ASPECTS OF SEED PROPAGATION OF COMMONLY UTILISED MEDICINAL TREES OF KWAZULU-NATAL

by

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DECLARATION

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These studies represent original work by the author and have not been submitted in any form to another University. Where use was made of the work of others it has been duly acknowledged in the text.

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ABSTRACT

Due to over-exploitation of commonly-used medicinal plants, mainly from KwaZulu-Natal, because of ever-increasing human population growth, many of the useful medicinal plants are becoming depleted in their natural habitats. Some species like *Warburgia salutaris*, which is currently declared very rare in the KwaZulu-Natal province, appear to be on the verge of extinction. In order to counteract this over-exploitation, this study sought to provide information that could help resource users to grow these threatened species through *ex situ* conservation methods.

A short list of heavily utilised medicinal tree species was selected from the approximately 700 tree species indigenous to KwaZulu/Natal. The criteria considered for short listing were; life form, species scarcity, past population status and part used. A total of 23 species were short listed, but a subset of 12 species was selected based on the availability of fruits and seeds. The aim of short-listing was to work on a manageable number of commonly utilised medicinal tree species.

The seed physiology and growth of these species were studied. With the exception of *Erythrophleum lasianthum* and *Curtisia dentata*, all of them had a moisture content of ≥ 20 % (on a dry mass basis), which is indicative of a recalcitrant behaviour. However, it could not be concluded that these seeds were truly recalcitrant because desiccation sensitivity was not directly assessed. Using the triphenyl tetrazolium chloride (TTC) viability test, most of the seeds of the 12 species seemed to be of good quality. Results of the TTC test for seed viability were similar to results obtained

using direct germination for most species. Results of flotation test for seed viability were different from the results obtained using direct germination for most spcies. The pre-treatment which achieved the highest germination percentage in almost all the seed types was cracking the outer coverings. Cracking pre-treatment appeared to be efficient in enhancing the removal of some substances which might inhibit germination of seeds. Hot water and acid pre-treatments frequently reduced germination.

Growth of young seedlings was assessed in terms of stem diameter, height, and leaf area under sun and shade. Seedling growth in terms of stem diameter and height of most species did not show any significant difference. One of the few species which showed statistically significant differences in stem diameter growth was *Ekebergia capensis*. It was found that 3 out of 10 of the species showed statistically significant differences in height growth. Two of the statistically significant differences in height occured on seedlings in the sun while one had statistically significant difference in the 40% shadecloth while 7 did not. Significant differences in leaf area occured on 7 out of 10 species. Of these, 4 species had higher growth in the shade than in the sun while 3 had higher growth in the sun than in the shade. Generally, it appears that young developing seedlings establish themselves well under shade environment; this could be because most of the species used in this study are forest species.

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ABBREVIATIONS

Abbreviation	
d	day
mm	millimeter
cm^2	square centimetres
min	minute
%	percentage
^0C	degrees Celsius/Centigrade
TTC	triphenyl tetrazolium chloride
y^{-1}	per year

"Man will destroy himself if he thoughtlessly and violently upsets the complex and delicate web of life of which he is part."

THOMAS R. DETWYLER

CHAPTER ONE

GENERAL INTRODUCTION

1.1. THE IMPORTANCE OF PLANTS IN TRADITIONAL SOCIETIES

Plants, because of their role as primary producers, are the basic primary resources which every human being is dependent on for a continued existence particularly for food and fuel. Traditionally, plants are the main direct supply of medicine (*muthi*), food, fibre, fuel and timber to indigenous people. Many ritual symbols are also drawn from the plant kingdom (Kokwaro, 1983).

Herbal medicines have been used since the beginning of human civilisation (Halloin, 1986). The world's population continue to rely chiefly on traditional herbal medicine for their primary health care (Williams, 1996). In some countries, therapy is still confined to medicinal plants (Sequeira, 1994). According to Cunningham (1994) and Kendler *et al* (1992), South Africans are dependent mainly upon wild populations of plants for food and medicine.

This dependence on medicinal plants, including trees, for primary health-care has become unsustainable. Many medicinal trees are becoming over-exploited in their natural habitats and some are killed everyday through ring-barking and root-cutting. Bark collecting through ring-barking at Tootabie Nature Reserve was also observed to be seriously threatening indigenous trees including *Curtisia dentata*, one of the commonly utilised medicinal trees (La Cock and Brier, 1992). Many of the gatherers have no formal employment and they depend on bulk harvesting for survival. In order to ensure future supplies, conservation must strongly be considered. This is particularly true in developing countries where there is the greatest dependence on such natural resources.

In the past in Southern Africa, the utilisation of medicinal plants (*muthi*) was done sustainably where the 'specialists' (*inyanga* and *sangomas*) were the only people who could gather. Utilisation practices were based on tradition and culture such that over-exploitation of the resources on which they were totally dependent upon was avoided. Thus, unintentional conservation was based on taboos, religious controls, technical inadequacies, seasonal and social restrictions (Cunningham, 1988). The tribal chiefs were the only people who could and did impose rules which also prohibited any gathering of edible fruits before they were ripe and the fine of a cow could be imposed to a perpetrator. Ring-barking was not allowed, only a small part of the bark was supposed to be removed from one side of the tree trunk and subsequently the other side could be used (east or west; north or south) while the opposite side was recovering. Such rotational harvesting of the bark on those different aspects was done because there is a general belief that the wind which has the ancestral spirit blows to any direction (Mabogo, pers. comm.). Such unintentional traditional conservation methods worked and over-exploitation and extinction were not that significant. The relatively small human population size and also its densities also meant that exploitation levels were low.

1.2. BIOLOGICAL DIVERSITY AND COMMERCIAL VALUES

South Africa has a remarkable rich flora of vascular plants with 23,404 taxa (Njuguma, 1994). The proportion of vascular plant species that are endemic to South Africa is exceptionally high, being more like what might be expected of an oceanic island than of a part of a continent. South Africa has one of the highest species densities in the world (Njuguma, 1994), contributing 8.4% to the world's total number of taxa.

Many of the useful medicinal plant species are becoming rare in parts of South Africa (Cunningham, 1994). They are getting depleted in their natural habitats through unsustainable harvesting. Such practices enhance a decline of their populations in their habitats where they have a limited distribution. Species which have limited distributions may be easily over-exploited. This appears to be the case for some plant species like *Warburgia salutaris* and *Siphononchilus natalensis* which are already endangered in KwaZulu-Natal.

South Africa has large plant biodiversity and the commercial utilisation of its indigenous species can benefit people considerably. Commercially, the horticultural industry, excluding cutflowers, bulb, rose and protea exports, is valued at approximately R390 million wholesale annual turnover and the ornamental plant turnover is approximately R42 million (Cunningham, 1994). The annual turnover for the indigenous plant sales locally (in South Africa) is approximately R8 million (Cunningham, 1994). The horticultural industry, is thought that it can in fact expand and become an even greater employer of labour (Cunningham, 1994). The informal *muthi* trade forms part of a multi-million rand 'hidden' economy which encompasses both rural and urban areas (Cunningham, 1989). This trade seems to be strong in KwaZulu-Natal because of the ever increasing demand.

Traders in traditional medicine were recorded in Durban as early as 1923 (Cunningham, 1989). In the year 1915, in Durban, herbal medicines were sold in small quantities mainly by herbalists and diviners at eMatsheni market (Cunningham, 1990). Currently, there are more than 500 species being harvested and traded as medicinal plants on the Witwatersrand (Williams, 1996). In Durban, 500 informal sellers, primarily women with no specialised training as traditional medical practitioners, supply the Durban area in bulk (Cunningham, 1989).

This cultural change, the increased entry into the cash economy and rising unemployment, however, have brought about the breakdown of conservation controls by resource gatherers and traders. The emergence of these commercial medicinal plant gatherers in response to urban demand for *muthi* and rural unemployment has resulted in indigenous medicinal plants being considered as a common resource instead of a resource used by a 'specialist' (Cunningham, 1993). The commercial gatherers and hawkers of medicinal plants all have a low level of education and little formal employment opportunities and as such they earn a subsistence living from wild plant resources (Scott-Shaw, 1990). Against this background it is not surprising that they unsustainably gather raw *muthi* materials and sell them in cities, towns and townships. Williams's (1996) study showed that the increase of *muthi* industry has grown partly as a result of abolition of the apartheid laws and partly because of the encouragement traditional practices, especially in health care, by the new government. This shows that the popular indigenous plants with economic values are under increasing pressure.

1.3. TRADITIONAL AND CURRENT CONSERVATION PRACTICES

The rapid human population growth rate which is directly generating the demand constitutes a threat to many useful medicinal plants. Cunningham (1988) and Osborne *et al* (1994) emphasised that the primary cause of over-exploitation of medicinal tree species and many other plants for the herbal trade is caused by rapid human population increase. This over-exploitation continues despite provincial and national legislation prohibiting the gathering of the protected species (Cunningham, 1988) and consequently the trade being illegal.

According to Levine and Miller (1991), the exponential human population growth and economic development have led to a dramatic alteration of many terrestrial and aquatic environments. It has been found that the population of KwaZulu-Natal is probably composed of more than 8 million people. About a 5 fold increase of population who use medicinal plants has occurred in the Natal region in 1980 (Central Statistics Service, 1986; Cunningham, 1988). The rate of increase of the black population in the Durban area has risen to an unprecedented 9% per annum in 1980 (Anon, 1984). In the KwaZulu-

Natal region, the present annual population growth rate is about 2.4% (Grobbelaar, 1985). The population of KwaZulu-Natal is expected to be 12 million by the year 2016 (Cunningham, 1988).

The increase in demand for traditional medicines has resulted in an unprecedented growth in commercial harvesting and sale of traditional medicines (Cunningham, 1988). Cunningham (1988) pointed out that in 1929, there were only two herb traders and by 1987 this had risen to over 100 registered herb traders belonging to Natal Herb and Traditional African Medicines Traders Association (HTA). At that time 400 herb traders were estimated to be operational throughout KwaZulu-Natal (Cunningham, 1988). According to Williams (1996), under the M2 highway south of Johannesburg, two years ago there were 10 people selling medicinal plants but today, there are more than 100. Therefore, the medicinal plant trade is well developed in South Africa and is on a scale that is a cause for concern amongst the conservation organisations and herbalists (Cunningham, 1988).

Over recent years, the demand has risen to the point where some of the species are becoming rare in the wild. The over-exploitation pressure is extreme on all those popular medicinal trees which are slow growing, have limited distribution, are sensitive to ring-barking and up-rooting. *Erythrophleum lasianthum*, *Ocotea bullata*, *Curtisia dentata* and *Warburgia salutaris* are some of the slow growing plants which can take 15-20 years to reach harvesting maturity. The only medicinal trees of which the overwhelming demand can still be met are for those which are fast growing. In KwaZulu-Natal, some of those species are: *Albizia adianthifolia*; *Ekebergia capensis*; and *Protorhus longifolia*. These medicinal plants can reach harvesting maturity at the age of 5-8 years. For the medicinal plant trade, much profit is derived from fast-selling popular trees, the 'bread-and-butter' plants for many traders (Williams, 1996). However, some of the fast-selling species are the slow growing species: *Warburgia salutaris*; *Ocotea bullata*; and *Curtisia dentata*. Thus because of their popularity and usefulness to resource users.

According to Williams's (1996) study, there has been a change in the origin of the harvested material. In 1992, a significant percentage of material was harvested in Natal, followed by the former Transvaal and Swaziland. Smaller amounts were gathered in Botswana and Zimbabwe. The depletion of resources in Natal has also led to the gathering of large amounts of medicinal plant resources from the former Transvaal, Botswana, Transkei, Mozambique and Cape Town (Williams, 1996). Some medicinal plant species are imported through traders in Durban to either supplement for indigenous plants that are becoming scarce on local markets or as new medicines (Williams, 1996).

