosystem to prevent the elimination of a specific woodland. This may well be the case in the Khai-Apple Nature Reserve. High stocking rates negatively affect seedling establishment and therefore pod production in the long run (see Chapter 6). Lower Bruchidae infestation rates in the latter location may be a compensatory response by the system to prevent the elimination of the *A. erioloba* woodland.
- That seeds from the control area have been lying on the ground for longer. The longer pods lie on the ground, the greater the insect predation levels (Hoffman *et al.* 1989). This phenomenon can be attributed to the following two factors: (1) these seeds are older and more weathered, and (2) larvae have the chance to undergo a longer period of development inside seeds (Hoffman *et al.* 1989). It is interesting to note that Johnson (1981a) stated the opposite: seeds from indehiscent pods (such as that of *A. erioloba*) are fed upon more heavily when they are in pods on the plant.
- Differences in the *A. erioloba* tree densities of the two areas. Nilsson and Wästljung (1987) found that insect seed predation decreases with a decrease in both tree size and density. Opposed to this, Ernst *et al.* (1990b) stated that bruchid infestation was significantly lower in areas with high tree densities than in areas with medium tree densities.

#### 9.4.2. THE INFLUENCE OF INSECT PREDATION ON THE GERMINATION CAPACITY OF *ACACIA ERIOLOBA* SEEDS

Scarified, non-predated seeds reached a final percentage germination of 82.00% within 40 h of incubation, compared to the 7.50% of predated seeds (Figure 9.1).

It was hypothesised in this study that bruchid-predated seeds will have an increased germination capacity, which can be attributed to the facilitation of imbibition through holes in the testa made by bruchids. A similar viewpoint was held by a number of authors (Lamprey *et al.* 1974; Louda 1982; Hoffman *et al.* 1989; Sabiiti *et al.* 1991; Miller 1994a; Mucunguzi 1995; Van der Walt & Le Riche 1999). The findings of the present study proved this hypothesis to be false, as predated seeds clearly exhibited a drastically lower germination rate than control treatments (Figure 9.1), most probably due to the consumption of the embryo by bruchids (Figure 9).

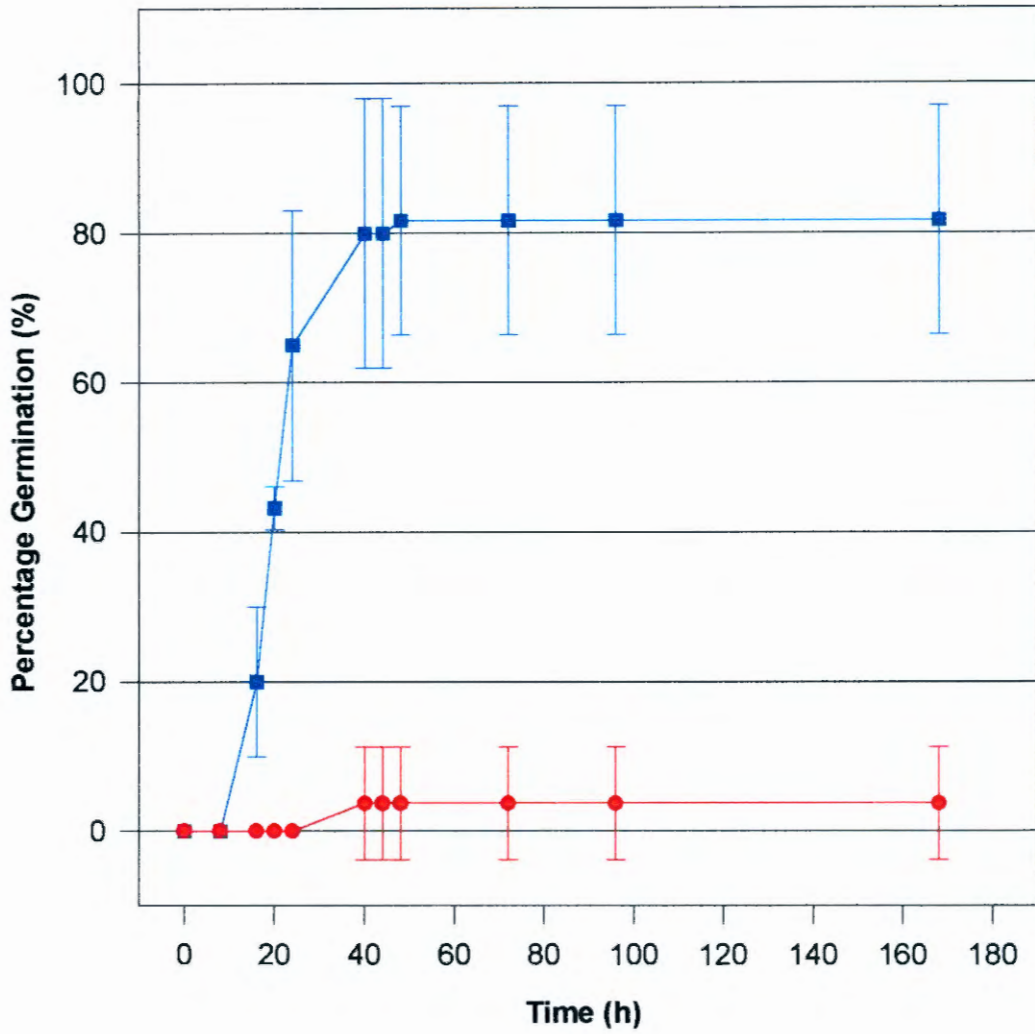


Figure 9.1. Percentage germination of bruchid predated *Acacia erioloba* seeds versus non-predated seeds (Non-predated seeds ■; Predated seeds ●).





Figure 9.2. Consumption of the embryonic axis of *Acacia erioloba* seeds by bruchid predators.

Infested *Acacia* seeds are not exclusively non-viable (Lamprey *et al.* 1974; Pellew & Southgate 1984; Miller 1994a), but seed predation does have an inhibiting effect on the germination of these seeds (Peake 1953; Ross 1965; Lamprey *et al.* 1974; Ernst *et al.* 1989; Hoffman *et al.* 1989). The extent to which bruchid infested seeds can germinate, depends on the extent of seed embryo consumption (Lamprey *et al.* 1974; Coe & Coe 1987; Miller 1994a; Mucunguzi 1995). Damaged seeds can only germinate if their embryo axes are still intact (Mucunguzi 1995). Seeds containing first instar larvae are more likely to have a higher germination potential than seeds containing adult beetles (Okello & Young 2000). This study confirmed that Bruchidae larvae often consume the embryonic parts of seeds before the cotyledonous reserves (Skaife 1926; Ernst *et al.* 1989; Mucunguzi 1995) (Figure 9.2). This phenomenon can be attributed to the point of entrance of the larvae: If the embryo lies in its path, the larvae will readily destroy it (Skaife 1926).

#### 9.4.3. INFLUENCE OF BRUCHID SEED PREDATION ON *ACACIA ERIOLOBA* POPULATION DYNAMICS

In a study on the effect of predispersal seed predation on seedling recruitment of Australian *Acacia* species, Auld (1986) stated that this relationship is influenced by dispersal, seed longevity in the soil, seasonality, soil moisture and seed germination. He concluded, however, that the effect of predispersal seed predation on seedling recruitment cannot be measured directly (Auld 1986). The rest of this chapter is therefore devoted to a brief literature review of the different opinions on the influence of seed predation on population dynamics.

According to Andersen (1989), the numerous evolutionary modifications to seed biology in response to seed predation do not necessarily imply that seed predators have a significant impact on plant population recruitment. The reason for this is that competition between plant individuals for rare safe-sites that can cause an oversupply of seeds. Plants can only regenerate successfully when seeds are dispersed to micro-habitats where they can germinate and establish seedlings (Crawley 1983). Every plant species has unique requirements for such safe-sites (Crawley 1983; Fenner 1985; Auld 1995). These sites must provide all the prerequisites of germination, root penetration and leaf expansion (Crawley 1983; Fenner 1985). The specific safe site of a scarified *A. erioloba* can be described as follows:

- It is situated some distance away from the parent plant to eliminate intra-specific competition (Crawley 1983; Smith & Goodman 1986; Tybirk *et al.* 1992).



- It provides shelter against seed predators and climatic adversities (Lamprey 1967).
- It receives adequate sunshine (Hoffman *et al.* 1989; Milton & Dean 1999).
- It has a heap of dung acting as fertilizer (Hoffman *et al.* 1989; Milton & Dean 1999).

The importance of seed losses to predation in terms of population recruitment at any point in time is related to the abundance of these sites (Andersen 1989). The availability of safe sites therefore places a ceiling on the population density of seedlings (Crawley 1983).

Southgate (1983a) postulated that any constructive attempt in the reforestation of arid and semi-arid areas would depend on the extension of the current available knowledge of bruchid-host relationships. This gives an indication of the potential importance of seed predation in plant population dynamics.

According to Pellew and Southgate (1984), however, factors, like seed predation, which influence seed viability, only become critical if the rate of seed production of a population has fallen. Figure 2.3 indicated that the current population structure of the *A. erioloba* population of the Khai-Apple Nature Reserve, in particular, is not healthy if compared to that of the control area. Reproducing individuals from the 2 and 3 m height classes are relatively scarce. It can, therefore, be assumed that pod production and subsequent seed production in this area is lower than optimal. The influence of seed predation on this population can, therefore, become critical, considering the previously mentioned statement of Pellew and Southgate (1984).

Andersen (1989) stated that seed predators can only have an impact on population size if they interfere with the establishment of a seed bank that is capable of exploiting future changes in safe site abundance. This implies that Bruchidae predation can influence the population size of *A. erioloba*, as its inhibiting effect on the germination of *A. erioloba* seeds was clearly demonstrated earlier (Figure 9.1). This will inevitably have a negative influence on the establishment of a healthy seed bank.