An important reason for the decrease in the area of natural vegetation in KwaZulu-Natal has been the spread of urban development, afforestation and agriculture (Cunningham, 1988; Scott-Shaw, 1990). This kind of problem seems to be difficult to solve given the population and the rate of urbanisation. Due to the increase in demand in KwaZulu-Natal, it appears that there will never be any recovery of the depleted natural forests unless cultivation of medicinal plants is not done on a large scale.

It also appears popular medicinal plants have been considerably affected in the past and harvesting, whether on a subsistence or commercial level of indigenous plant products has led to a decline in their population size (Cunningham, 1994). For example, almost a century ago, *Mondia whitei* (uMondi), had been almost exterminated in the Durban area (Medley-Wood and Evans, 1898). The disappearance of the endemic *Siphonochilus natalensis* (iNdungulo) from one of the few known localities in Natal had occurred by 1900 (Medley-Wood and Frans, 1911). The heavy exploitation of *Warburgia salutaris* (isiBhaha), *Erythrophleum lasianthum* (umKhwangu) and *Alepidia amatyambica* (iKhathazo) was recorded over 50 years ago (Gerstner, 1938; 1946). Nearly all these cases of heavy exploitation were associated with a commercial trade (Cunningham, 1988). Ring barking of most large *Ocotea bullata* (stinkwood) and *Curtisia dentata* (assegai) trees in KwaZulu-Natal has reduced their numbers considerably. The consequence of complete ring barking is the death of the tree and subsequently the forest if alien species start invading the gaps left by open canopies.

Outside the strict conservation areas in Natal, *Warburgia salutaris* were ring-barked and some of those inside the conserved areas had their bark removed as well (Cooper and Swart, 1992). This species is now endangered and nearly extinct in the area. Every year in KwaZulu-Natal *W. salutaris* was being cut down (Cunningham, 1990). Kokwaro (1983) also confirms that some of the largest *Warburgia salutaris* trees have been completely ring-barked and died in Kenya. This extensive commercial trade in traditional medicine has had three important consequences: over-exploitation of certain popular species; a rapid increase in prices of species that have been depleted in the wild; and the major 'loss' of valuable timber of *Ocotea bullata* and *Curtisia dentata* (Cunningham, 1988).

This demand and dependence on medicinal plants has been primarily caused by many factors; the indigenous people stay in areas remote from hospitals (Kokwaro, 1983), they prefer indigenous medicine to Western because it is safe, effective, cheap, readily available (Sequeira, 1994) and traditional systems are more culturally acceptable and are able to meet the psychological needs in a way Western medicine does not; and lastly crowding and inefficient service in hospitals (Sequeira, 1994). In the year 1976, there was an average of 17,400 patients to one doctor in KwaZulu-Natal and in 1982, there were 116,000 patients to one doctor in QwaQwa and 30,000 patients to one doctor in Lebowa (Scott-Shaw, 1990). With respect to traditional medicine, however, the situation is different. In Zimbabwe, there were 575 patients to one traditional healer and in Venda, 720 patients to one traditional healer were recorded (Scott-Shaw, 1990).

The over-exploitation of some medicinal plants is exacerbated by other factors like timber gathering. Selective exploitation of forests for timber in the late nineteenth and early twentieth centuries in KwaZulu-Natal and Transkei also affected supplies of traditional medicinal plants (Cunningham, 1988). For an example, *Curtisia dentata* and *Ocotea* *bullata* are known for their durable wood which is good for timber. In 1901, 52% of forests in Transkei were exhausted of the exploitable timber of *Ocotea bullata* and *Curtisia dentata* (Cunningham, 1988) and the value for timber for each species was R 1500 per square metre (cm^2) in the early 1980's. Furthermore *Curtisia dentata* is reported to have been heavily exploited for its timber in Transkei (Cooper and Swart, 1992). *Curtisia dentata* wood has also been used to make 'assegai' shafts, hammer handles, wheel spokes and wagons, rafters and floors (Pitman and Palmer, 1972). At present, the basal area of *Ocotea bullata* in afromontane forest in Transkei is 27.6 m^2 per ha (Cawe, 1986) compared with King's (1941) estimate of 60 m^2 per ha, a difference that Cawe (1986) attributes to timber exploitation.

Intentional management practices are uncommon and are represented by cultivation of *Siphonochilus aethiopicus* (iNdungulo), the removal of small patches of bark from trees rather than ring-barking and possibly the sustainable harvesting of *Helichrysum ordatissimum* (iMpepho) (Cunningham, 1988). *Prunus africana* has an excellent resilience if small patches of the bark are removed (Cunningham, 1990). The only reported species which is very sensitive to bark removal is *Faurea macnaughtonii* because according to Cunningham (1988; 1990), it is very susceptible to fungal infection, woodborer attack and heart-rot even where small patches of the bark are removed. This shows that the removal of small patches of the bark from other medicinal trees is not an absolute solution.

Traditionally, the exploitation of medicinal plants has been constrained by taboos, religious beliefs, technical inadequacies, seasonal and social restrictions (Cunningham, 1988). Before the common availability of bush knives and metal hoes, traditional healers and their trainees collected roots and bulbs with a special sharpened stick (Krige, 1936) which limited digging efficiency (Cunningham, 1988). Practising as diviners or herbalists was a specialist activity and knowledge about resources was restricted by spiritual calling (Berglund, 1976). There is also a strong gender bias amongst the divining (mainly women) and herbalists (mainly men) professions. Collection of medicinal plants by menstruating women is also restricted by taboo as it is believed that it reduces their healing power (Fernandoh, pers. comm.).

Some herbalists now use magical medicine to give plants back their healing power when they have been collected by menstruating women (Cunningham, 1988). Taboos also restrict the seasonal (summer) collection of *Alepidea amatyambica* (iKhathazo), *Siphonochilus natalensis* (iNdungulu), *Peucedanum thodii* (umPhondovu), *Cassipourea gerrardii* (uMemezi obomvu) due to fear that collection during summer will cause storms and lightning (Cunningham, 1988) but the collection of *A. amatyambica* on misty day in Summer is considered acceptable as long as the material is not taken home.

Another reason why ring-barking and cutting of roots were not acceptable was because such practices lead to the death of trees. The belief was such that if the patient is treated with the specimens from plants which are dying of ring-barking and uprooting, the patient is going to die.

Unsustainable harvesting was also reduced by the 'odd' collection method of certain medicinal trees. The gatherer in that case was supposed to be naked and it should be done at night, otherwise if it was done during the day, it would never be effective (Mabogo, pers.comm).

Although backed up by religious beliefs, the careful harvesting of *Helichrysum ordatissimum* (iMpepho) and allied species may be intentional management practice (Cunningham, 1988). It is possible that this practice and seasonal restrictions on gathering of *Alepidea amatyambica* and *Siphonochilus natalensis* may have been motivated by the increased utilisation resulting from century-old trade in these species recorded in Webb and Wright (1976) and Cunningham (1988). The value and scarcity of *Siphonochilus natalensis* are certainly the motivating factors behind the cultivation by herbalists in KwaZulu-Natal (Cunningham, 1988).

The traditional healers and heredity chiefs who control access to communal lands admit that ring-barking and over-exploitation are "bad" practices (Cunningham, 1988). In some areas it appears that restrictions placed by chiefs and enforced by headmen and tribal police have greatly reduced commercial exploitation by gatherers.

Currently, there are clear indications, however, that customary controls are breaking down. The resource users gather medicinal extracts like bark and root unsustainably in order to make cash for survival. Gathering and trading are now regarded as ways of generating money.

1.4. LEGISLATION

Herbalists were registered on the recommendation of hereditary chiefs in whose area the herbalists resided in Natal under the Native Code of Law of 1891 and in Zululand under Section 194 of Zululand Proclamation No. 7 of 1895. Divining was equated with witchcraft and, therefore regarded as an offence by colonial administrators (Cunningham, 1988). It was not considered necessary to register traditional midwives. The registration of both herbalists and traditional midwives is now covered by the KwaZulu Act on the code of Zulu Law (Act 6 of 1981) (Cunningham, 1988). In Natal, herb traders need a General Dealers Licence and Patent Medicines Licence to sell unprotected flora: they also need a permit to sell protected and specially protected flora (Williams, 1992). Permits to gather protected plants are issued by the Natal Parks Board (NPB) if the gatherer has written permission from a land-owner to harvest such plants (Williams, 1992) or "where the Board considers it necessary" (Scott-Shaw, 1990).

All provinces in South Africa have legislation restricting the indiscriminate removal and damage of indigenous vegetation (Williams, 1992). In Natal, the Natal Provincial

Ordinance 15 of 1974 prohibits the possession or import into Natal province of any specially protected plant and include many of the popular medicinal plant species like *Warburgia salutaris* (isiBhaha), *Siphonochilus natalensis* (iNdungulu) and *Faurea macnaughtoni*.

According to Cunningham (1988), legislation that exists aimed to prevent:

(1) exploitation of indigenous plant species in State Forests (Forest Act No. 122, 1984, KwaZulu Forest Act No. 15, 1980, KwaZulu Nature Conservation Act No. 8, 1975 and the Natal Provincial Ordinance 15 of 1974)

(2) exploitation and sale of special protected species (Natal Provincial Ordinance of 1974)

(3) hawking, including hawking of medicinal plants [legal restrictions of the Group Areas Act (1950), Natal Ordinance 11 of 1973] and other laws on hawking reviewed in Anon (1984)

(4) the sale of poisonous substances (e.g. Potassium dichromate) by herb traders (Medicines and Related Substances Control Act No. 101 of 1965)

(5) the practising of unlicensed herbalists or any practising by diviners (Suppression of Witchcraft Act, 3 of 1957).

The legislation has failed to achieve all these objectives (Cunningham (1988). According to Gerstner (1946) legislation has slowed down the rate of increase in forest exploitation without providing solutions and the situation is not better today. Despite these control measures contained in restrictive legislation, populations of species which are vulnerable to over-exploitation are neither conserved nor replaced, thus depleting the local supply of popular medicinal plants (Cunningham, 1988). It also appears that without the restrictive legislation, traditional healers may lose self-sufficiency and commercial gatherers may lose their resource base.

1.5. CULTIVATION OF MEDICINAL TREES

Progress in conservation of medicinal plants can only be made by first assessing the extent of the trade and then the risk a plant faces as a result of being harvested (Williams, 1996). Cultivation initiatives for most threatened species can be implemented, but it is unfortunate since the most threatened species are slow-growing plants harvested for their roots and bark and for example they happen to be popular in the Witwatersrand 'muthi' markets (Williams, 1996). The wealth of plant life useful to people within threatened tropical and sub-tropical ecosystems is a strong contemporary justification for their conservation (Sequeira, 1994). Sequeira (1994) also pointed out that if conservation is not done, the destruction and degradation of high density ecosystems will not only erode traditional contact which local people have with their native flora, but also reduces chances of discovering many new economically plants. It is currently evident that many of the popular medicinal plants like *Warburgia salutaris* are on the verge of extinction and several others are threatened. Because of their usefulness to the rural population the survival and future replenishment of these medicinal plant species should be ensured by planting more in large scale. The cultivation of medicinal plants as recommended by

Cunningham (1989) can take pressure off the wild population. This may help restore the rare and the endangered species. This cultivation of medicinal plants as an alternative supply source suggested by Gerstner (1938, 1946) and Cunningham (1989) has recently received considerable publicity. Gerstner (1946) suggested that cultivation should be done on scientific lines. The cultivation of medicinal plants such as *Warburgia salutaris* was also proposed to the South African forestry department in 1946 (Scott-Shaw, 1990). Such cultivation was never undertaken and has resulted in the pepper-bark tree being now considered endangered in South Africa.