The results of the germination trials of the present study have important consequences for the Kathu Forest Reserve. Larger browsing ungulate species from the adjacent Khai-Apple Nature Reserve are prevented from entering this area. Uncollected, fallen pods are therefore not consumed by ungulates, which play a major role in both the distribution and germination of *A.*



*erioloba* seeds (Leistner 1961; Sabiiti & Wein 1987; Hoffman *et al.* 1989; Milton & Dean 1999; Dudley 1999). Hard seededness must now be overcome by slow mechanical weathering processes, which include being trodden on and broken down by fungal attack (Coe & Coe 1987; Miller & Coe 1993), as Bruchidae predation does not overcome hard-seededness as was earlier hypothesised. It furthermore decreases the chances of germination due to embryo consumption. These seeds therefore only have a slight chance of germination.

The absence of ungulates in the Kathu Forest Reserve may have another implication in terms of Bruchidae infestation: The decreasing effect that passing through the gut of ungulates has on Bruchidae infestation (Leistner 1961; Halevy 1974; Lamprey *et al.* 1974; Pellew & Southgate 1984; Coe & Coe 1987; Miller 1994a; Leistner 1996), is absent. It can therefore be assumed that seed loss due to Bruchidae predation would be lower if the correct numbers of browsers and other seed-eaters were attracted to the areas concerned.

#### 9.4.3.1. Is seed predation a problem?

Despite the statements of Southgate (1983a), Pellew and Southgate (1984) and Andersen (1989), the bulk of the *A. erioloba* populations of both the study (65.20% of the total population) and control (35.60%) areas consist of seedlings (Figure 2.3), suggesting that seed predation does not presently have a drastic effect on regeneration. Sabiiti and Wein (1987) and Ernst *et al.* (1989, 1990b) stated that *Acacias* have overcome the problem of insect predation to a large extent by producing large numbers of seeds. The current study revealed that 65.00% of seeds in the study area were not predated and can therefore be classified as viable, while 54.00% of seeds of the control area showed no signs of predation. This adds up to quite an impressive number of viable seeds, if it is taken into consideration that a single pod can bear 5 to 25 seeds (Leistner 1961; Hoffman *et al.* 1989; Milton and Dean 1999; Dudley 1999) and that a single, century-old tree can produce 200 kg (Milton & Dean 1999) or even up to 500 kg of pods per year (Dudley 1999). This leaves more than enough opportunities for the establishment of new individuals in a limited number of available safe sites.

It is, however, clear that the portion of the population consisting of seedlings in the control area, which has a higher predation level than the study area, is almost half the size of that of the study area. It can therefore be reasoned that although seed predation does not have a



significant negative impact on the general *A. erioloba* population dynamics of these areas, it can potentially affect the number of seedlings recruited.

Management recommendations on the control of bruchid beetles are given in Chapter 11.

## 9.5. CONCLUSIONS

In contrast to what was hypothesised in the present investigation, it was concluded from the results obtained that Bruchidae predation has a substantial inhibiting effect on the germination capacity of *A. erioloba* seeds. Through a thorough literature investigation it was, however, determined that *A. erioloba* overcomes this obstacle through mass pod production.

**CHAPTER 10**

**FINAL CONCLUSIONS**



This study addressed various factors that influence *A. erioloba* at different stages of development and that could potentially be responsible for the observed decline in the *A. erioloba* population of the Kathu area. It is not clear which of the investigated factors play the most important role in the decline of the *A. erioloba* population, and it is postulated that every investigated factor contributes, to some extent, to the application of pressure to this population. The aim of this chapter is to place all the investigated factors into perspective.

The first potentially susceptible stage of development of *A. erioloba* is germination. *Acacia erioloba* seeds are hard seeded, i.e. seed coats are tough and thick and do not allow the passage of water and oxygen through the testa. The latter two factors are essential for the germination and survival of *A. erioloba* under natural conditions. Investigation into the germination capacity of these seeds therefore required scarification treatments to break innate dormancy (Fenner 1985; Hoffman *et al.* 1989). Two scarification phenomena commonly occur in nature, namely scarification through the acidic digestive juices of ungulates (endozoochory) (Sabiiti & Wein 1987; Hoffman *et al.* 1989; Dudley 1999; Van der Walt & Le Riche 1999) and mechanical weathering of the testa over time, which is accomplished by, for example, the trodding of animal hooves on pods (Miller & Coe 1993). Both these natural scarification phenomena are present in the Kathu area in the form of ungulates, cattle and livestock and therefore it can be postulated that the breaking of dormancy of *A. erioloba* seeds in order to enable germination, is not currently a factor responsible for the decline in the *A. erioloba* population. This was confirmed by determining the population structure of *A. erioloba* in various study sites: a large fraction of each site's population is made up of seedlings (0.5 m).

Yet another aspect regarding the germination of *A. erioloba* seeds may be responsible for the decline in the *A. erioloba* population of the Kathu area: scarified seeds can only germinate in a suitable micro-environment. Such an environment provides all the prerequisites for germination, root penetration and leaf expansion (Crawley 1983; Fenner 1985). The specific safe site of a scarified *A. erioloba* can be described as follows:

- It is situated some distance away from the parent plant to eliminate intra-specific competition (Crawley 1983; Smith & Goodman 1986; Tybirk *et al.* 1992).
- It provides shelter against seed predators and climatic adversities (Lamprey 1967).
- It receives adequate sunshine (Hoffman *et al.* 1989; Milton & Dean 1999).
- It has a heap of dung acting as fertilizer (Hoffman *et al.* 1989; Milton & Dean 1999).



Wind plays no significant role in the distribution of *A. erioloba* seeds to safe sites, as pods are relatively heavy and have no adaptations for wind dispersal. The species is furthermore not adapted to water dispersal, as it is distributed in areas where rivers are dry for the largest part of the year, and more specifically during the dry season, when pods ripen (Leistner 1961). *Acacia erioloba* seeds are distributed to safe sites mainly by means of endozoochory (Leistner 1961; Sabiiti & Wein 1987; Hoffman *et al.* 1989; Milton & Dean 1999; Dudley 1999). This factor is present in abundance in the study area and can therefore be eliminated as a contributing factor in the decline of the *A. erioloba* population of the Kathu area.

It was postulated in the present study that mine dust deposition could also inhibit the germination of *A. erioloba* seeds by altering the soil properties (Turchenek *et al.* 1987; Shukla *et al.* 1990; Mayo *et al.* 1992; Farmer 1993), and in this manner contribute to the decline of the *A. erioloba* population of the Kathu area. The results of this study indicated the opposite: the presence of mine dust in incubation mediums stimulated, rather than inhibited, the germination capacity of *A. erioloba* seeds under controlled conditions. Mine dust was therefore disqualified as a contributing factor to the decline of the *A. erioloba* population of the Kathu area by means of inhibiting germination.

Bruchidae seed predation was also identified as a factor with a potentially inhibitive effect on the germination of *A. erioloba* seeds. Scarified seeds in a suitable micro-environment can only germinate if it is supplied with the nutrients needed for germination. These nutrients are available to the seed in the form of the reserves (endosperm) stored in the cotyledons. It was determined in this study that seed predation by Bruchidae larvae inhibits the germination potential of *A. erioloba* seeds through consumption of up to 100% of the endosperm and embryo (Miller 1994a). Bruchidae seed predation is therefore regarded as a potential contributing factor in the decline of the *A. erioloba* population of the Kathu area. A literature study on this subject revealed, however, that *A. erioloba* overcomes the problem of Bruchidae seed predation to a great extent through mass seed production (Sabiiti & Wein 1987; Ernst *et al.* 1989, 1990b).

The next stage of development of *A. erioloba*, namely seedling growth, is also generally associated with high mortality rates (Crawley 1983; Fenner 1985; Auld 1995). Seedling deaths can therefore potentially play a major role in the decline of the *A. erioloba* population of the Kathu area. The reason for the susceptibility of seedlings is that a plant is most vulnerable to



suppression and defoliation when it starts to rely on its own photosynthetic products for the first time (Crawley 1983). Three factors were identified in the present study as being potentially harmful to *A. erioloba* seedlings, namely browse pressure, the presence of mine dust and the uninformed use of chemicals. It was determined that the Khai-Apple Nature Reserve, in particular, is grossly overstocked with browsers and mixed feeders and the detrimental effect of this on the *A. erioloba* population structure was clear from the results of this study. The advantage of the presence of ungulates in the development of *A. erioloba*, namely in seed scarification and distribution, therefore seems to be eliminated by the detrimental effect of a high browse pressure on seedling establishment. It was furthermore hypothesised in this study that the presence of mine dust in the soil would inhibit seedling growth. The results of this study indicated the opposite: radicle growth was stimulated by the presence of mine dust, thus eliminating this factor as contributor to the decline of the *A. erioloba* population of the Kathu area. Through population structure analyses it was also determined that the uninformed use of chemical substances in the vicinity of *A. erioloba* seedlings in the Knapdaar area caused irregularities in the population structure, thus influencing the long-term survival of the species. This factor is therefore regarded as contributing to the decline in the *A. erioloba* population of the Kathu area.

Three factors were identified in this study as having a potentially inhibitive effect on the next phase of development of *A. erioloba*, namely growth. These factors are: Mine dust deposition on leaves, the lowering of ground water levels as a result of the mining activities of the Sishen Iscor Iron Ore Mine and high browse pressure. It was hypothesised in this study that the deposition of mine dust on *A. erioloba* leaves would impede the transpiration rate, chlorophyll *a* and *b* content, as well as protein content of *A. erioloba* leaves, thus also impeding optimal growth. By means of controlled dusting experiments it was, however, determined that the deposition of mine dust on leaves in both wet and dry states, which mimicked rainy and windy conditions in nature, does not markedly inhibit the above mentioned processes. This factor was therefore eliminated as contributing to the inhibition of the growth of *A. erioloba*. Although the results of previous studies indicated that the lowering of underground water levels in the Sishen Iscor Iron Ore Mine area do not influence the Kathu and Khai-Apple Nature Reserve aquifers, this could not be concluded beyond reasonable doubt in the present investigation. A relationship between the pumping rate of water from the southern mining compartment and the level of a bore hole in the Kathu aquifer was clear from the results of this study. It is therefore suggested that an independent, hidrological study be conducted on the Kathu area as soon as possible.



The irregularities in population structure caused by a high browse pressure was clear from the results of this study: Only a relatively small fraction of the population reached height classes two (1 m) to four (3 m). High browse pressure is therefore regarded as a contributing factor to the decline in the *A. erioloba* population of the Kathu area.

Pollination can be regarded as the next potentially susceptible phase of development of *A. erioloba*. After an intensive literature study a factor was identified as having a potentially harmful effect on the pollination of *A. erioloba*, namely the high browse pressure present in the Khai-Apple Nature Reserve. The visitation frequency, as well as time spent per flower of flower visitors in the study area did, however, not differ markedly from that of the control area. High browse pressure was therefore eliminated as a potential contributing factor to the decline of the *A. erioloba* population of the Kathu area through its potential inhibitive effect on pollination.

The next phase of development of *A. erioloba*, namely pod and seed formation, can be inhibited by high browse pressure. Marked pollinated flowers in both the Khai-Apple and Sandveld Nature Reserves were monitored for an extensive period, after which it was concluded that a high browsing pressure does indeed inhibit the growth of pods. None of the marked pollinated flowers in either area reached maturity, i.e. the stage where the seeds inside the pod are ripe.

Viable but dormant *Acacia* seeds accumulate in the upper soil layers in the vicinity of pod-bearing trees, which seems to act as a general survival strategy (Sabiiti & Wein 1987). The absence of this strategy could, therefore, be a contributing factor in the decline of the *A. erioloba* population of the Kathu area. *Acacia erioloba* seeds seem well adapted to a strategy of seed dispersal over time: it has a hard seed coat, and it is both long-lived and dormant upon pod-bearing (Coe & Coe 1987). A consistent seed bank has various advantages, including the building up of a genetic memory of a species, which can be drawn upon intermittently in case of future environmental change (Templeton & Levin 1979; Keddy & Reznicek 1982; Fenner 1985; Graham & Hutchings 1988; Andersen 1989; Diemont 1990; Hulme 1998). Pods are collected from various sites in the Kathu area for the purpose of being sold as cattle fodder in times of food scarcity. Through the digging of soil profiles it was determined that pod collection has an inhibiting effect on the building up of an *A. erioloba* soil seed bank. This may prove disastrous in terms of the long-term survival of this species in case of future environmental changes.



It is concluded that the following factors are potentially partly responsible for the observed decline in the *A. erioloba* population of the Kathu area:

- The lowering of water table levels as a result of the mining activities of the Sishen Iscor Iron Ore mine;
- High browse pressure, through its inhibiting effect on seedling establishment and growth;
- The uninformed use of chemicals, through its detrimental effect on seedlings and young individuals; and
- Pod removal, through its inhibitive effect on the establishment of an *A. erioloba* seed bank.

Management recommendations on the conservation of *A. erioloba*, with special emphasis on the factors listed above, are made in Chapter 11.

**CHAPTER 11**

**MANAGEMENT RECOMMENDATIONS**



## 11.1. PREFACE

Before any management recommendations are made, it must be said that many of the following suggestions regarding the decline in the *A. erioloba* population in the Kathu area have already been made by Van Hoven and Guldmond (1992) and Laan (1998). It therefore appears as if the real problem concerning *A. erioloba* in the Kathu area is not a shortage of ideas on ways to conserve this species, but instead a lack of implementation of such ideas, for whichever reason. It is therefore suggested that, first and foremost, an environmental officer be appointed by Iscor with the specific task of implementing and monitoring a conservation strategy (as is briefly suggested in this chapter) in Kathu and the surrounding areas. This will ensure that the current document does not become yet another collection of unimplemented suggestions.

This chapter is not a rigid set of rules to be followed to the letter. Implementation and subsequent monitoring of these ideas should be accompanied by adjustments to optimise this management strategy so as to accommodate unanticipated developments.

## 11.2. INTRODUCTION

Legislation regarding protected plant species (see Appendix A) resulted in the implementation of a "hands-off" conservation strategy regarding *A. erioloba* in the Kathu area. This approach to conservation can be harmful in the long run, as is explained in the paragraphs that follow.

Despite the efforts of organizations such as the World Conservation Union (IUCN), which have placed the focus on both conservation and sustainable utilization for the past 45 years (Holdgate & Giovannini 1994), humankind's view of the utility of species is still conservative (Beattie 1995). The *World Conservation Strategy* emphasises that the conservation of nature can only be carried out within development that meets human needs. Development will, however, not meet those needs unless it is soundly based on the conservation of the natural systems of the biosphere (IUCN 1980). A growing number of specialists in both conservation and development currently regard the inclusion of local communities in wildlife management as indispensable for successful conservation (Gibson & Marks 1995).

Living resources can, however, also be utilised to a degree that is not sustainable. A balance should therefore be found between sustainable and non-sustainable utilization. Sustainable

utilization of a species requires knowledge of its abundance and demography, together with measures that will ensure that utilization does not exceed critical thresholds. The ideal situation is that access to a specific resource should not exceed the resource's capacity to sustain exploitation. This can be achieved through, for example, quotas and limited participation implemented at the onset of exploitation. The situation is, however, seldom ideal and the reduction of existing participation is often faced. This inevitably requires a short-term sacrifice of investment capital, labour opportunities and production for future gains in the form of more stable utilization, which will require fewer inputs (Allen *et al.* 1982).

### 11.3. OBJECTIVE

The aim of this chapter is to:

- Provide practical management recommendations on the conservation of *A. erioloba* in the Kathu area.

### 11.4. GENERAL MANAGEMENT RECOMMENDATIONS

#### 11.4.1. COMMUNITY EDUCATION AND AWARENESS

The need for educating local communities in environmental awareness is often emphasized (Mwanyama 1997). This need exists because man's attitude towards plants and animals differs from culture to culture and it changes over time. Without an understanding of the significance of life-support systems, ecological processes and biotic diversity, it is unlikely that human societies will make the decisions necessary to ensure the continued functioning of the biosphere to sustain future generations (Allen *et al.* 1992). It is especially important to educate the youth, as children's opinions can still be molded. Adults' opinions, on the other hand, have to be changed – a task that is slightly more difficult (Joosten 1997).

A shocking number of Kathu residents (18.61%) indicated that the decline in the *A. erioloba* population of the area is of no concern to them (Chapter 3). Reasons varied from "...my children step in the thorns" to "...it is an unattractive gardening tree". It is therefore clear that



the residents of Kathu are in dire need of education on the value of *A. erioloba* to them, as was clearly motivated in Chapter 1, and the role of this species in the local ecology.

Through educational efforts, such as the visiting of schools and clubs, and the implementation of a community game guard programme, which is discussed later in this chapter, the following can be accomplished (Joosten 1997):

- An increased understanding of personal impact on natural systems.
- The reinforcement of a caring attitude towards nature.
- Encouragement of the conservation and improvement of private and public lands.
- The prevention of future wildlife casualties due to misunderstandings.

#### 11.4.2. COMMUNITY INVOLVEMENT

Until recently the accepted management strategy for the preservation of natural resources throughout Africa, as well as other parts of the world, was to exclude all human occupation and utilization from protected areas (McCabe *et al.* 1992). However, the new focus of conservation lies on the management of these resources through sustainable utilization in order to benefit the human population (McCabe *et al.* 1992; Els & Bothma 2000).

Since 1980, the philosophy arguing the dependence of biodiversity conservation on direct interaction with local communities by linking sustainable utilisation to sustainable development, has become an integral part of wildlife management policies across the globe (IUCN 1980). Little (1995) defines community-based conservation (CBC) as "*local, voluntary initiatives involving a minimum of several households in which at least one of the outcomes of local management practices is either the maintenance of habitats, the preservation of species, or the conservation of certain critical resources, and another outcome is improvement of social and economic welfare*". This "hands-on" approach to conservation changes the attitude of the man on the street towards protected areas and species: Nature is no longer regarded as a liability and as someone else's legal property to be tolerated, stolen or destroyed. Instead, it is regarded as a resource (Murphree 1990). The role of local participation in conservation has, however, drawn both enthusiastic praise and wary criticism. The latter is usually based on the concept's idealism and impracticality (Little 1995).



In Eastern and Southern Africa the practical implementation of community-based wildlife management and conservation programmes has blossomed over the past few years, albeit with mixed results (<http://www.panda.org/resources/publications/forest/sparetrees/page2.htm>; Collett 1987; Doungoube 1990; Etoori 1990; Kamugasha 1990; Kiss 1990; Lawson & Mafeka 1990; Lungu 1990; Murphree 1990; Talbot & Olindo 1990; Martin 1991; Murphree 1991; McCabe *et al.* 1992; Gibson & Marks 1995; Alpert 1996; Marks 1996; Mwanyama 1997; Peake 1999; Landman 2001). The South African National Parks, both as a national conservation body and the conservation authority in the nine provinces of South Africa, sets a prime example by propagating interaction with local communities as a part of their policy statements (<http://www.parks-sa.co.za>; <http://www.parks-nw.co.za/>). However, the largest section of the wildlife managers and academics involved in South African and southern African conservation activities still have to, mostly with reluctance, make a paradigm shift towards community-based management (Matowanyika 1994; Els & Bothma 2000).