The following potential propagation techniques may help restore useful medicinal plants: tissue culture (micropropagation) where a mass of explants can be propagated from parts of the mother plant like leaf-buds and leafy-twigs; cuttings where leafy twigs are put into the soil; and propagation from seed. Propagation from seed is a suitable technique only if the seeds are readily available and of good quality. Many of the species used in traditional medicines are slow growing, therefore take time to reach maturity (flowering and fruiting). Some of the popular medicinal plants also may have a low seed set, produce seeds which may have a very short life-span, or produced seeds which are not viable. Propagation from seeds and cuttings are being practised on a relatively large scale at Silverglen Nursery, Chatsworth and are very successful. The aim of the nursery is to grow as many medicinal plant species as possible and by some years ago, Silverglen Nursery had as many as 200 species in cultivation. Education about propagation practices as is being carried on with the resource users (especially *inyangas*) can as well create job opportunities for people who received little education and with no employment.

However, there are social problems with the use of cultivated medicinal plants. Generally, there is a wide spread opinion that cultivated plants are less active than those collected from their natural environment (Rowson, 1973). The same opinion has been supported by a number of medicinal plant gatherers at Ezimbuzini *muthi* market, near Umlazi. Fernandoh (pers.comm.) has raised the idea that plants grown and raised in nurseries are very weak medicinally because they have diluted active ingredients. This idea was counteracted by Rowson's (1973) finding that the research done over many years have shown that cultivated plants are at least as active as the wild plant species. Some traditional doctors views emphasise the association and interaction of the different plant species in the wild. Plant species which are grown in the nurseries are isolated from other species in the wild. The plant species in the wild, according to traditional doctors have both physical and spiritual healing power whereas the ones raised artificially have only physical healing power , with no interaction with the ancestral spirit. Plants/trees growing in the wild interact with other organisms, including mycorrhiza, nitrogen fixing bacteria and other micro-organisms, and grow under fluctuating conditions. However, it is unlikely that species growing under controlled conditions experience such interactions. Physiologically, plants growing under controlled conditions might grow better than those in the wild, but may not have the same curative powers. This requires testing by the screening of compounds extracted from plants growing in cultivation and in the wild..

Since most of the resource users still do not believe fully in medicinal plants which are cultivated, an additional approach to ensure regrowth and propagation in the wild should be adopted. The 'take and replace' philosophy could be encouraged, possibly even by legislation.

1.6. AIMS OF THIS STUDY

The use of trees and other plants for medicinal purposes is an ancient practice which continues to thrive in South Africa and other parts of the world today because traditional medicine (*muthi*) is an important part of African tradition. But the rapid increasing human population pressure is seriously threatening the continued existence of popular medicinal trees growing in the natural environment through continuous unsustainable harvesting. The popular medicinal trees are becoming more commercialised than ever before and as such they may become endangered species. Currently their disappearance and possibly extinction in the wild becomes more than a possibility. The following aims of this study were organised to help in combating this over-exploitation:

1. To determine which species in KwaZulu-Natal are particularly threatened by medicinal plant use, and the reasons for this. In order to achieve this aim, it is necessary to determine which species are widely used, or used in a way that makes harvesting unsustainable - such as excessive removal of roots and ring-barking;
2. To investigate aspects of seed biology relevant to the timing of germination and to breaking dormancy;

3. To investigate seed germination, seedling establishment and sapling growth so as to increase the probability of re-establishment success, both *in-situ* and *ex-situ*.

CHAPTER TWO

SELECTION OF MEDICINAL TREE SPECIES FOR THIS STUDY

2.1. AN INVENTORY OF COMMONLY UTILISED MEDICINAL TREES

This study was conducted at the informal herbal markets at the Victoria street, Durban, and Isipingo, near Umlazi township. It was quite a difficult task to conduct a research in those informal herbal markets because the traders do not trust the researchers who they think might be police; secondly, since the *muthi* trading business is competitive, they think the researchers want to trade the same kind of traditional medicine they were selling; thirdly, it was disturbing because the traders could not attend to their customers well; fourthly, they also request some incentives as a compensation for their time and lastly, there was a language barrier because the resource users could not understand English. In order to avoid some of those problems in this study, informal herbal markets were frequented often to make the traders more familiar with the researchers and even some compensation in the form of money was given to many of them. Identity documents (student cards) were also produced and shown to them emphasising that the researchers were not police. In case of the language, a Zulu speaker was used to help translating isiZulu into English and vice versa.

Commonly utilised and popular medicinal plants are gathered from natural forest systems without replanting. Because of that, tree populations are declining and resources are becoming depleted in the wild. However, there is no doubt that the herbal medicine trade will continue to expand and that the pressure on indigenous plants will increase still further. An inventory of 140 commonly utilised medicinal trees was organised to help review the situation in KwaZulu/Natal. This inventory was based upon species described in Pooley (1993). Tables 2.1 and 2.2 summarise information in medicinal tree inventory. From this, a short list of species requiring further study was compiled using the criteria; percentage scarcity, past conservation status, part used and the importance of medicinal trees. Additionally, any information concerning the distribution and microhabitats, sexes (monoecious/dioecious), growth rate, phenology, general behaviour of seeds and some records of germination of certain species was also included. This was obtained through literature reviews, personal communications and personal observations. The short list is discussed in the subsections which follow.

Table 2.1. The part used and ailments treated by medicinal tree species. This information was collated from Barry *et al* (1992), Brandenwyk and Brandenwyk (1974), Breitenbach (1974), Cooper and Swart (1992), Cunningham (1988; 1990), Morty and Johnson (1987), Pooley (1993), Pujol (1993), Scott-Shaw (1990) and Van Wyk (1994/95) and from interviews with resource users (gatherers and traders).

Family /Species	**Zulu Names**	**Part Used**	**Treatments**
Ulmaceae *Trema orientalis*	umVangazi	Bark	medicinal uses
Moraceae *Ficus sur*	aNkuwa	Bark	Respiratory complaints
Ficus natalensis	umThombe	Bark/fruits	Gynaecological complaints during pregnancy
Ficus sycomorus	uMkhiwane	Bark/Milk latex /Fruits	Ringworms
Proteaceae *Faurea macnaughtonii*	iSefu/iSafu	Bark/wood	Purifies blood Treats pimples
Olacaceae *Ximenia americana*	umThunduluka-omncane	Bark/seed	Medicinal purposes
X. caffra	umGwenya	Leaves/stems roots/seeds	Medicinal purposes
Annonaceae *Annona senegalensis*	isiPhofu	Bark/leaves Roots/fruits	Wean babies
Trimeniaceae *Xymalos monospora*	umHlungwane	Bark/roots	Medicinal purposes
Lauraceae *Cryptocarya latifolia*	umHlangwenya	Bark	Gastro-intestinal and chest complaints/stomach cramps/allergy/magical
C. myrtifolia	iThungwa	Bark	Magical/medicinal
C. woodii	umThongwane	Bark	Medicinal purposes
Ocotea bullata	umNukani	Bark/wood	Bleeding/stomach/emetic/ bladder diseases
Caparaceae *Boscia albitrunca*	umVithi	Roots	Medicinal purposes
B. foetida	umVithi	Fruits	Magical and medicinal properties. Prevents lightning
Cladestemon kirkii	uPhanda	Roots	Medicinal purposes
Pittosporaceae *Pittosporum viridiflorum*	umKhwenkwe	Bark	Medicinal purposes

Table 2.1. Continues...

Rosacea *Leucosidea sericea*	isiDwadwa	Wood	Medicinal purposes
Prunus africana	iNyazangoma	Bark	Treats benign and prostatic hyperplasia/purgative for cattle/stomach ache/fever/
Mimosaceae *Albizia adianthifolia*	iGowne umBhelebhele	Bark/leaves /wood	Emetic/cleansing blood/skin diseases
A. anthelmintica	umNala	Bark/roots	Worm and tapeworm remedy
A. petersiana	umNyazangoma	Bark/roots	Stomach disorders
A. suluensis	uNyazangoma	Wood	Nervous complaints
A. versicolor	umPhisu	Bark/leaves /roots/wood	Backache/persistent cough
Faidherbia albida	umHlalankwazi	Bark/Wood	Ornamental carvings and also medicinally
Acacia caffra	umNyamanzi	Bark/wood	Medicinal and magical properties
A. burkei	umkhaya	Bark/leaves /Roots/wood	Eye/Back complaints
A. karroo	umuNga	Bark/wood /Gum	Treats sore throats
A. nilotica	umNqawe	Bark/leaves Roots/wood	Respiratory complaints
A. tortilis	isiThwethwe	Bark/Gum	Medicinal purposes
A. xanthophloea	umKhanya-gude	Bark	Fever and eye complaints
Dichrostachys cinerea	umZilazembe	Bark/leaves /fruits/wood	Treats snake bite/pain relieve
Newtonian hildebrandtii	umFomothi	Bark/roots /Twigs	Medicinal and magical purposes
Caesalpiniaceae *Erythrophleum lasianthum*	umKhwangu	Bark/roots Seeds/wood	Headache/stomachache/colds/bodypain/arthritis
Schotia brachypetala	iHluze umVovovo	Bark/roots	Heartburn/hangover /purifies blood
Afzelia quanzensis	inKele	Bark/roots	Bilharzia remedy/eye complaints
Senna petersiana	umNembenembe	Leaves/Roots	Medicinal purposes
Peltophorum africanum	umSehle	Bark/roots /wood	Against sterility/backache
Fabaceae *Bolasanthus speciosus*	umHohlo	Bark/wood	Medicinal purposes
Mundulea sericea	umaMentabebi	Bark/roots	Magical and medicinal purposes
Milletia grandis	umSimbithi	Roots/seeds /wood	Medicinally used
Erythrina caffra	umSinsi	Bark/leaves	Used medicinally

Table 2.1. Continues...

Balanitaceae *Balanites maughamii*	umNulu	Bark	Magical and medicinal purposes
Zanthoxylum capense	umLungamabele	Bark/leaves /roots	Snakebite remedy/strengthen babies/toothache
Z. davyii	umNungamabele	Bark/leaves /roots	Fever remedy
Vepris lanceolata	uMozane	Roots	Influenza remedy
Clausena anisata	isiFudu	Leaves/twigs	Strengthen Xhosa babies/reduce fever/kill tapework
Commifora africana	iMinyela	Resin/bark	Used medicinally
Ptaeroxylaceae *Ptaeroxylon obliquum*	umThathe	Bark	Treats headaches/ sinusitis/rheumatism/ magical
Turraea floribunda	uMadlozane	Bark/roots	Treats rheumatism/ heart ailments
T. obtusifolia	uMadlozane	Leaves	Treats enema
Meliaceae *Ekebergia capensis*	umNyamathi	Bark/roots	Treats coughs/skin-diseases/pimples/dysentry /headaches/ chronic coughs/acne/ vomiting/evil spirits
Trichilia emetica	uMathunzini	Bark/leaves	Used as emetic and treats broken bones
T. dregeana	uMathunzini	Bark/leaves/root s/seed/oil	Medicinally used
Malpighiaceae *Antidesma venosum*	umHlalanyoni	Bark/leaves /roots/fruits	Treat stomach complaints
Cleistanthus schlechteri	umZithi	Bark	Treats burns
Bridelia micrantha	umHlahle	Bark/roots	Treats sterility/respiratory/ gatric and eye problems
Croton gratissimus *Croton sylvaticus*	umaHlabakufeni/ umZilazembe	Bark/leaves	Treats rheumatism and pleurisy
Macaranga capensis	umPhumelele	Bark	Medicinally used
Spirostachys africana	umThombothi	Bark/roots /sap	Medicinally used/widely used
Sapium ellipticum	umHlepha	Bark	Medicinally used
S. integerrimum	umHlepha		Medicinally used
Euphorbia cooperi	umHlonhlo	Sap	Medicinally used
E. ingens	umHlonhlo	Roots	Treats warts
Anacardiaceae *Sclerocarya birrea*	umGanu	Bark	Strengthen babies
Harpephylum caffrum	umGwenya	Bark	Medicinally used
Protorhus longifolia	uNhlangothi	Bark/leaves	Vaccine for

Table 2.1. Continues...

		/roots	paralysis/ward of eveil spirits/good luck
Loxostylis alata	isiBara	Bark/leaves	Helps at childbirth
Ozoroa engleri	isiFice	Bark/leaves /roots	Medicinally used
Rhus chirendensis	umHlabamvubu	Bark/roots	Treats heart complaints
Aquifoliaceae *Ilex mitis*	umDuma	Bark/leaves	Medicinally used
Maytenus acuminata	isiNama	Bark	Treats stomach complaints
Celastraceae *Pterocelastrus echinatus*	uSahlulamanye	Bark	Medicinally used
P. tricuspidatus	uSahlulamanye	Bark	Medicinally used
P. rostratus	uSahlulamanye	Bark	Medicinally used
Cassine aethiopicus	umBovane	Bark	Medicinally used
C. papillos	umBovane.	Bark	Medicinally used and for magical purposes
C. transvaalensis	iNgwavuma	Bark	Treats stomach complaints
Salacia loptoclada	iSundwana	Leaves	Used as aphrodisiac
Sapindaceae *Deinbollia oblongifolia*	uMasibele	Roots	Treats gatric complaints
Pappea capensis	iNdaba	Bark/leaves and seeds	Treats baldness/ring worm/eye infection/ venerial diseases
Dodonae angustifolia		Leaves/Roots	Treats common cold and leaves have anaesthetic/stimulant qualities
Hippobromus pauciflorus	umFazi	Bark/leaves /roots	Treats coughs/diarr-hoea/headaches/eye-problem/hysteria and common cold
Melianthaceae *Bersama lucens*	uNdiyaza	Bark	Medicinally used
B. swinnyi	iNdiyandiya	Bark	Medicinally used
B. stayneri	uNdiyaza	Bark	Medicinally used
B. tysoniana	iNdiyandiya	Bark	Medicinally used
Greyia flanaganii	uSinya	Roots	Medicinally used
Rhamnaceae *Ziziphus mucronata*	umPhafa	Bark/leaves /roots	Treats respiratory complaints/pain/skin-infections and used magically
Berchemia discolor	uMumu	Bark/leaves	Used as poultices for wounds
B. zeyheri	umNini	Bark	Treats stomach dis-order/backache/evil-spirits

Table 2.1. Continues...

Sterculiaceae *Dombeya rotundifolia*	iNhliziyonkulu	Bark	Treats heart problems and stomach complaints
Ochnaceae *Ochna holstii*	isiBhanku	Bark	Medicinally used
O. natalitia	umNandi	Roots	Treats sterility
Clusiaceae *Garcinia gerrardii*	isiBinda		Medicinally used
G. livingstonei	umGobandlovu	Root	Used as aphrodisiac
Cannellaceae *Warburgia salutaris*	isiBhaha	Bark/root and stem	Stomach ulcer/sore-throat/coughs/blood-disorder/skin sores/toothache/ backache/VD/rheu-matism/nightmares/ malaria/respiratory complaints
Passifloraceae *Adenia gummifera*	uPhindamshaya		Widely used for medicinal purposes and as a charm
Rhynchocalycaceae *Barringtonia racemosa*	iBoqo		Treats fever
Rhizophoraceae *Cassipourea gerrardii*	uMemezi	Bark	Medicinally used
C. gummifera		Bark	Medicinally used
Combretaceae *Combretum apiculatum*	umBondwe	Leaves	Medicinally used
C. molle	umBondwe	Bark	Fever and stomach complaints
C. zeyheri	umBondwe	Bark	Treats gall stones
Pteleopsis myrtifolia	umWandla		Medicinally used
Terminalia sericea	umKhonono		Respiratory complaints
Syzygium cordatum	UmDoni	Bark	Treats stomach and respiratory ailments including magical
Araliaceae *Cussonia spicata*	umSenge	Leaves	Treats malaria/stomach complaints/venerial diseases
Schefflera umbellifera	umSengane	Leaves	Rheumatism and malaria
Cornaceae *Curtisia dentata*	umLahleni	Bark/twigs	Treats bleeding running stomach and promotes sexual activity
Myrsinaceae *Maesa lanceolata*	iNdende	Fruits and leaves	Treats worms/stomach complaints, dress wounds
Sapotaceae *Sideroxy inerme*	aMasethole-amhlophe	Bark/roots	Treats broken bones and fever

Table 2.1. Continues...

Englerophytum magalismontanum	Fruits/roots	Roots/fruits	Treats headaches rheumatism and epilepsy
Mimusops obovata	mKele	Bark	Medicinally used
Manilkara concolor	umNqambo	Roots	Medicinally used
M. mochisia	umNqambo	Roots	Medicinally used
M. discolor	umNqambo	Roots	Back pain/ brittle bones
Ebenaceae *Euclea coriacea*	umHlangula	Roots	Toothache
E. crispa	umNquma/o	Roots	Toothache
Azima tetracantha	iNgungumela	Bark/roots wood	Headaches/respiratory and renal ailments
Salvadora angustifolia		Pliable stems	Snakebite/disinfect-ant and toothache
Loganiaceae *Strychnos henningsii*	uManana	Bark	Nausea/intestinal worms/pains
S. spinosa	umHlala	Bark/wood	Snakebite/emetic/eye nose and fevers
Nuxia floribunda	iThambo	Bark	Used mdicinally
Apocynaceae *Acokanthera oblongifolia*	iNxinebe	Bark/leaves /roots	Snakebite/emetic
Acokanthera oppositifolia	iHlungunyembe	Bark	Snakebite/spiderbite colds/intestinal worms
Tabernaemontana elegans	umKhadu		Chest-complaints
Verbenaceae *Vitex ventricos*	uKhamamasane	Leaves	Treats fever
Vitex rehmannii	umLuthi umDuli	Bark/roots	Chest and stomach complaints
Clerodendrum glabrum	uQangazana	Roots/Fruits	Chest-infections colic/snakebite/intestinal worms in children and calves
Rubiaceae *Breonadia seilelna*	umHlume	Bark/wood	Stomach complaints
Burchellia bubalina	iThobankomo	Roots/fruits /wood	Used medicinally and for charm
Hyparacanthus amoenus	umThombothi	Root	Stomach complaints
Vangueria infausta	umVili/umVilo	Roots/leaves	Malaria and chest-complaints
Asteaceae/Compositae *Tarchonanthus camphoratus*	iGqepha-elimlophe	Bark/roots	Treats headaches/ respiratory/ complaints/ toothache
Rubiaceae *Rothmannia capensis*	iBolo/isiThebe	Bark/roots	Treats wounds/burns
Oleacea *Olea woodiana*	iSahlulambhazo	Bark	Used medicinally

Table 2.2. The past population status (how heavily was it used in the past) and the species scarcity (expressed in terms of the number of resource users who pointed out species which are scarce) of medicinal tree species. This information was collated from Barry *et al* (1992), Brandenwyk and Brandenwyk (1974), Cooper and Swart (1992), Cunningham (1988; 1990), Morty and Johnson (1987), Pooley (1993), Scott-Shaw (1990) and Van Wyk (1994/95) and 40 resource users, * Scarce species of concern; # species selected for further consideration because of heavy utilisation.

Species	Past Population Status	No of Resource Users
Trema orientalis		
Ficus sur		0
Ficus natalensis		0
Ficus sycomorus		0
*Faurea macnaughtonii** #	Heavily utilised Population declining	12
Ximenia americana		2
X. caffra		2
Annona senegalensis		
Xymalos monospora		
Cryptocarya latifolia		26
*C. myrtifolia** #	Heavily utilised	26
*C. woodii** #	Widely used	26
*Ocotea bullata** #	Vulnerable/Population declining/90% were over-exploited	28
Boscia albitrunca		
B. foetida		
Cladestemon kirkii		
Pittosporum viridiflorum		4
Leucosidea sericea		
*Prunus africana** #	Heavily utilised Population declining	8
*Albizia adianthifolia**	Widely used/plenty	10
A. anthelmintica		
A. petersiana		
*A. suluensis** #	Heavily utilised	12
A. versicolor		
Faidherbia albida		0
Acacia caffra		1
A. burkei		0

Table 2.2. Continues...

A. karroo		0
A. nilotica		0
A. tortilis		0
A. xanthophloea		0
Dichrostachys cinerea		0
Newtonian hildebrandtii		
Erythrophleum lasianthum#*	Vulnerable/Decline	3
Schotia brachypetala		0
Afzelia quanzensis		0
Senna petersiana		0
Peltophorum africanum		0
Bolasanthus speciosus		
Mundulea sericea		
Milletia grandis		0
Erythrina caffra		1
Balanites maughamii #*	Heavily utilised	15
Zanthoxylum capense #*	Vulnerable	12
Z. davyii		
Vepris lanceolata		
Clausena anisata		3
Commifora africana		0
Ptaeroxylon obliquum		0
Turraea floribunda #*	Widely used in the past	8
T. obtusifolia		
Ekebergia capensis #*	It is heavily used/Very high demand	18
Trichilia emetica		0
T. dregeana	Widely used/plenty	
Antidesma venosum		
Cleistanthus schlechteri		
Bridelia micrantha		
Croton gratissimus *Croton sylvaticus* #*	Popular and heavily used/very scarce	12
Macaranga capensis		
Spirostachys africana		
Sapium ellipticum		
S. integerrimum		
Euphorbia cooperi		
E. ingens		
Sclerocarya birrea	Heavily utilised	4
Harpephylum caffrum #*	Bark heavily utilised	8
Protorhus longifolia #*	It is heavily utilised	12
Loxostylis alata		
Ozoroa engleri		
Rhus chirendensis		
Ilex mitis #*	It is heavily utilised	8

Table 2.2. Continues...

Maytenus acuminata		
Pterocelastrus spp. * #	It is heavily utilised, great demand declining	30
Cassine aethiopicus		
C. papillos * #	Bark is highly prized for 'muthi'	16
C. transvaalensis * #	Bark is in high demand. Vulnerable/declining	16
Salacia loptoclada		
Deinbollia oblongifolia		0
Pappea capensis		0
Dodonae angustifolia		
Hippobromus pauciflorus		
Bersama spp. * #	Very high demand Heavily exploited	22
Greyia flanaganii	High demand	
Ziziphus mucronata		
Berchemia discolor	In great demand	
B. zeyheri		
Dombeya rotundifolia		
Ochna holstii		
O. natalitia		
Garcinia gerrardii		
G. livingstonei * #	High demand	12
Warburgia salutaris * #	Very high demand It is nearly extinct	36
Adenia gummifera * #	In great demand Declining	8
Barringtonia racemosa		
Cassipourea gerrardii * #	Bark in great demand/declining	20
C. gummifera * #	Bark in great demand	
Combretum apiculatum		
C. molle		
C. zeyheri		
Pteleopsis myrtifolia		
Terminalia sericea		
Syzygium cordatum		
Cussonia spicata		
Schefflera umbrellifera		
Curtisia dentata * #	In great demand and large specimens rare/vulnerable	24
Maesa lanceolata		
Sideroxy inerme	Plenty	
Englerophytum	Plenty	

Table 2.2. Continues...

magalismontanum		
Mimusops obovata	Not plenty	
Manilkara concolor	Plenty	
M. mochisia	Not plenty/low demand	
M. discolor	Plenty	
Euclea coriacea	Not plenty/high demand	
E. crispa	Not plenty	
Azima tetracantha		
Salvadora angustifolia		
Strychnos henningsii		
S. spinosa	Low demand/plenty	0
Nuxia floribunda		
Acokanthera oblongifolia	High demand/plenty	
Acokanthera oppositifolia		
Tabernaemontana elegans		
Vitex ventricos	Scarce	3
Vitex rehmannii	Plenty	
Clerodendrum glabrum		
Breonadia seilelna		
Burchellia bubalina		0
Hyparacanthus amoenus		0
Vangueria infausta	Plenty	2
Tarchonanthus canphoratus	Plenty	0
Rothmania capensis		0
Olea woodiana	Scarce	9

2.1.1. Species Scarcity and the Past Population Status

Species scarcity was the first criterion considered for short-listing. The species scarcity was adapted from Cunningham (1988). Forty reliable resource users were interviewed and asked about the availability of individual species in Table 2.1. The species scarcity was expressed in terms of the number of resource users who mentioned that certain species were scarce (Table 2.2). Where the species scarcity was zero, the species was regarded to be abundant; where there was no comment regarding scarcity, the species was not known well by the traders. All trees which were within a range of 8 to 40 number of people who said such species were scarce in the wild were short-listed. A minimum number of 8 people who said certain species were scarce was used to allow for all possible species which might be of concern to be included. Scarcity of the species within this range (8-40) were indicated by an asterix (*) in Table 2.2. Twenty-six species fell within this range in Table 2.2.