Coordinated Resource Management (CRM), which entails that representatives of both the public and private sectors work together to resolve land management conflicts, is also implemented more and more (Melynk 1994; Krausman 1996). This strategy achieves coordination through a timely process of analysis, bargaining and compromise (Krausman 1996).

Despite a variety of institutional structures, all community-based conservation programmes share one key assumption: Conservation policies will be successful only if local communities receive sufficient benefits to change their behavior from taking wildlife, to conserving it. These benefits can be divided into three categories (Gibson & Marks 1995):

- Firstly, benefits that stem directly from nature, e.g. jobs as scouts or meat from supervised culling operations;
- Secondly, benefits that are indirectly linked to nature, e.g. the building of schools and clinics; and;
- Finally, benefits that relate to the empowerment of rural residents, e.g. the opportunity to play a role in decision making processes.

Achieving meaningful local participation in rural conservation programs is essential, but difficult, as these programs usually occur in situations of poverty and pressing short-term needs (Little



1995). A failure to generate active local participation has, however, been the reason for various community conservation projects, e.g. WINDFALL (Wildlife Industries New Development for All) in Zimbabwe, to fail. One of the main reasons for poor participation is the perceived lack of return of dividends to locals (Murphree 1990).

The Kathu district lends itself perfectly to the implementation of a community-based conservation programme: The protected *A. erioloba* tree is wide-spread in large parts of the region, including on various private and municipally owned properties. Prior to the implementation of such a program in this area, overviews of existing programmes (e.g. by Murphree (1990) and McCabe *et al.* (1992)) should, however, be meticulously studied. In this way lessons can be learnt from mistakes that were previously made. Practical guidelines for the implementation of CRM or a community-based conservation programme in the Kathu area, include:

- The key persons involved in the bargaining process should be few in number, and have the authority to speak for the landowner or agency they represent (Krausman 1996).
- Goals should be attainable and involve definite action steps to keep all parties involved and communicating (Krausman 1996).
- It is essential that there be a signed contract between the management of a specific area (e.g. the Khai-Apple Nature Reserve) and the respective communities (Mwanyama 1997).
- Results should be regularly monitored and changes should be met with flexibility (Krausman 1996).
- Effective law enforcement must be continued until locals start practising responsible utilization (Mwanyama 1997).
- Representatives of the community and conservation authorities should strive to resolve one problem before attempting to tackle the next. That first decision is a landmark because it is proof that diverse interests can agree to management practices by bargaining and serves as motivation for future discussions (Krausman 1996).

#### 11.5. DEVELOPMENT OF THE KHAI-APPLE NATURE RESERVE

According to Allen *et al.* (1982) protected areas should meet the following requirements:

- The maintenance of biotic diversity;

- The provision of research facilities;
- The promotion of public understanding and demand for conservation; and
- The partial satisfaction of human recreational needs.

If measured against these standards, the Khai-Apple Nature Reserve is not currently living up to its full potential. In addition to this, little or no profit is generated (Laan 1998), while its management strategy is plagued by criticism (Bosch, pers. comm.<sup>1</sup>). It is therefore clear that a complete paradigm shift in regard to the management strategy of this area is needed to turn it into an asset on for both its owners and the community.

#### 11.5.1. MULTIPLE RESOURCE USE

To spark the interest of a wider spectrum of eco-tourists, as well as to benefit as many as possible community members, it is suggested that the Khai-Apple Nature Reserve be developed as an area of multiple resource use. This concept is defined as *"the development and management of activities not directly related to the original objective of an area"* and has been introduced successfully to many parts of South Africa (Sappi 2001). Practising various land use options on a single piece of land increases its earnings per hectare, and in the words of Martin (1991): *"... rural peoples make excellent conservationists when conservation is profitable"*. Multiple resource use of the Khai-Apple Nature Reserve is furthermore 100% in line with the National Forestry Act (No. 84 of 1998), which promotes the sustainable use of forests for environmental, economic, educational, recreational, cultural, health and spiritual purposes (Appendix A).

The original main objective of the Khai-Apple Nature Reserve was tourism in the form of game viewing (Van Hoven & Guldemond 1992). Two secondary objectives were also identified: Conservation of the Kathu Forest, and the sustainable use of the aquifers in the area (Laan 1998). Through a "multiple resource use-perspective" this area can also be utilised as:

- **An environmental education venue.** Schools, clubs (cub scouts, etc.) and interested individuals can be educated by community game guards on informal outings (the concept of community game guards is described later in this chapter). School groups can undertake clean-up campaigns in the reserve. People can be made aware of indigenous vegetation by

<sup>1</sup> Gert Bosch. Environmental Manager: Sishen Iscor Iron Ore Mine. ☎ : 083 461 5734.



attaching name plates to some of the dominant indigenous plant species of the area (Van Hoven & Guldemond 1992). Posters identifying the birds of the area can be displayed in bird hides. Commercially available posters on the snakes, mammals and reptiles of the Kalahari, or stuffed examples of such animals, can be displayed in the lapa area.

- **A hiking, horseback riding or mountain biking venue.** Hiking, horse back riding or mountain biking enthusiasts can be taken on hiking trips, horse- and biking trails by community game guards. This can double-up as an education opportunity: Game guards should share information on animal tracks, insects and other oddities of the veld. It is essential that game guards accompany visitors, as this will prevent actions that are potentially harmful to the environment.
- **A bird watching venue.** The Khai-Apple Nature Reserve is, as was mentioned earlier, home to more than 200 bird species (Repro Touch 1996) and can be successfully propagated as a bird watcher's paradise. It is, however, vital that the current bird watching facilities be upgraded. Some of the existing bird hides are indiscreet and do not allow an unannounced approach to water holes. Suggestions on ideal bird watching facilities are given by Du Toit and Van Rooyen (1996a; 1996b) and will not be discussed here.

Although the primary goal of multiple resource use projects is not to generate income, some projects, such as larger ecotourism developments like the ones suggested above, have income-generating potential to the developer, operator and local community (Sappi 2001).

#### 11.5.2. COMMUNITY GAME GUARDS AND GUIDES

A simple and effective way to integrate the population living near conservation areas into both ecotourism activities and the economy, is by training and appointing local naturalist guides to accompany, entertain and educate visitors (Paaby & Clark 1995). This strategy has been implemented worldwide, albeit with mixed results (Reardon 1986; Gibson & Marks 1995; Paaby & Clark 1995; Alpert 1996; Marks 1996), and has the following advantages:

- It acts as a mechanism to increase the economic returns of ecotourism to local levels (Paaby & Clark 1995; [http://www.panda.org/resources/inthefield/lop/lop\\_na.htm](http://www.panda.org/resources/inthefield/lop/lop_na.htm)) by providing jobs to the unemployed.
- It provides a rationale for conservation (Paaby & Clark 1995; [http://www.panda.org/resources/inthefield/lop/lop\\_na.htm](http://www.panda.org/resources/inthefield/lop/lop_na.htm)).

- It increases the capacity of nature reserves to receive the growing number of ecotourism enthusiasts in an environmentally benign fashion (Paaby & Clark 1995).
- The game guards themselves act as a link with the community that fosters a more positive attitude towards conservation (Gibson & Marks 1995).
- Appointed guides act as the eyes and ears of the reserve manager, reporting any illegal hunting operations (Reardon 1986; Alpert 1996). This is especially effective when guides are offered a cash bonus for every poacher handed over (Gibson & Marks 1995).
- The knowledge and skill of local guides can be used to enumerate trends in wildlife populations, thus eliminating the need for costly annual game counts (Gibson & Marks 1995; Marks 1996).

The implementation of a community game guard programme does, however, also have potential disadvantages:

- Game guards may become unpopular in or estranged from their communities, causing social tension in the community, as happened with the ADMADE (Administrative Management Design for Game Management Areas) program in Zambia (Gibson & Marks 1995).
- Game guards' enthusiasm may wane without effective leadership, leading to poaching and stealing. Some scouts may even choose to aid hunters in their illegal operations. Unless advantages are offered for individual behavior, stakes for piggy-backing on public goods are high (Gibson & Marks 1995).

Practical advice on the implementation of variations of a community game guard project is given by Paaby and Clark (1995).

### 11.5.3. RECOMMENDED STOCKING RATES

The management of veld stocked with wildlife is complex and must be adapted to the particular form of land use that is being practised (Trollope 1990). The main objective of the Khai-Apple Nature Reserve is currently game viewing, and therefore the number of game species should be kept at a maximum, while at the same time minimising the number of individuals of each species. This should make for an interesting game viewing experience.



As is evident from the data presented in Chapter 6, the current stocking rates of both browsers and mixed feeders grossly exceed the browsing potential of the reserve. The suggested stocking rates (Table 11.1) are therefore aimed at decreasing the number of browsing units sustained by the reserve (i.e. animal numbers), while at the same time ensuring a satisfying game viewing experience (i.e. keep the number of species at a maximum). These stocking rates are NOT a rigid set of rules to be followed to the letter. It should be tested in practice and adapted, if necessary, in the light of field experience (Trollope 1990).

The number of individuals from each species were lowered to the minimum viable group number throughout (Table 11.1). Although the total number of BU's still exceeds the current browsing capacity, Table 11.1 already indicates a drastic lowering of animal numbers. It is suggested that these suggestions be implemented immediately, while at the same time closely monitoring any changes in veld condition. If no increase in veld condition is detected after a predetermined period of, for example, 5 years, stocking rates can again be lowered until a positive trend in veld condition is noticed.

#### 11.5.4. ROTATIONAL RESTING

According to Trollope (1990) continuous browsing generally leads to the selective over-utilization of preferred forage species. This may lead to sub-optimal leaf production, as woody plants need a long resting period in order to maximise leaf production (Teague 1989). This problem can be solved through rotational resting: Extensive areas of veld are withdrawn from utilization for extended periods of time for specific objectives like seed production or the recruitment of new plants (Trollope 1990).