The past population status was assessed through literature reviews. This past population status in this study was based on information concerning the degree of use of the species and its abundance. The species which were described as being heavily utilised with declining population were strongly considered for short-listing. Twenty-five species which were heavily utilised were indicated by hatch sign (#) in Table 2.2. As can be seen from Table 2.2, twenty-five species were indicated to be both within scarcity range of concern and being heavily utilised.

2.1.2. The Part Used and the Importance of *Muthi*

The use of bark and roots were parts of concern in this short-listing because ring-barking and excessive root-cutting result in the death of the whole tree. The excessive utilisation signifies the popularity of the species concerned. Species where twigs, seeds, fruits and leaves were used for treatment were considered less important for short-listing. For example, harvesting of leaves, fruits and seeds encourages rapid re-sprouting of trees. From the 25 species selected for being heavily utilised and within the indicated scarcity range in Table 2.2, twenty-three tree species were short-listed for being more over-exploited than others as their bark and/or root is used for treating many different diseases as shown in Table 2.1. Among the 23 tree species in Table 2.3, certain species like *Ekebergia capensis* and *Warburgia salutaris* were observed to treat many diseases, and probably that was the reason why such species are very popular.

Table 2.3. Short-listed tree species (from Table 2.2) selected for being perceived as heavily utilised and potentially vulnerable.

Species	**Species**
Erythrophleum lasianthum	*Ilex mitis*
Ekebergia capensis	*Garcinia livingstonei*
Balanites maughamii	*Harpephylum caffrum*
Zanthoxylum capense	*Adenia gummifera*
Warburgia salutaris	*Albizia suluensis*
Curtisia dentata	*Olea woodiana*
Bersama lucens	*Albizia adianthifolia*
Prunus africana	*Cassine transvaalensis*
Faurea macnaughtonii	*Cassipourea gerrardii*
Protorhus longifolia	*Ocotea bullata*
Pterocelastrus triscuspidatus	*Cryptocarya woodii*
Croton sylvaticus	

2.2. THE SPECIES SELECTED FOR FURTHER STUDIES

Information concerning the traditional medicine (*muthi*) demand in terms of the number of bags purchased per annum and their prices, distribution, growth rate and seed physiology and phenology and sexes of the 23 short-listed species was collected. The information was obtained through literature reviews, personal observations and personal communications.

2.2.1. The Number of Bags of *muthi* Sold and Prices Per Bag

Thirty resource users (gatherers and traders) from Victoria street and Isipingo informal herbal markets were interviewed in order to obtain information about the number of bags of particular medicinal plant items sold per annum and the price per bag. The problem encountered was that the resource users did not have any accurate record of whatever they sold per annum, but some of the resource users knew of the amounts they sold per week. Some resource users could not even estimate how much they sold per week as their presence in the informal herbal markets was very variable because they were also gatherers. A rough estimate for certain *muthi*, gave a probable number of bags sold per annum per sum of both markets (Table 2.4) from the number of weeks added together for a period of a year. Such was done after estimating a rate of *muthi* purchasing. The second criterion was the price of a bag of *muthi* for a particular species and whether the material sold rapidly, which would indicate high popularity. Such kind of information could be very useful when assessing demand and supply.

Table 2.4. The *muthi* demand (plant items in 50 kg bags sold per annum and the price per bag) for the short-listed medicinal tree species. The information was collated from the resource users (gatherers and traders) at the Victoria street and Isipingo informal herbal markets in Durban. An asterix (*) indicates that the material sells quickly.

Species	No. of Bags/Annum	Price/Bag, R/Bag
Erythrophleum lasianthim	339	120*
Ekebergia capensis	289	120*
Balanites maughamii	187	50*
Zanthoxylum spp.	151	65
Warburgia salutaris	1212	120 and above*
Curtisia dentata	672	45-50*
Bersama spp.	423	50*
Prunus africana	205	50-60
Faurea macnaughtonii	363	45*
Protorhus longifolia	300	60*
Pterocelastrus spp.	901	45*
Cryptocarya spp.	480	40
Ocotea bullata	930	50*
Cassipourea gerrardii	508	120*
Cassine transvaalensis	282	140*
Albizia adianthifolia	1368	40*
Olea woodiana	210	45-50
Albizia suluensis	1372	50-60
Adenia gummifera	201	45-50
Harpephylum caffrum	230	40-45
Garcinia livingstonei	273	40-50
Ilex mitis	198	35-40

Table 2.4. Continues...

Croton sylvaticus	480	50-60

2.2.2. Distribution of Medicinal Trees

The distribution of the tree species gives a guideline about the specific habitats where those species grow in the conditions to which they are well adapted (Table 2.5). This information showed which trees were forest species, and which not. In such case predictions could be made on the habitats where certain seedlings could do well. For example, forest species which grow under canopies of other plants could be expected to do well under shade.

Table 2.5. The distribution of the short-listed medicinal tree species. The information was collated from Johnson and Johnson (1990), Pooley (1993), Nichols, Pillay and Mari (pers. comm.).

Species	**Distribution**
Erythrophleum lasianthum	Restricted to sand forest, found in False Bay in Zululand, Maputaland and Mozambique.
Ekebergia capensis	Found in evergreen forest, coast to midlands, riverine vegetation, in Natal and Transkei and also in Cape, Transvaal, Swaziland, Mozambique, Botswana, Zimbabwe, Sudan and Ethiopia.
Warburgia salutaris	Bushveld and forest in Zululand, also in Transvaal, Swaziland, Mozambique and tropical Africa.

Table 2.5. Continues...

Curtisia dentata	Evergreen forest, from coast to 1800m altitude in Natal/Transkei, Cape Peninsula, Transvaal, Swaziland, tropical africa.
Ocotea bullata	High forest from Cape, Transkei, south facing slope in Natal midlands, Zululand, Swaziland.
Cassipourea gerrardii	evergreen forests, thicket and swamp forest in Natal/Transkei from coast to midlands, eastern Cape, Transvaal, Swaziland, tropical Africa
Protorhus longifolia	Forest, forest margin, rock-outcrop, riverine vegetation , Natal/Transkei, eastern Cape, Swaziland, Transvaal
Pterocelastrus tricuspidatus	Margins of drier forest, rocky outcrop, southern Natal/Transkei, southern Cape, Transvaal, Swaziland
Faurea macnaughtonii	Widely scattered distribution in Natal/Transkei, Knysna, eastern Transvaal, Tanzania and Madagascar
Cryptocarya latifolia	Along streams and rivers from eastern Cape, Transkei to Zululand
Cassine transvaalensis	Open woodland, bushveld and thicket in central Natal and Zululand, Transvaal, Swaziland, Mozambique, Zimbabwe, Zambia to Angola
Prunus africana	Evergreen forest from near coast, mistbelt in Natal/transkei, eastern Cape, Swaziland, eastern Transvaal to Zimbabwe, tropical Africa

Table 2.5. Continues...

Albizia suluensis	Found in forest, riverine thicket and open woodland, endemic to Hlabisa district in Zululand, locally common in suitable habitat
Balanites maughamii	Found in open woodland, dry forest, thorn thicket and coastal forest in northern Zululand from Kwambonambi to Maputaland. Also from Transvaal, Swaziland, southern Mozambique to tropical Africa
Ilex mitis	Found near water in forest, widespread from sea level to mountatins in Natal and Transkei
Garcinia livingstonei	Found in bushveld and coastal grassland in Zululand, also in Transvaal, Swaziland, Mozambique, Botswana, Namibia and tropical Africa
Adenia gummifera	Found in forest and scrub from coast to 1200m in Natal and Transkei. Widespread in Transvaal, Swaziland to tropical Africa
Zanthoxylum capense	Found in dry scrub, bushveld and on forest margins. Occurs in Natal and Transkei, also from the eastern Cape to Swaziland, Transvaal, Mozambique and Zimbabwe
Croton sylvaticus	Found in low altitude forests in Natal and Transkei (Pondoland). Also in Transvaal, Swaziland, Mozambique and tropical Africa
Harpephylum caffrum	Found in forests in Natal and Transkei. Also from eastern Cape to Swaziland, Transvaal and Mozambique
Pterocelastrus tricuspidatus	Margins of drier forest, rocky outcrop,

Table 2.5. Continues...

	southern Natal and Transkei, southern Cape, Transvaal, Swaziland
Olea woodiana	Occur in evergreen forest, woodland and coastal bush

2.2.3. Growth rates of Medicinal Trees

Information concerning growth rates of the seedlings and trees was summarised (Table 2.6).

Table 2.6. The general tree growth rate (F, fast; S, slow) and seedling growth rate (cm y^{-1}) of the short-listed medicinal tree species. The information was collated from Pitman and Palmer (1972), Pooley (1993) and Pillay (personal communication).

Species	**Growth rate of trees**	**Growth rate of seedlings**
Erythrophleum lasianthum	S	50
Ekebergia capensis	F	70
Warburgia salutaris	S	50
Curtisia dentata	S	60
Ocotea bullata	S	60
Cassipourea gerrardii	S	Not recorded
Protorhus longifolia	F	80
Pterocelastrus spp.	S	Not recorded
Faurea macnaughtonii	S	Not recorded
Balanites maughamii	S	40

Table 2.6. Continues...

Cryptocarya woodii	S	50
Cassine transvaalensis	S	Not recorded
Prunus africana	S	100
Albizia adianthifolia	S	Not recorded
Ilex mitis	S	80
Garcinia livingstonei	S	30
Adenia gummifera	S	Not recorded
Harpephylum caffrum	F	100
Zanthoxylum capense	S	Not recorded
Croton sylvaticus	F	120
Bersama lucens	S	40
Olea woodiana	S	Not recorded

2.2.4. The Phenology and Sex (Dioecious/Monoecious) of Medicinal Trees

The phenology of flowering and fruiting was also considered as important (Table 2.7). This information was very important because it indicated the time of the year at which ripe fruits of short-listed species were available. Knowledge of different sexes (monoecious/dioecious) was also very important in order to assess the viability of seeds and pollination of flowers because some seeds could be non-viable probably because there was no pollination when a particular tree was flowering.

Table 2.7. The phenology (flowering and fruiting) and sexes (monoecious/dioecious) of the short-listed medicinal tree species. This information was collated from Pitman and Palmer (1972) and Pooley (1993).