Rotational resting can be implemented without the erection of unsightly fences (Baker *et al.* 1999), through the strategic placement of licks (Young 1992). This strategy is, however, never 100% effective on a game ranch, as preferred areas, such as permanent watering points, will always be well visited. Another disadvantage is that territorial species will not move readily. It is therefore important that the overall stocking rate of an area remain the most important veld management strategy (Trollope 1990).

Table 11.1. Suggested stocking rate of browsers and mixed feeders for the Khai-Apple Nature Reserve.

Type of Animal	Number of Animals	Minimum Viable Group Size	Number of Males per Group	Number of Females per Group	Mean Animal Mass (kg)	Percentage Graze in Diet	Percentage Browse in Diet	LSU's per Animal	BU's per Animal	Equivalent LSU's per Group	Equivalent BU's per Group	% of Ecological Graze Capacity	% of Ecological Browse Capacity
<b>Mixed Feeders</b>													
Common Impala	22	22	4	18	50	60	40	0.12	0.18	2.54	4.07	0.95	25.57
Eland	12	12	3	9	500	40	60	0.43	1.56	5.19	18.71	1.94	117.64
Kudu	8	8	2	6	200	10	90	0.05	1.18	0.44	9.41	0.16	59.17
<b>Sub-Total</b>	<b>42</b>									<b>8.17</b>	<b>32.19</b>	<b>3.05</b>	<b>202.38</b>
<b>Browse Feeders</b>													
Common Duiker	2	2	1	1	19	0	100	0.00	0.22	0.00	0.45	0.00	2.81
Giraffe	6	6	2	4	830	0	100	0.00	3.80	0.00	22.80	0.00	143.37
Steenbok	6	6	3	3	11	0	100	0.00	0.15	0.00	0.89	0.00	5.60
<b>Sub-Total</b>	<b>14</b>									<b>0.00</b>	<b>24.14</b>	<b>0.00</b>	<b>151.79</b>
<b>TOTAL</b>										<b>8.17</b>	<b>56.33</b>		



### 11.5.5. PROTECTION OF ACACIA ERIOLOBA SEEDLINGS AGAINST BROWSERS AND MIXED FEEDERS

From the results of Chapter 2 it is clear that *A. erioloba* regeneration, especially in the Khai-Apple Nature Reserve, needs protection. Three approaches in protecting woody species regeneration, apart from correcting stocking rates, have been attempted in North America, namely fencing-in specific areas, and the use of browsing repellents and the installation of motion sensor sprinklers (<http://www.redwing.net/~tlyockey/deerproducts.htm>; Baker *et al.* 1999).

Enclosures made of electric or non-electric fencing are said to be the most effective in reducing damage to seedlings caused by deer (Palmer *et al.* 1985; Hygnstrom & Craven 1988; <http://www.extension.umn.edu/info-u/environment/BD590.htm>) and elk (Byrne 1989). The cost of installation, potential human hazards and high maintenance of especially electric fences are, however, prohibitive (<http://www.extension.umn.edu/info-u/environment/BD590.htm>; Baker *et al.* 1999), especially if the current economic state of the Khai-Apple Nature Reserve is considered.

Browsing repellents may offer a promising alternative to fencing, especially in areas, like the Khai-Apple Nature Reserve, with game viewing as its main objective. In such instances fencing can diminish the visual aesthetics of the landscape (Baker *et al.* 1999; <http://www.fwprdc.org.au/projects/completed/p706/pn97604.htm>). Two groups of browsing repellents exist, namely household repellents and registered commercial repellents. Household repellents work on the basis of either odour or taste and include human hair, deodorant soap, garlic oil, predator urine and hot sauce (<http://www.extension.umn.edu/info-u/environment/BD590.htm>; <http://www.redwing.net/~tlyockey/deerproducts.htm>). Registered browsing repellents include:

- **Deer Away®.** This product contains inedible egg solids as active ingredient and repels through odour, therefore preventing browsers from "taste-testing" foliage ([http://www.intagra.com/deer\\_away.htm](http://www.intagra.com/deer_away.htm)).
- **Deer-Off™.** This all-natural repellent repels through both odour and taste (<http://www.dutchbulbs.com/cat/F2000/z30576.22848.htm>).
- **Tree Guard™.** This repellent contains Bitrex™, a bitter tasting substance, as active ingredient and repels through taste (<http://www.itascagreenhouse.com/page20.html>).



Repellents are applied annually until seedlings reach a height where they are not harmed by browsing (Baker *et al.* 1999). More frequent reapplication may, however, be necessary in areas with a high browse pressure ([http://www.intagra.com/deer\\_away.htm](http://www.intagra.com/deer_away.htm)). The effectiveness of browse repellents depends on factors like the product used, weather conditions, application frequency, familiarity to the browsing population Andelt (pers. comm.<sup>2</sup>) and feeding pressure (<http://www.extension.umn.edu/info-u/environment/BD590.htm>).

The effectivity of browsing repellents has not yet been tested on South African ungulates ([http://www.intagra.com/deer\\_away.htm](http://www.intagra.com/deer_away.htm)). Before this strategy can be implemented in the Khai-Apple Nature Reserve, detailed studies on the effectiveness of these substances, as well as the effect thereof on a Southern African eco-system, should therefore be conducted.

Repellent management of sprouts has the following disadvantages:

- Application problems, e.g. various safety precautions to be adhered to; the need for periodic reapplication; and the regular clogging of spraying mechanisms (Baker *et al.* 1999; Andelt, pers. comm.<sup>2</sup>);
- High costs (Baker *et al.* 1999; Andelt, pers. comm.<sup>2</sup>); and
- Accustomation of browsers to the product after some time (<http://www.extension.umn.edu/info-u/environment/BD590.htm>).

Repellent management can, however, be economically feasible for isolated populations and urban landscapes (Baker *et al.* 1999).

#### 11.5.6. VELD MONITORING

Management philosophies should focus on “learning by doing” (Pauw 1994). The successful implementation of an adaptive management plan therefore requires constant monitoring of the veld. In this way any changes that occur as a result of the implementation of such a plan can be evaluated and adjusted accordingly (Grimsdell 1978; Botha 1999).

A permanent representative monitoring point should be identified in each of the two plant communities of the Khai-Apple Nature Reserve, as was identified by Van Hoven and

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<sup>2</sup> Dr. W.F. Andelt. ☐: Department of Fishery & Wildlife Biology, Colorado State University, Fort Collins, CO 80523.



## 11.7. USE OF BUSH ERADICATION CHEMICALS

Although most of the herbicides that are available today show high activity and excellent selectivity (Reinhardt 2000), the incorrect use of such compounds could, on top of being costly, also be potentially harmful to the *A. erioloba* population of the Kathu area (Van Rensburg, pers. comm.<sup>3</sup>). For this reason, manual eradication of invasive *A. mellifera* is recommended. This process is, as mentioned previously, extremely labour intensive, and therefore also an ideal opportunity for job creation. Follow-ups are essential if entire plants (i.e. including roots) are not removed (Reinhardt 2000).

The following guidelines on the safe application of Molopo® 20 GG, used for bush eradication, were compiled by Mr. Dihan van Rensburg<sup>3</sup>, a farmer in the Kathu district. Through years of trial and error Mr. Van Rensburg accumulated this set of practical guidelines, which, he believes, eliminates unnecessary *A. erioloba* deaths in the event of chemically combatting bush encroachment.

- Chemicals should only be applied from September to the end of February.
- No chemical solutions should be prepared at home, since only a few spilled drops can destroy an entire garden. Solutions should be prepared in the encroached area to be treated.
- After application the containers should be rinsed in the encroached area. The water used for rinsing containers should be thrown on bushes identified for eradication.
- Chemicals should be applied to the soil surface approximately 30 cm from the stem.
- Chemicals should not be applied within a 20 m-radius of an *A. erioloba* individual.
- Dead individuals should not be removed, as it provides shelter from environmental adversities to seedlings.

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<sup>3</sup> Dihan van Rensburg. ☎: P.O. Box 678, Kathu, 8446.

## 11.8. SEED PREDATION

Very little work has been done on the control of bruchid pests. Useful attempts have, however, been made for controlling bruchids through chemical, biological, and other means (Arora *et al.* 1969). Peake (1953) named the dusting of mature forest as a possible (though impractical) control measure against bruchid infestation. Since the Kathu Forest is currently being "dusted" by the mining activities of the Sishen Iron Ore Mine, bruchid infestation should theoretically not be at its full capacity at present.

## 11.9. POD COLLECTION

As is evident from Chapter 7, the absence of a seed bank can have catastrophic consequences for the survival of *A. erioloba* in the Kathu area on the long run. It is therefore vital that steps be taken to disarm this potentially harmful situation. The following is suggested:

- It is understandable that home-owners refuse to leave pods lying around to decompose on their properties for the purpose of establishing a seed bank. It is therefore suggested that the residents of Kathu be encouraged to plant *A. erioloba* seedlings in their gardens to replace individuals dying of old age. Iscor officials are currently investigating the cultivation of *A. erioloba* seedlings for the purpose of being sold to the public. It is suggested that these seedlings be sold to locals at a discounted price to encourage purchases. In this way, genetically diverse individuals, that might survive future environmental changes, are introduced into the area.
- Residents should be monetarily rewarded by the *A. erioloba* working group ("Friends of Camel Thorn Trees") for bags of *A. erioloba* pods collected from their gardens and handed in to the group. These pods can be scattered around in the Khai-Apple Nature Reserve as a supplement to the pods produced there. Pods collected from the Sishen Golf Course premises should also be purchased and scattered in the Khai-Apple Nature Reserve, instead of being sold as cattle fodder. In this way, the browsing pressure on *A. erioloba* seedlings will be relieved, and a seed bank of mature, viable seeds may form if supply exceeds demand.
- Pod removal is vital to the management of the Sishen Golf Course because of both practical and aesthetic reasons. It is therefore suggested that the Sishen Golf Course management be encouraged to plant *A. erioloba* seedlings on the premises to replace individuals dying of old age. This may not solve the problem of no seed bank establishing, but genetically



diverse individuals who might survive future environmental changes, are introduced to the golf course in this way.