Species	**Flowering Period**	**Fruiting Period**	**Sex**
Erythrophleum lasianthum	September-November	June-August	Monoecious
Ekebergia capensis	August-December	November-April	Dioecious
Balanites maughamii	July-October	September-May	No record
Zanthoxylum capensei	October-January	January-May	Dioecious
Warburgia salutaris	April-May	October-December	Monoecious
Curtisia dentata	December-January	May-October	Monoecious
Bersama lucens	September-May	February-August	Mon/Dioecious
Prunus africana	March-May	September-November	No record
Faurea macnaughtonii	December-March	November-April	Monoecious
Protorhus longifolia	July-September	September-December	Dioecious
Pterocelastrus echinatus	November-June	February-August	No record
Cryptocarya woodii	June-September	October-December	Monoecious
Ocotea bullata	January-May	February-June	Dioecious
Cassipourea gerrardii	September-January	January-May	No record
Cassine transvaalensis	December-April	February-September	No record
Albizia adianthifolia	August-December	September-February	No record
A. suluensis	September-December	May-September	No record
Olea woodiana	October-January	January-April	Mon/Dioecious
Adenia gummifera	October-December	December-February	No record
Harpephylum caffrum	November-February	March-August	No record
Garcinia livingstonei	August-September	November-February	No record
Ilex mitis	October-February	March-April	Dioecious
Croton sylvaticus	September-January	December-May	Monoecious

2.3. FINAL SHORT LIST OF MEDICINAL TREES

A final short list of 12 species from Table 2.3 was selected to be investigated in more detail. The criteria used for further reducing the list were the availability of fruit and seed for experimental studies. The historical background of some of these 12 species is briefly discussed below.

Erythrophleum laisanthum (Caesalpiniaceae)

It was known as *E. guineense* or *E. suaveolens* (Palgrave, 1985). This species was confused in South Africa with *E. suaveolens*, a tropical species, which does not occur at all in the Republic of South Africa (Pitman and Palmer, 1972). It is commonly known as umKhwangu in Zulu. It is also known as the Swazi Ordeal tree (Palgrave, 1984). Its compound leaves are alternate from slightly swellings on the branchlets. It has twice bipinate compound leaves with 7-13 pairs (Pooley, 1990; Dyer, 1975). It has large and showy flowers in axillary, tiny yellow-green flowers with orange anthers borne in honey scented racemes in terminal sprays. Its species name *lasianthum* came from its arrangement of terminal sprays of its flowers meaning 'with woolly flowers (Dyer, 1975). The generic name *Erythrophleum* was derived from its powerful alkaloid named *erythrophleine* (Dyer, 1975). Concerning the sex of flowers, refer to Table 2.7. It has large curved pod fruits and it is a legume. The pod fruit has two valves or it is indehiscent without seed release and the seed is rarely with endosperm and fleshy cotyledon and its radicle is straight (Moll, 1992). Its actual habitat is dry forest on sandy soils (Moll, 1992), open forests, forest margins and stream banks (Pitman and Palmer, 1972). Its bark and seeds were found to have the powerful alkaloid, *erythrophleine* . This metabolite compound was regarded as an ingredient of arrow poison for fish, game and rats (Pitman and Palmer, 1972). Its leaves killed cattle in South Africa and sheep have also died after eating the leaves (Pitman and Palmer, 1972). Its bark is of great market value for its potency (Pooley, 1990). According to Pitman and Palmer (1972), the bark is used as a remedy for lung sickness in cattle and the snuff made from powdered bark to relieve colds is sold in Durban. The other medicinal and magical uses are in Table 2.1. Its only mode of propagation known so far is through seed. The leguminous seed is said to germinate quickly if scarified (Pooley, 1993; Nichols, pers. comm.). The seedlings are said to be frost sensitive and drought resistant (Nichols, pers. comm.).

Ekebergia capensis (Meliaceae)

It was also known as *E. meyeri* (Pitman and Palmer, 1972), *E. ruepelliana and E. buchananii* (Palgrave, 1984). According to Pitman and Palmer, 1972), there are three species of *Ekebergia* in Transvaal, Natal and southern Cape near George, South Africa. Its common name is umNyamathi in Zulu and it is commonly known as Mutobvuma in Tshivenda. It is also commonly known as the Cape ash or the Cape dogplum (Pooley, 1993; Palgrave, 1984). Its genus name was given by a traveller and a naturalist, Andrew Spartan who first saw it in the year 1775 (Pitman and Palmer, 1972). It was named in compliment to a Captain Ekeberg who made it possible for Andrew Spartan to visit Cape (Pitman and Palmer, 1972). The species name *capensis* was given after the country Cape where it was named. It has spirally arranged compound leaves with large leaflets of 1-7 pairs with a terminal leaflet. It has a tall trunk with a grey-brown bark, smooth to rough and flaking. The flowers are borne in the axils of leaves. The fruiting and flowering periods are in Table 2.7. Its flowers are pollinated by ants and bees (Pitman and Palmer, 1972). The fruit is round, more or less succulent with 2-5 cells, containing one to several hard seeds. The fruit is bright red when ripe, smooth and shiny and the period for ripening is recorded in Table 2.7. Fruits are eaten by birds, baboons and monkeys. Its leaves are browsed by antelopes and they are also used for fodder in times of drought (Pitman and Palmer, 1972). It is a food plant for *Bunea alcinoe* moth larvae and *Charaxes brutus natalensis* (Pooley, 1993; Pitman and Palmer, 1972). Its habitat is forest, riverine bushland and rock outcrop bushveld (Moll, 1992). According to van Wyk (1992) this species also does well in sandy soil and in dry areas. Apart from being used for medicinal purposes, the bark is also used for tanning (Palgrave, 1985). This species is also used for panelling beams for boats, building sides of wagons, and was used for the outside doors and windows of the Anglican Church in Somerset East (Pitman and Palmer, 1972). This tree can be used for shade and as ornamental in streets, homestead, parks and bus ranks. Magically, in the field, the burnt branches ward off evil spirits (Pitman and Palmer, 1972). The medicinal uses are all in Table 2.1. The only known mode of propagation is through seed. According to Pooley (1993), seeds germinate quickly when sown while still very fresh. Generally, it takes 10-15 days for the seeds to germinate (Pillay, personal communication). According to Carr (1994), the seeds do not germinate well. Such might be happening in the natural environment where there are a number of influences (fungi) on seeds. Seedlings and trees of this species are said to be cold resistant but tender to severe frost (Pitman and Palmer, 1972).

Curtisia dentata (Cornaceae)

Cornaceae is a small family of about 15 genera and over 100 species of trees and shrubs most common in temperate parts of northern hemisphere and the only member indigenous to South Africa is *Curtisia dentata* (Pitman and Palmer, 1972). It was also known as *Curtisia faginea* (Palgrave, 1984) and easily confused with *Sideroxylon dentatum* which is also known as 'Assegai tree' (Moll, 1990). *Curtisia dentata* is commonly known as umLahleni in Zulu, Musangwe in Tshivenda because of its hard wood, and as the 'Assegai' tree. Its generic name was given in honour of William Curtis, the founder of Unique Botanical Magazine which was first published in 1786 (Pitman and Palmer, 1972). The species name *dentata* was a description of the serrated leaves which resemble fine teeth. The common name 'Assegai' meaning spear is not Zulu as is generally thought. The word is derived either from *Azzaghayah* which is Arabic (Pitman and Palmer, 1961), or through Portuguese from Latin '*Hasta*' meaning spear (Pitman and Palmer, 1961). The leaves of this species are shaped like the sharp pointed head of the spear. Its leaves are oppositely arranged, leathery, shiny, dark green and serrated with velvety grey to reddish hairs (Pooley, 1993). The flower is composed of creamy, velvety terminal sprays and the fruit is round and pea-sized, a four celled drupe. The flower sexes, the flowering and fruiting periods are in Table 2.7. Fruits are eaten by birds, monkeys and bush pigs (Pitman and Palmer, 1972). Its habitat is at high altitude (2500m) on cliffs and rocky outcrops, near strongly flowing streams in Natal and Transkei and at the coast it does well on the 1800m altitude in the rainforest (Pooley, 1993). It also does well in forest and occasionally at the margins (Pitman and Palmer, 1961). This species is better known for its use than for its beauty (Pitman and Palmer, 1961). It is also used in the making of hammer handles, wheel spokes, rafters and flooring (Pitman and Palmer, 1972). Since the earliest times, its durable wood was much prized for wagon making in particular as the economy of South Africa was dependent on wagons and building of strong hard-wearing vehicles (Pitman and Palmer, 1972). 'Assegai' trees were felled in their thousands and consequently tall trees disappeared from the forest and today a well mature tree is uncommon (Pitman and Palmer, 1972). Even the Trojan horse was carved from the famous tree 'Assegai' (Pitman and Palmer, 1972). As the trees of this family have an early connection with spear making, most of spears of Roman soldiers and African Warriors were made from it (Pitman and Palmer, 1972). It is also widely used for medicinal and magical purposes. More information about the medicinal uses is in Table 2.1. Its known mode of propagation is both through seed and cutting. Seeds have a stony coat and it is difficult to germinate them with such a coat. It can take 3-11 months or more to germinate. Tissue culture is another way of propagating this species. The cutting and seed propagation are done in Silverglen. The propagation using seeds was said to be difficult as the germination is very slow and erratic (Nichols, pers. comm.). The seeds are frost resistant (Carr, 1994).

Warburgia salutaris (Canellaceae)

It was also known as *Chibaca salutaris*, *Warburgia ugandensis* and *W.breyeri* (Dyer, 1975). It is commonly known as isiBhaha in Zulu. It is also commonly known as the pepperbark because of its peppery taste. The genus was named after Dr Otto Warburg, 1859-1938, born in Hamburg (Pitman and Palmer, 1972). The tree was first collected in South Africa in 1917 by Dr H.G. Breyer, hence *Warburgia breyeri* (Pitman and Palmer, 1972). Its species name *salutaris* meaning healthy, was of Arabian origin 'karamboki', isiBhaha in Zulu (Pitman and Palmer, 1972). To date back to days when Arab traded with Africa, the Arabs used to carry back with them the bark of this tree for use as incense and probably as medicine (Pitman and Palmer, 1972). It has simple leaves, alternate arrangement, untoothed, gland-dotted leaves and shiny like tea-bush (Pitman and Palmer, 1972). It has greenish to yellowish flowers and its fruit is a roundish berry with a leathery glandular skin. The flower sexes, flowering and fruiting periods are in Table 2.7. Its fruits are eaten by monkeys and baboons. This species can grow with other species like *Acacia* and *Dichrostachys* species (Pooley, 1993). It also grows with *Euclea racemosa* (Pooley, 1993). It can be found in forests, gorges, bushveld and in lowveld areas (Pitman and Palmer, 1961). It is also a tropical species (Dyer, 1975). This species is known only for its medicinal and magical properties and this information is in Table 2.1. The known modes of propagation are through seed and cuttings and these methods are being practised in Silverglen Nature Reserve. Seeds germinate quickly when sown while still very fresh. It takes 10-15 days to germinate (Pillay, pers. Comm.). In order to avoid rife parasitism, fruits should be collected while still green. The specific parasite for fruits is a fruitfly (Pillay, pers. comm.).

Zanthoxylum capense (Balanitaceae)

It was also known as *Z. thunbergii*, *Z. grandifolia*, *Fagara magalismontana* and *Fagara capensis* (Palgrave, 1984). It is commonly known as umNungamabele in Zulu. It is also known as the small knob-wood (Palgrave, 1984). It has compound leaves with 3-6 pairs of leaflets plus a terminal leaflet. The leaflets are shiny dark green the dorsal side and paler dull on the ventral side (Pooley, 1993). The information about their flowering period is in Table 2.7. It has small round fruits, lemon scented in clusters. The fruiting period is in Table 2.7. It can be found in the forest, scrub forest which are fairly mesic (Moll, 1984). This species is also strongly used medicinally and magically. More information about this in Table 2.1. Currently, the only propagation known is through seeds. Black, oily and shiny seeds have also a strong sweet lemon flavour. Seeds are very hard and it is difficult to germinate them because they are hardseededness. Normally it 30-60 days to get germination (Padayachee, pers. comm.).