#### 11.10. FIRE WOOD

The South African National Parks and the Working for Water program adopted a campaign called "Don't let our own trees die – use invaders for your braai". In an effort to create employment using the wood cleared from alien-infested parts of the Kruger National Park (KNP), charcoal and braai wood markets have been developed, assisting the communities to empower themselves and provide a better living standard for impoverished areas. Co-operative efforts have also been established to phase out indigenous hardwoods from shops in the KNP, and replace them with locally cleared and packaged exotic woods (Foxcroft 1999).

An amendment to the Forestry Act 84 of 1998 (Appendix A) states that *A. erioloba* wood may no longer be chopped, transported or processed. It is therefore suggested that, after the analogy of the project discussed in the paragraph above, the existing, well-established braai wood market of Kathu is altered so as to slowly phase out the use of *A. erioloba* wood. The latter can be replaced with, instead of alien species (which is not currently a substantial problem in the study area) as is suggested above, *A. mellifera* wood. As was mentioned earlier, the bushveld areas of South Africa are subject to invasion by *A. mellifera* (Van Rooyen *et al.* 1996), as is evident in the study area.

Phasing out the use of *A. erioloba* as fire wood will undoubtedly be a slow and painful process, but could be initiated by:

- Displaying posters, which state the reasons for the use of *A. mellifera* or the exotic *Prosopis* spp. instead of *A. erioloba* for braais, wherever possible (Foxcroft 1999).
- Creating awareness by visiting schools, clubs and exhibitions. Awareness campaigns should be a top priority for establishments such as "Friends of Camel Thorn Trees".
- Setting a good example. Informed members of the public and members of "Friends of Camel Thorn Trees" should inspire others by using *A. mellifera* instead of *A. erioloba* in their OWN braais.

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SUMMARY/OPSOMMING



## SUMMARY

**Keywords:** *Acacia erioloba*; decline; Kathu; mine dust; water levels; browse pressure; chemicals; pod removal; Bruchid beetle predation.

Concerned residents have been reporting a decline in the *A. erioloba* population of the Kathu area to the Northern Cape Nature Conservation Service (NCNCS) since the early 1980's. This is the third study on this subject initiated by the NCNCS, and aims to elucidate the possible causes of decline in the *A. erioloba* population of the Kathu area.

Five investigation sites were identified: the Khai-Apple Nature Reserve (KANR); the farms Lylyveld and Demaneng, both situated down-wind with regard to the Sishen Iscor Iron Ore Mine (SIOM); the Sishen Golf Course; and the farms Swarthaak and Knapdaar, both situated up-wind with regard to the SIOM. The Sandveld Nature Reserve on the Free State side of the Bloemhof Dam, served as control site.

In order to identify potential problem areas regarding the *A. erioloba* population of the Kathu area, the *A. erioloba* population structure of the study and control areas were compared. Irregularities in the structure of the study area indicated that some factor(s) is either a) preventing individuals from reaching middle height classes, or b) killing trees in these classes. To eliminate one of these options, another structure study was conducted, comprising dead individuals only. Results indicated that both factors (a + b) play a role.

By means of questionnaires that were distributed throughout the region, three major factors, potentially harmful to the *A. erioloba* population, were identified. They are the mining activities of the SIOM, management strategies and natural phenomena.

Two aspects of the SIOM were postulated to be potentially harmful to the *A. erioloba* population: the mine dust formed as a by-product of mining activities; and the lowering of ground water levels. Scanning electron microscopy confirmed that *A. erioloba* leaves are indeed damaged by mine dust. Through further investigations the effect of mine dust on the transpiration rate, chlorophyll *a* and *b* content and protein content of *A. erioloba* leaves were determined. The results of this study indicated that mine dust has no marked effect on any of

these variables. The effect of mine dust on the germination of *A. erioloba* seeds and the growth potential of its embryos were also determined. No inhibitive effect was detected on either of these processes – in fact, mine dust seemed to stimulate both. No trials regarding the effect of the lowering of ground water levels by the SIIOM on *A. erioloba* were conducted, due to its impracticality. Instead, with the aid and insight of geohydrologists it was concluded that the lowering of ground water levels does not affect *A. erioloba*. The aquifer underneath the mining area is separated from the other two aquifers in the area (situated under Kathu and the KANR) by a dolomite dyke, which is impermeable to water. This was confirmed in the present study by comparing the water pumping rates of the SIIOM to bore hole levels throughout the region.

Three management strategies applied in the Kathu area were identified as being potentially harmful to *A. erioloba*: the overstocking of browsers and mixed feeders in the KANR; pod removal; and the uninformed use of chemicals. The current stocking rate of the KANR compared to its current browsing capacity, revealed that the reserve is grossly overstocked. This results in the suboptimal regeneration of *A. erioloba*, as seedlings cannot reach the stage where browsing does not prove to be fatal anymore. Pod removal also inhibits optimal regeneration, as no *A. erioloba* soil seed bank was found. This implies that no genetic variation in the *A. erioloba* population is built up over time, which may prove to be fatal in the event of future changes in environmental conditions. The uninformed use of non-specific chemicals in an attempt to eradicate *A. mellifera* on farms is furthermore also eradicating *A. erioloba*.

One natural phenomenon was hypothesised to be inhibiting to the regeneration of *A. erioloba*, namely seed predation by Bruchidae. Germination trials revealed that bruchid seed predation inhibits the regeneration of *A. erioloba*. It is, however, compensated for by producing a relatively large seed yield per tree in an attempt to over-saturate predators.

Management recommendations on the effective management of *A. erioloba* in the Kathu area were made. Recommendations included correct stocking rates, increasing community involvement in conservation, veld monitoring and the correct use of chemicals.



## OPSOMMING

Besorgde inwoners van Kathu rapporteer reeds sedert die vroeë 1980's 'n afname in die grootte van die *A. erioloba* populasie van dié gebied aan die Noord-Kaap Natuurbewaringsdiens. Hierdie is die derde studie rakende dié aangeleentheid wat deur die Noord-Kaap Natuurbewaringsdiens geïnisieer is, en het die doel om moontlike oorsake van die afname in die populasiegrootte van die *A. erioloba* in die Kathu distrik te identifiseer en aan te spreek.

Vyf ondersoek-areas is geïdentifiseer, naamlik die Khai-Appel Natuurreservaat (KAN); die plase, Lylyveld en Demaneng, wat albei wind-af van die Sishen Yskor Ysterertsmyl (SY) geleë is; die Sishen Golfbaan; en die plase, Swarthaak en Knapdak, wat albei wind-op van die SY geleë is. Die Sandveld Natuurreservaat aan die Vrystaatkant van die Bloemhofdam is as kontrolegebied geïdentifiseer.

Met die doel om verdere ondersoeke te rig, is die *A. erioloba* populasiestruktuur van die studie- en kontrolegebiede vergelyk. Onreëlmatighede in die struktuur van die studiegebied het aangedui dat daar wel faktore teenwoordig is wat a) saailinge verhoed om hoër hoogteklaas te bereik, of b) wat bome in die middel-hoogteklaas doodmaak. 'n Struktuuropname waarin net dooie *A. erioloba* individue aangeteken is, is dus gedoen om een van bogenoemde moontlikhede te elimineer. Resultate het getoon dat albei hierdie moontlikhede (a + b) in Kathu 'n rol speel.

Deur middel van vraelyste wat deur die distrik versprei is, is drie hoofareas wat moontlik skadelik vir *A. erioloba* kan wees, geïdentifiseer, naamlik die mynbou aktiwiteite van die SY, bestuurspraktyke, en natuurlike verskynsels.

Twee aspekte van die SY is geïdentifiseer as potensieel skadelik vir die *A. erioloba* populasie, naamlik die mynstof wat gevorm word as 'n byproduk van mynbou-aktiwiteite, en die verlaging van grondwatervlakke. Skandeer-elektron-mikroskopie het getoon dat blare wel deur mynstof beskadig word. Die invloed van mynstof op die transpirasietempo, chlorofil *a* en *b* inhoud en proteïeninhoud van *A. erioloba* blare is bepaal. Daar is gevind dat mynstof geen noemenswaardige invloed op enige van hierdie veranderlikes het nie. Sowel die invloed van mynstof op ontkieming, as die groeipotensiaal van die embrio is bepaal deur middel van

ontkiemingsproewe. Geen inhiberende invloed is op laasgenoemde prosesse waargeneem nie; intendeel, dit blyk dat mynstof albei stimuleer. Geen studies is onderneem aangaande die invloed van 'n verlaging in grondwatervlakke op *A. erioloba* nie, weens die onuitvoerbaarheid van sulke proewe. Navraag aangaande die kwessie is wel gedoen by verskeie geohidroloë. Die volgende afleiding is gemaak: weens die teenwoordigheid van 'n ondeurdringbare dolerietgang tussen die mynakwifer en die ander twee akwifers van die gebied, het die verlaging van grondwatervlakke in die myngebied geen invloed op die bome van Kathu nie. Hierdie stelling is bevestig deur die waterpompsyfers van die verskillende mynkompartemente met dié van boorgatwatervlakke regdeur die streek te vergelyk.