Protorhus longifolia (Anacardiaceae)

It was also known as *Anaphrenium longifolia* and *Rhus longifolia* (Pitman and Palmer, 1972). It is commonly known as iHluthi in Zulu and it is also known as the red beech (Palgrave, 1984). Its species name *longifolia* describes the elongated leaves. It has opposite and sub-opposite or scattered large simple leaves (Pooley, 1993). It bears greenish-white flowers and the fruit is a drupe like small kidneys. The fruiting and flowering periods are in Table 2.7. Fruits are eaten by birds, monkeys, and bats. Its seeds do not have a hard coat and that makes them to be vulnerable to maggots and fungi. The presence of maggots might be caused by the butterflies of the blue family (Lycaedae) which breed on this tree. It can be found in forest and in forest margins (Pooley, 1993). The tree is reputed to be poisonous and Gerstner says that African witches use it to cause paralysis of one side of the body and the powder is used for making the vaccination powder to cure it (Pitman and Palmer, 1972). African women use strong smelling fruits as a perfume (Pitman and Palmer, 1972). The roots can be used to ward of evil spirits and attract good luck (Pitman and Palmer, 1972). The related information is in Table 2.1. Its mode of propagation seems to be only through seed. According to Pooley (1993), seedlings grow well from fresh seed. Its seed germination is very fast because it takes about 10-16 days (Pillay, pers. comm.).

Ocotea bullata (Lauraceae)

This species was commonly known as uNukani in Zulu because of its malodiferous properties. It is also known as the Black Stinkwood. Its species name *bullata* has to do with 'bullae' or small roundish projections on the leaf. It has simple leaves which are arranged alternately. The flower information is in Table 2.7. Its fruit is ellipsoidal, half enveloped by the encroaching perianth (Palgrave, 1977). Its fruits are eaten by Rameron Pigeons. Its seeds have hard coat, but if sown being fresh, they germinate quickly. The seeds are also subjected to fungal attack and maggots. Viable seeds may be gathered from the tree or immediately after falling to the ground. This species is highly prized in the world for its timber (Palgrave, 1977). Since the earliest days of settlement in South Africa, this tree has been in constant demand and even by 1812 the Knysna forest had been seriously depleted of all accessible specimens (Palgrave, 1977). Sometime ago, all felling was forbidden in order to set this matter to right. Today with a well organised management programme, the Department of Forestry is again removing timber (Palgrave, 1985).

Prunus africana (Rosaceae)

This medicinal tree species is also known as *Pygeum africanum* (Palgrave, 1984). It is well known as iNyazangoma in Zulu. It is also commonly known as the Red Stinkwood or the Bitter Almond (Palgrave, 1984). It has alternately arranged leaves with serrated margins. The fruiting and flowering periods were included in Table 2.7. Its fruits are eaten by birds and also favoured by bees. Seeds germinate well, but it is difficult to get viable seeds because they become parasitised while still green. It is highly used medicinally and such related information is in Table 2.1.

Cryptocarya woodii (Lauraceae)

It is also known as *Cryptocarya acuminata*. It is commonly known as umThungwa in Zulu and it is also commonly known as Cape Quince or Bastard Camphor (Palgrave, 1984). The related information about flowering and fruiting is in Table 2.7. It medicinal importance was included in Table 2.1.

Croton sylvaticus (Euphorbiaceae)

It is commonly known as amaHlabakufeni/umZilanyoni in Zulu (Pooley, 1993). It is also commonly known as Forest Fever-berry or Forest Croton (Palgrave, 1984). It has alternate leaves. The information related to flowering and fruiting is in Table 2.7. Its flowers are always visited by bees, flies, honey bees and moths (Pooley, 1993). Fruits are eaten by bushpigs and blui-duiker and spittle bugs (froghopper larvae) are frequently found on branches. Seeds germinate quickly. Its medicinal and magical importance are in Table 2.1.

Harpephyllum caffrum (Anacardiaceae)

It is commonly known as wild plum in English, umGwenya in Zulu (Palgrave, 1984). It has alternate, crowded compound leaves at the ends of the branchlets. The compound leaf is composed of 4 to 8 pairs of opposite leaflets and a terminal leaflet. The information relating to flowering and fruiting is in Table 2.7. Its fruits are eaten by people, monkeys, baboons, antelopes and birds. Its fruits can make a wine and a jelly (Pooley, 1993). Apart from its medicinal uses, it has been used for furniture, beams and as a general purpose timber. Even though the wood takes polish well, it is not durable (Palgrave, 1984). It is planted along the streets of Durban city as an ornamental plant. Its known mode of cultivation is through seed propagation. It is also cultivated in Zimbabwe as a garden ornamental.

Bersama lucens (Melianthaceae)

It is commonly known as Glossy bersama in English and uNdiyaza in Zulu (Pooley, 1993; Palgrave, 1984).It has 2 to 3 pairs of opposite compound leaflets with a terminal leaflet. The information relating to flowering and fruiting is in Table 2.7. Its fruits are eaten by monkeys, birds and bats. Seeds germinate quickly because they do not have a hard coat. Parts of the tree have been regarded poisonous, but the Zulus use the bark to relieve menstrual pains and to treat cases of potency and barrenness (Palgrave, 1984).

CHAPTER THREE

SEED PHYSIOLOGICAL STUDIES

3.1. INTRODUCTION

3.1.1. Moisture Content

The moisture content of the seeds is one of the most important factors influencing their retention of viability and longevity. High moisture content of the seed decreases the germination capacity of orthodox seeds in storage. According to Kozlowski (1972), Justice and Bass (1978) and Bewley (1986), high seed moisture content encourages fungal and insect attacks and germination in storage. Additionally, in uncontrolled storage conditions, high moisture content can kill the seed rapidly because of the heating of the seed caused by the respiration of the seeds, fungi and bacteria in and on the seed and because of insect population which build up in such a moist environment. The heating of the seeds is caused by the metabolic activity which increases seed moisture content and temperature. This modifies the microenvironment which encourages the establishment and infection of other major fungi like *Aspergillus* and *Penicillium* (Halloin, 1986). Fungi degrade complex sugars (carbohydrates) in the seed into simple sugars by producing amylase.

With respect to storage there are two major types of seeds; recalcitrant and orthodox. Recalcitrant seeds cannot withstand drying below relatively high moisture contents without serious loss of viability (Bradweer, 1989; Justice and Bass, 1978). Recalcitrant seeds do not undergo maturation drying as the final phase of development, tolerate very little post-shedding desiccation and tropical species are often chilling-sensitive. Orthodox seeds are tolerant to desiccation and in this state are tolerant to low temperatures. This type of seed can be stored in the dehydrated state and still retain viability for relatively long periods. Seeds of *Cassia* species are reported to have survived for a period of 1.58 centuries and *Trifolium* species for a century (Bewley, 1986)). Some orthodox seeds like peanut are not long-lived.

3.1.2. Seed Viability

For a seed to be considered viable, it should have both live cotyledons and embryos, irrespective of dormancy state. According to McDonald and Copeland (1989), seed viability can be defined as the capacity of a seed to germinate under favourable conditions in the absence of dormancy. This implies that the difference between the viability and germination represents the percentage of dormant seeds. The seed viability test thus establishes the quality of the seeds. Not all seeds which are viable can germinate but all seeds which germinate are viable. This is in agreement with McDonald and Copeland (1989) who pointed out that the viability of a seed lot may be high even though the germination results may be low. The development and utilisation of the triphenyl tetrazolium chloride (TTC) test (in the early 1940s) as a rapid method of seed viability testing was a major advancement in seed quality assessment (McDonald and Copeland, 1989). The test avoids working on or sowing seeds which are dead or of bad quality. Both

TTC and floatation tests were considered in this study in order to assess the quality of the seeds which were to undergo germination testing. TTC assesses the quality of seeds by staining embryos and cotyledons red. The TTC test makes use of a colourless testing solution that produces colour differences between normal, weak and dead embryo tissue (ISTA, 1993; Tietema *et al*, 1993). Healthy and viable seeds stain pink because of the process of oxidation-reduction (respiration), dead seeds remain colourless and the damaged remain red or mottled. On the other hand in the flotation test, seeds which sink when soaked in water are probably full with viable embryos and cotyledons.

3.1.3. Germination Tests

Probably the single most convincing and accepted index of seed quality is the ability to germinate (McDonald and Copeland, 1989). Germination is defined as the emergence and development from the seed embryo of those essential structures which, for the kind of seed in question, are indicative of the ability to produce a normal plant under favourable conditions (McDonald and Copeland, 1989). According to Bryant (1985), the term 'germination' is more difficult to define than would be expected at first sight. Gardeners and farmers speak of seed germination when the shoot makes its appearance above the ground while on the other hand, many laboratory workers take the protrusion of the radicle axis through the testa as the culmination of germination. In this study, germination is defined as the immediate emergence of either radicle or plumule axis.

Germination includes many processes during the transformation of a plant embryo into an independent established seedling. Lea and Joy (1982), Bryant (1985), Mayer and Poljakoff-Mayber (1989), Mayer (1980/81), Fenner (1985) and Ting (1985) all pointed that during germination, food reserves stored either in the endosperm or cotyledon are mobilised so that they become accessible to the developing embryo. Enzymes break down the polymer food reserves in the endosperm which provide the energy for embryo development. In cereals, when water is added, the embryo is activated and produces gibberelins (GA) which diffuse into the aleurone layer and promote the releasation of alpha-amylase enzyme (Rayle and Wedberg (1980; Oaks, 1982). This enzyme degrades the starch into simple sugars.

Seed germination is sometimes delayed by dormancy. There might be some germination inhibiting factors. Those factors might be the growth hormones which play a role in the enhancement or inhibition of seed germination and seedling growth. Sometimes the dormancy is caused by a consequence of a hard seed coat which causes impermeability to water, impermeability to oxygen, impermeability to leakage of germination inhibitors from the embryo through the envelope, impermeability to carbon dioxide diffusion from the embryo to the outside and generally a mechanical barrier to embryo expansion (Werker, 1980/81; Bradweer, 1989; Simon and Mills, 1982). These causes of dormancy can often be overcome by mechanical rupture of the seed coat (scarification) or its complete removal. An aim of this study was to investigate the effectiveness of hot water, concentrated sulphuric acid and cracking pre-treatments in breaking hardseededness in some selected species

3.2. MATERIALS AND METHODS

Seeds of different species were collected from different places as in Table 3.1 below. Moisture contents, viability tests and germination tests were studied on those seeds.

Table 3.1. Sites where seeds of different species were collected from.

Species	**Collection Sites**
Ekebergia capensis	Near Knysna (dry seeds) and at the bus rank near the Workshop, Durban (very fresh seeds)
Erythrophleum lasianthum	False Bay, St Lucia (very dry seeds)
Curtisia dentata	Natal Parks Board, Pietermaritzburg (very fresh seeds)
Ocotea bullata	Kloof and Botanic Gardens, Durban (fresh seeds)
Protorhus longifolia	Natal University, Durban campus (very fresh seeds)
Cryptocarya woodii	Natal University, Durban campus (very fresh seeds)
Croton sylvaticus	Natal University, Durban campus (very fresh seeds)
Prunus africana	Eston, Mid. Illovo Area, Durban (fresh seeds)
Zanthoxylum capense	Silverglen, Chatsworth (very fresh seeds)
Warburgia salutaris	Silverglen, Chatsworth (young seedlings)

3.2.1. Sterilisation

Microbial infection can be a problem in seed viability. They infect seeds in three ways; through vascular connections of the mother tree, through the developing flower, or on the surface of the seed. In order to reduce such infection, immediately after collecting the fruits, the flesh or fruit peel was removed to avoid fermentation and the seeds were cleaned. Seeds were then sterilised by soaking them in a solution of 1 part concentrated domestic bleach to 3 parts water for 10-20 minutes. Then the seeds were rinsed using running water until the soapy feeling disappeared. Cleaned seeds were immediately germinated. Seeds collected or received late during the day were then dried using a paper towel and stored in a plastic bag for 24 hours. A small amount of the fungicidal powder, Benlate, was mixed evenly with the seed batch in the plastic bag.