Drie bestuurspraktyke is geïdentifiseer as potensieel skadelik vir *A. erioloba*, naamlik die oorbelading van blaar- en gemengde vreters; peulverwydering; en die onoordeelkundige gebruik van chemikalieë. 'n Vergelyking tussen die huidige belading van die KAN en die huidige blaarvreterkapasiteit van dié gebied het aan die lig gebring dat hierdie area totaal oorbelaa is. Dit het tot gevolg dat *A. erioloba* saailinge nie 'n kans gegun word om hoogteklasse te bereik waar benutting nie meer fataal is nie. Peulversameling beperk voortplanting deurdat daar geen saadbank opgebou word nie. Dit impliseer dat geen genetiese variasie in die *A. erioloba* populasie oor tyd opgebou word nie, wat fataal kan wees indien omgewingstoestande in die toekoms sou verander. Die onoordeelkundige gebruik van chemikalieë in 'n poging om *A. mellifera*, wat as indringer in hierdie gebied beskou word, uit te roei, doen tans groot skade aan die *A. erioloba* populasie.

Een natuurlike verskynsel wat as potensieel skadelik vir *A. erioloba* bestempel is, is ondersoek, naamlik saadpredatering deur Bruchidae kewers. Ontkiemingsproewe het aan die lig gebring dat saadpredasie wel die voortplanting van *A. erioloba* inhibeer. Daar word egter hiervoor gekompenseer deurdat elke volwasse *A. erioloba* individu 'n groot aantal sade produseer. In die proses word oorvoorsien in saadpredatore se behoeftes en het saadpredasie nie 'n negatiewe impak op die *A. erioloba* populasie nie.

Aanbevelings is gemaak aangaande die effektiewe bestuur van *A. erioloba* in die Kathu omgewing, insluitend die korrekte belading van wild, groter gemeenskapsbetrokkenheid in bewaring, veldmonitering en die korrekte gebruik van chemikalieë.



APPENDIX A

(4) Neither—

- (a) a reference to a duty to consult specific persons or authorities; nor
- (b) the absence of any reference to a duty to consult or give a hearing,

in this Act exempts the official or authority exercising a power or performing a duty from the duty to proceed fairly in respect of all persons entitled to be heard.

(5) Explanatory notes, printed in bold italics, at the beginning of Chapters and Parts must not be used to interpret this Act.

## CHAPTER 2

### SUSTAINABLE FOREST MANAGEMENT

*The purpose of this Chapter is to promote the sustainable management of forests.*

#### PART 1

##### *Management*

*Part 1 lists principles of sustainable forest management, which apply to all official decisions affecting forests, whether in terms of this Act or other laws. The Minister is given the power to—*

- \* set criteria, indicators and standards for assessing and enforcing sustainable forest management; and
- \* create incentives to manage forests sustainably,

*on the advice of the Committee for Sustainable Forest Management.*

3. Principles to guide decisions affecting forests.—(1) The principles set out in subsection (3) must be considered and applied in a balanced way—

- (a) in the exercise of any power or the performance of any duty in terms of this Act;
- (b) in the development and implementation of government policies affecting forests;
- (c) in the exercise of any power or the performance of any duty in terms of any other legislation where the exercise of that power or the performance of that duty will impact on a natural forest or woodland;
- (d) in the issuing of a licence or other authorisation relating to the use of water for afforestation or forestry in terms of section 39 (1) or 40 (1) of the National Water Act, 1998; and
- (e) by any person required in terms of any legislation to carry out an environmental impact assessment in respect of any activity which will or may have an effect on natural forests or woodlands.

(2) An organ of State applying these principles must—

- (a) take into account the differences between natural forests, woodlands and plantations;
- (b) recognise that conservation of biological diversity within plantations should be promoted in a way which is consistent with the primary economic purpose for which the plantation was established;
- (c) only apply those principles which it considers relevant to the decision or action which is contemplated; and
- (d) give such weight to each principle as it considers appropriate.



(3) The principles are that—

- (a) natural forests must not be destroyed save in exceptional circumstances where, in the opinion of the Minister, a proposed new land use is preferable in terms of its economic, social or environmental benefits;
- (b) a minimum area of each woodland type should be conserved; and
- (c) forests must be developed and managed so as to—
  - (i) conserve biological diversity, ecosystems and habitats;
  - (ii) sustain the potential yield of their economic, social and environmental benefits;
  - (iii) promote the fair distribution of their economic, social, health and environmental benefits;
  - (iv) promote their health and vitality;
  - (v) conserve natural resources, especially soil and water;
  - (vi) conserve heritage resources and promote aesthetic, cultural and spiritual values; and
  - (vii) advance persons or categories of persons disadvantaged by unfair discrimination.

(4) The Minister must determine the minimum area of each woodland type to be conserved in terms of subsection (3) (b) on the basis of scientific advice.

**4. Promotion and enforcement of sustainable forest management.**—(1) For the purposes of this section, "owner" means—

- (a) the registered owner; or
- (b) where the registered owner has transferred control of the forest management unit in question to another person or organ of State, whether by way of assignment, delegation, contract or otherwise, that person or organ of State.

(2) The Minister may—

- (a) determine—
  - (i) criteria on the basis of which it can be determined whether or not forests are being managed sustainably;
  - (ii) indicators which may be used to measure the state of forest management; and
  - (iii) appropriate standards in relation to the indicators; and
- (b) create or promote certification programmes and other incentives to encourage sustainable forest management,

on the advice of the Committee for Sustainable Forest Management.

(3) The Minister must—

- (a) publish the criteria, indicators and standards in the form of regulations made under section 53 (2) (b);
- (b) identify clearly where the breach of a standard may be an offence.

(4) The Minister may publish the criteria, indicators and standards in such other media as he or she considers appropriate.

(5) Specific regional, economic, social and environmental conditions must be taken into account in determining criteria, indicators and standards.

(2) The decision to declare a protected area may not be revoked, nor may a protected area which is State forest be sold, nor may a servitude over a protected area be granted, without—

- (a) the Minister following the same procedure as that required for declaring the protected area; and
- (b) the approval by resolution of Parliament.

(3) Changes to the boundaries of an existing protected area require compliance with subsection (2) (a) only.

**11. Management of protected areas.**—(1) The Minister is responsible for the management of the protected area.

(2) The Minister must—

- (a) manage the protected area in a manner which is consistent with the purpose for which it was established; and
- (b) make rules for the management of the protected area so as to achieve the purpose for which the area has been protected, unless suitable rules already exist for the area.

(3) The Minister may grant financial or other assistance to the registered owner of land referred to in section 8 (1) (c) for the management of a protected area.

### PART 3

#### *Protection of trees*

*Part 3 allows the Minister to declare a tree, a group of trees, a woodland or a species of trees as protected. The procedure for and the effect of this declaration are set out. An emergency procedure is included to protect trees threatened with immediate harm.*

**12. Declaration of trees as protected.**—(1) The Minister may declare—

- (a) a particular tree;
- (b) a particular group of trees;
- (c) a particular woodland; or
- (d) trees belonging to a particular species,

to be a protected tree, group of trees, woodland or species.

(2) The Minister may make such a declaration only if he or she is of the opinion that the tree, group of trees, woodland or species is not already adequately protected in terms of other legislation.

(3) In exercising a discretion in terms of this section, the Minister must consider the principles set out in section 3 (3).

**13. Normal procedure for declaring protected trees.**—(1) Except in the circumstances referred to in section 14, the Minister must, before making a declaration under section 12—

- (a) give notice of the proposal to protect a tree, group of trees, woodland or species and invite comments and objections within a specified period; and
- (b) consider the comments and objections received in response to the notice.



(2) The Minister must—

- (a) publish the notice referred to in subsection (1) in the *Gazette* and in two newspapers circulating in, and air it on two radio stations broadcasting to—
  - (i) the vicinity, in the case of a particular tree or group of trees or woodland; or
  - (ii) the entire country, in the case of a species; and
- (b) deliver the notice to—
  - (i) the persons and bodies referred to in section 9 (2) (b), in the case of a particular tree or group of trees or woodland;
  - (ii) the bodies referred to in subparagraphs (i) and (ii) of section 9 (2) (b), in the case of a species.

(3) After deciding to make a declaration the Minister must publish a notice in the media referred to in subsection (2) (a)—

- (a) recording his or her decision; and
- (b) identifying the particular tree or group of trees or woodland or species to be protected.

**14. Emergency procedure for protecting trees.**—(1) If the Minister is of the opinion that any tree sought to be protected in terms of this Part may be damaged or destroyed before a declaration under section 12 could come into effect, he or she may act under this section.

(2) The Minister may declare any tree or group of trees to be temporarily protected by publishing a notice in two newspapers circulating in, and airing it on two radio stations broadcasting to—

- (a) the vicinity, in the case of a particular tree or group of trees or woodland; or
- (b) the entire country, in the case of a species.

(3) The Minister may act under subsection (1) without consulting or hearing any person if the urgency of the situation justifies this.

(4) The prohibition referred to in section 15 (1) applies to a tree or group of trees temporarily protected in terms of this section.

(5) The temporary protection lapses when—

- (a) the Minister publishes a notice in terms of section 13 (3);
- (b) the Minister decides not to protect the trees under section 12, in which event he or she must publish a notice confirming this in the media referred to in subsection (2); or
- (c) the Minister fails to act in terms of paragraph (a) or (b) within 12 months of the day the notice referred to in subsection (2) became effective.

**15. Effect of declaration of protected trees.**—(1) No person may—

- (a) cut, disturb, damage, destroy or remove any protected tree; or
- (b) collect, remove, transport, export, purchase, sell, donate or in any other manner acquire or dispose of any protected tree,

except under a licence granted by the Minister.

(2) The decision to declare a tree, group of trees, woodland or species protected may not be revoked, nor may the notice referred to in section 13 (3) be amended, without the Minister following the procedure set out in section 13.

(3) The Minister must publish—

- (a) a list of all species protected under section 12; and
- (b) an appropriate warning of the prohibition referred to in subsection (1) and the consequences of its infringement,

annually in the *Gazette* and in two newspapers circulating nationally.

**16. Registration against title deeds.**—(1) Where the Minister has declared—

- (a) a forest to be a natural forest under section 7 (2); or
- (b) a particular tree or group of trees or woodland to be protected under section 12 (1),

the Minister may request the registrar of deeds for the area to make an appropriate note.

(2) On receiving such a request, the registrar of deeds must make a note of the particulars of such declaration in his or her registers in terms of section 3 (1) (w) of the Deeds Registries Act, 1937 (Act No. 47 of 1937).

(3) The State does not acquire any rights—

- (a) in the land on which any natural forest or any protected tree is situated; or
- (b) to any tree or forest produce,

as a result of the prohibition in section 7 (1) or a declaration under section 7 (2), 12 (1), 14 (1) or 17 (2) or the making of a note in terms of this section.

#### PART 4

##### *Measures to control and remedy deforestation*

*Part 4 gives the Minister powers to intervene urgently to prevent deforestation and to rehabilitate deforested areas. The procedure for and the effect of the exercise of these powers are set out. It also provides for the Minister to enter into an agreement with the owner to remedy the situation.*

**17. Power to declare controlled forest areas.**—(1) For the purposes of this section, "owner" means—

- (a) the registered owner; and
- (b) where the registered owner has transferred control of the forest management unit in question to another person or organ of State, whether by way of assignment, delegation, contract or otherwise, that person or organ of State.

(2) If the Minister is of the opinion that urgent steps are required to—

- (a) prevent the deforestation or further deforestation of; or
- (b) rehabilitate,

a natural forest or a woodland protected under section 12 (1) which is threatened with deforestation, or is being or has been deforested, he or she may declare it a controlled forest area.

(3) The Minister declares a controlled forest area by publication of a notice in two newspapers circulating in, and by airing it on two radio stations broadcasting to, the vicinity—

- (a) recording his or her decision;
- (b) stating a fixed time period for which the declaration is effective;
- (c) describing the area;
- (d) identifying the activities which are or become prohibited in the area in terms of subsection (4);



## CHAPTER 7

## OFFENCES AND PENALTIES

*This Chapter sets out the relevant offences in terms of the Act and the penalties applicable.*

## PART 1

*Sentencing*

*Part 1 deals with matters relating to sentencing.*

**58. Penalties.**—(1) A person who is guilty of a first category offence referred to in sections 62 and 63 may be sentenced to a fine or imprisonment for a period of up to three years, or to both a fine and such imprisonment.

(2) A person who is guilty of a second category offence referred to in sections 62, 63 and 64 may be sentenced on a first conviction for that offence to a fine or imprisonment for a period of up to two years, or to both a fine and such imprisonment.

(3) A person who is guilty of a third category offence referred to in sections 62 and 63 may be sentenced on a first conviction for that offence to a fine or imprisonment for a period of up to one year, or to both a fine and such imprisonment.

(4) A person who is guilty of a fourth category offence referred to in sections 63 and 64 may be sentenced on a first conviction for that offence to a fine or community service for a period of up to six months or to both a fine and such service.

(5) A person who is guilty of a second, third or fourth category offence may be sentenced on a second conviction for that offence as if he or she has committed a first, second or third category offence, respectively.

(6) A person who is guilty of a fifth category offence referred to in section 61 may not be sentenced to imprisonment, but may be sentenced to a fine up to R50 000.

(7) The maximum amount of the fine referred to in subsection (6) may be amended by the Minister by a notice in the *Gazette* in order to counteract inflation.

(8) A court which sentences any person—

- (a) to community service for an offence in terms of this Act must impose a form of community service which benefits the environment if it is possible for the offender to serve such a sentence in the circumstances;
- (b) for any offence in terms of this Act, may suspend or revoke a licence granted to the offender under section 7 or 23.

**59. Compensatory orders in criminal proceedings.**—(1) A court which convicts a person of an offence in terms of this Act, may order—

- (a) the return of any forest produce or protected tree which has unlawfully been removed, cut or damaged, to the person entitled to it if it is feasible to do so; and, in addition to or instead of such return,
- (b) the person convicted to pay damages to any person who suffered a loss as a result of the offence.

(2) The power in subsection (1) is in addition to any other powers the court has in the proceedings in question.

(3) An order under subsection (1) is executed in the same manner as a judgment of that court in a civil case.

**60. Award of part of fine recovered to informant.**—(1) A court which imposes a fine for an offence in terms of this Act, may order that a sum of not more than one-fourth of the fine, be paid to any person whose evidence led to the conviction or who helped bring the offender to justice.

(2) An officer in the service of the State may not receive such an award.

## PART 2

### *Offences*

*Part 2 lists all the offences in terms of the Act in relation to the corresponding Chapters in the Act.*

**61. Offences relating to sustainable forest management.**—Any person who fails to take the steps which he or she has been instructed to take in terms of section 4 (8) within the period or the extended period laid down, is guilty of a fifth category offence.

**62. Offences relating to protection of forests and trees.**—(1) Any person who contravenes the prohibition of certain acts in relation to trees in natural forests referred to in section 7 (1) is guilty of a second category offence.

(2) Any person who contravenes—

- (a) the prohibition on the cutting, disturbance, damage or destruction of forest produce in or the removal or receipt of forest produce from a protected area referred to in section 10 (1) is guilty of a second category offence;
- (b) the rules referred to in section 11 (2) (b), is guilty of a third category offence;
- (c) the prohibition on—
  - (i) the cutting, disturbance, damage, destruction or removal of protected trees referred to in section 15 (1) (a); or
  - (ii) the prohibition on the collection, removal, transport, export, purchase or sale of protected trees referred to in section 15 (1) (b),is guilty of a first category offence.

(3) Any person who contravenes a prohibition or any other provision in a notice declaring a controlled forest area under section 17 (3) and (4) is guilty of a second category offence.

**63. Offences relating to use of forests.**—(1) Any person who—

- (a) without authority, enters or is in an area of a forest which is not designated for access for recreation, education, culture or spiritual fulfilment, is guilty of a fourth category offence;
- (b) contravenes a rule made by an owner in terms of section 20 (3) or a registered owner in terms of section 21 (2), is guilty of a fourth category offence;
- (c) invades the privacy of, or causes damage to the property of, a registered owner in contravention of the prohibition referred to in section 21 (5), is guilty of a third category offence;
- (d) damages, removes or interferes with any beacon, boundary, fence, notice board or other structure in a forest without authority, is guilty of a fourth category offence;
- (e) without authority makes a mark or sign on a rock, building, tree or other vegetation in a forest, is guilty of a third category offence;
- (f) dumps or scatters litter in a forest, is guilty of a fourth category offence.



**APPENDIX B**

Please take time to fill in the following questionnaire regarding the deaths of *Acacia erioloba* (camelthorn) trees in the Kathu region. Your time and input will be highly appreciated. Completed questionnaires will be collected from you.

1. Occupation \_\_\_\_\_
2. Number of years resident in the Kathu area \_\_\_\_\_
3. Are you resident a) on a farm \_\_\_\_\_  
b) in town \_\_\_\_\_
4. Have you noticed a general decline in the size of the *Acacia erioloba* population over time?  
\_\_\_\_\_
5. Have you noticed an increasing number of deaths of *Acacia erioloba* trees in recent years?  
\_\_\_\_\_

If your answer to question 4 or 5 was yes, please answer the following:

5.1 When did you first notice this decline/these deaths?  
\_\_\_\_\_

5.2 Where did you notice this decline/these deaths?

- a) The Khai-Apple Nature Reserve \_\_\_\_\_
- b) The Sishen Golf Club \_\_\_\_\_
- c) The streets/gardens of Kathu \_\_\_\_\_
- d) A Farm \_\_\_\_\_
- e) The roadside \_\_\_\_\_
- f) The entire region \_\_\_\_\_

5.3 What would you ascribe this decline/these deaths to?

- a) Natural causes \_\_\_\_\_
- b) Human influence \_\_\_\_\_
- c) Mining activities in the region \_\_\_\_\_
- d) Management practices \_\_\_\_\_
- e) Other \_\_\_\_\_

5.4 Do(es) this decline/these deaths trouble you? \_\_\_\_\_

If yes, why? \_\_\_\_\_

Answer questions 6-11 only if you are resident on a farm.  
\_\_\_\_\_



6. Have you noted a decline in the number of *Acacia erioloba* (camelthorn) trees on your property in recent years? \_\_\_\_\_

7. If yes, when? \_\_\_\_\_

8. To what would you ascribe this decline?

a) Natural causes \_\_\_\_\_

b) Mining activities of the region \_\_\_\_\_

c) Your own management strategies \_\_\_\_\_

d) Other \_\_\_\_\_

9. Which of the following height classes of *Acacia erioloba* are prominent on your farm?

a) <0.75 m \_\_\_\_\_

b) 0.75-1.5 m \_\_\_\_\_

c) 1.5-2.5 m \_\_\_\_\_

d) 2.5-3.5 m \_\_\_\_\_

e) 3.5-5.5 m \_\_\_\_\_

f) > 5.5 m \_\_\_\_\_

10. What was your observation regarding pod production over the years?

a) It is constant from year to year \_\_\_\_\_

b) It varies from year to year \_\_\_\_\_

c) It is dependent on the rainfall \_\_\_\_\_

If so, in what way? \_\_\_\_\_

d) It is dependent on the age of the tree \_\_\_\_\_

e) Good production occurs in cycles of several years \_\_\_\_\_

11. Do you have any suggestions on how to preserve the Kathu Forest for the generations to come?

\_\_\_\_\_  
\_\_\_\_\_

12. If you are willing to be quoted on your answers, or contacted for further information, please state your name, address and contact number.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Your time and input are highly appreciated.