3.2.2. Moisture content

After pre-treatment, 20 seeds were picked at random from the seed batch of each different species. The coats were removed from the seeds and water content was determined by determining fresh weight and dry weight (at 90^0C in the oven overnight) on individual seeds. Water contents were expressed on a dry mass basis. Logically, the reason for water contents to be expressed on a dry mass basis was to determine how much water was contained in the seed.

3.2.3. Seed Viability

The viability of the seeds was assessed using the flotation technique and staining with triphenyl tetrazolium chloride (TTC) salt. The extent of predation was assessed visually.

a. Flotation test

For each species, seeds were added to an excess of water and left period of 24 hours. Seeds which were found floating were considered to be empty and dead and those which sank were considered full and possibly viable. This method was adapted from Kioko *et al* (1993), ISTA (1993) and Tietema *et al* (1993). The proportion of seeds which sank was taken as a measure of seed viability.

b. TTC test

This method has been strongly recommended by Tietema *et al* (1993) as it can be used to assess quality seeds. As recommended by both ISTA (1993) and Tietema *et al* (1993), a solution of 1 part of TTC to 1000 parts of tap water which was adjusted to a pH of 7.1 was prepared. The solution was kept in the dark as light can turn the solution red before the test. Twenty seeds had their hard coats (if present) completely removed and the cotyledons were split open. The seeds were then soaked in water (adjusted to pH 7.1) for 24 hours before putting them into the TTC solution. This was to hydrate the seeds and so enhance the diffusion of TTC solution into the tissues. After soaking, they were then put into beaker with the TTC solution and again kept in the dark for 24 hours. Observations on the degree of staining of different tissues were done the following day in order to assess the quality and viability of those seeds. The percentage viability was calculated as the proportion of embryos and particularly the tips strongly stained pink. Seeds which were partially stained with the embryos also unstained were considered non-viable.

3.2.4. Germination Studies

Germination tests were conducted immediately after the seeds were collected in order to avoid reduction of seed vigour and vitality. Plastic petri-dishes and paper towels were used for monitoring the germination of seeds. Germination was scored positive when the radicle could be observed to have emerged from the seed.

However, the seed coat may influence the ability of seeds to germinate by interfering with water uptake, gas exchange or the diffusion of endogenous inhibitors or mechanically restricting embryo growth (Martins-Loucao *et al*, 1996; Wolf and Kamondo, 1993). Pre-treatments to soften the seed coat were applied on hard seeds of different species in order to achieve high germination results within a short period of time. Three treatments were conducted to promote germination of the seeds. Those were; hot water, concentrated sulphuric acid and mechanical coat cracking or a complete removal of the hard coat. Sulphuric acid can also be detrimental to both seed. Untreated seeds constituted the control. In each replicate there were 10 seeds selected at random from the seed batch. All these experiments were done in the laboratory at a temperature of 25-28^{0}C with the germination dishes kept in the dark in a cupboard.

a. Hot water treatment

Water was heated up to 90^0 C as recommended by Tietema *et al* (1993) and Wolf and Kamondo (1993) and seeds were put into a glass beaker and the hot water was then added. The beaker was then kept in the cupboard overnight and the heated water cooled down with the seeds. The seeds were then put on a moist paper towel into four plastic petri-dishes, each having 10 seeds. The seeds were then monitored for germination everyday. This treatment was done only on the seeds with the hard coat.

b. Concentrated Sulphuric Acid

Forty seeds were soaked in concentrated sulphuric acid for 5 , 10, 20, 30, 60 or 80 minutes and then washed thoroughly for 30 minutes under running water. Thereafter seeds were put on a moist paper towel which was rolled four times in their respective plastic petri-dishes and then monitored for germination on daily bases. The treatment was on all the seeds with a hard coat.

c. Partial Cracking and Removal of the Hard Coat

These methods were used only on seeds with hard coats. The method is mechanical and needs patience, and is potentially destructive to both the cotyledons and the embryo of the seed. A vice was used to crack the hard coat and it was removed manually. For seeds which had a fairly soft coat, this was removed by using scalpel. The cracking and of the hard coat was done on the portions of the seed which were furthest away from the embryo. Each sample consisted of ten seeds and there were four replicate samples per treatment.

3.3. RESULTS

3.3.1. Moisture Contents

With the exception of *Erythrophleum lasianthum*, *Curtisia dentata* and *Ocotea bullata* which have 2 %, 13 % and 15 % moisture contents respectively, other species in Table 3.2, have a range of 20 to 197 % moisture contents. The only seed types which carried more water than their dry weight were of *Protorhus longifolia* and *Bersama lucens* with moisture contents of 197 % and 162 % respectively. The seeds with high moisture content ≥ 20 % might show recalcitrant behaviour. *Erythrophleum lasianthum* is a leguminous species with a very hard seed coat and probably shows orthodox behaviour. The desiccation sensitivity of the seeds was not tested directly because of limited supply of seeds.

Table 3.2. Mean (n=20) moisture contents of medicinal tree species.

Species	**%Moisture Contents (standard deviation)**
Warburgia salutaris	not determined
Curtisia dentata	13 ± 1
Ekebergia capensis	77 ± 6
Erythrophleum lasianthum	2 ± 1
Protorhus longifolia	197 ± 105
Croton sylvaticus	20 ± 2
Zanthoxylum capense	46 ± 4

Table 3.2. Continues...

Cryptocarya woodii	56 ± 7
Prunus africana	71 ± 4
Ocotea bullata	15 ± 2
Harpephylum caffrum	67 ± 35
Bersama lucens	162 ± 49

3.3.2. Viability of the Seeds

Table 3.3 shows the results of viability tests using both flotation and triphenyl tetrazolium chloride (TTC). Flotation test shows that almost all the seeds of different species were full, suggesting 90 to 100 % viability (Table 3.3). With the TTC test, viability ranged from 55 to 95 % but most of the species have 90 % to 100 % viability (Table 3.3). Generally, the flotation and TTC tests show similar results. *Ekebergia capensis* seeds were tested when still fresh, with the TTC test showing 80 % viability (Plate 3.1).

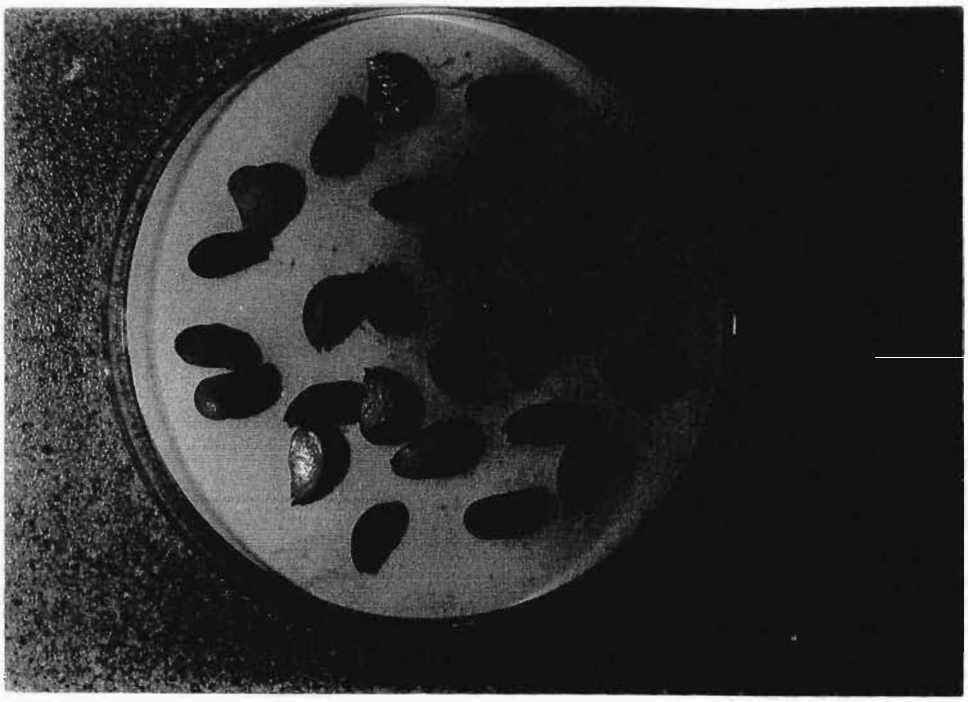


Plate 3.1. TTC viability test showing the staining affinity of *Ekebergia capensis* seed embryos and cotyledons.

Protorhus longifolia showed 100 % viability with the TTC test (Plate 3.2), with both the cotyledon and embryo fully stained.

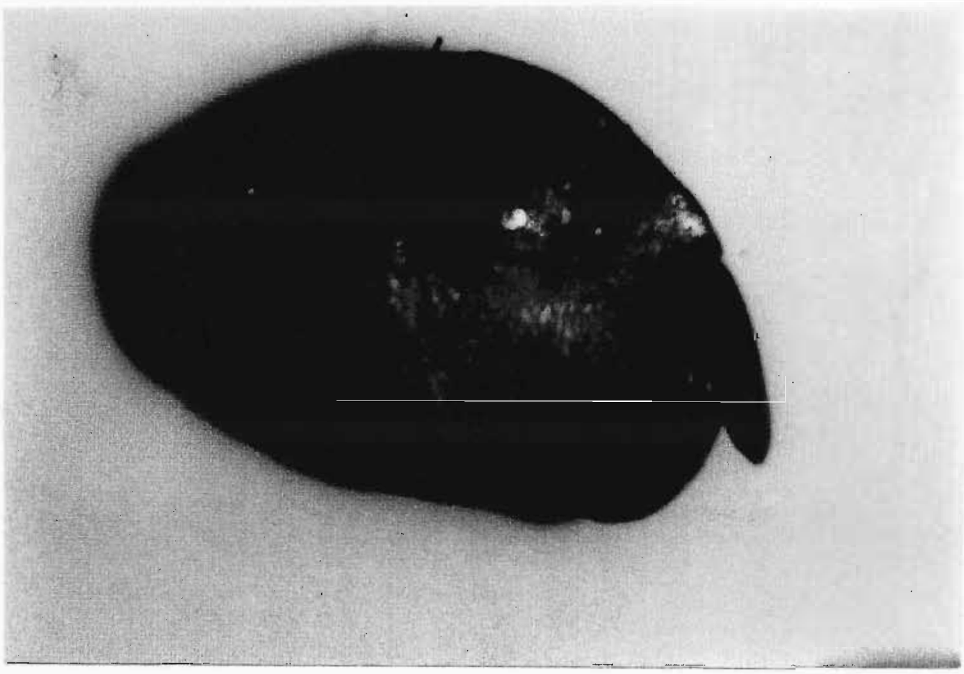


Plate 3.2. TTC viability test showing the staining affinity of *Protorhus longifolia* seed embryos and cotyledons.

The lowest viability of 55 % using TTC test was recorded for *Erythrophleum lasianthum* seeds and Plate 3.3 shows detailed staining where several cotyledons show cracks, which might be the result of being too dry. Most of the other seeds were partially stained on their cotyledons and on the tip of their radicles as shown in Plate 3.3.

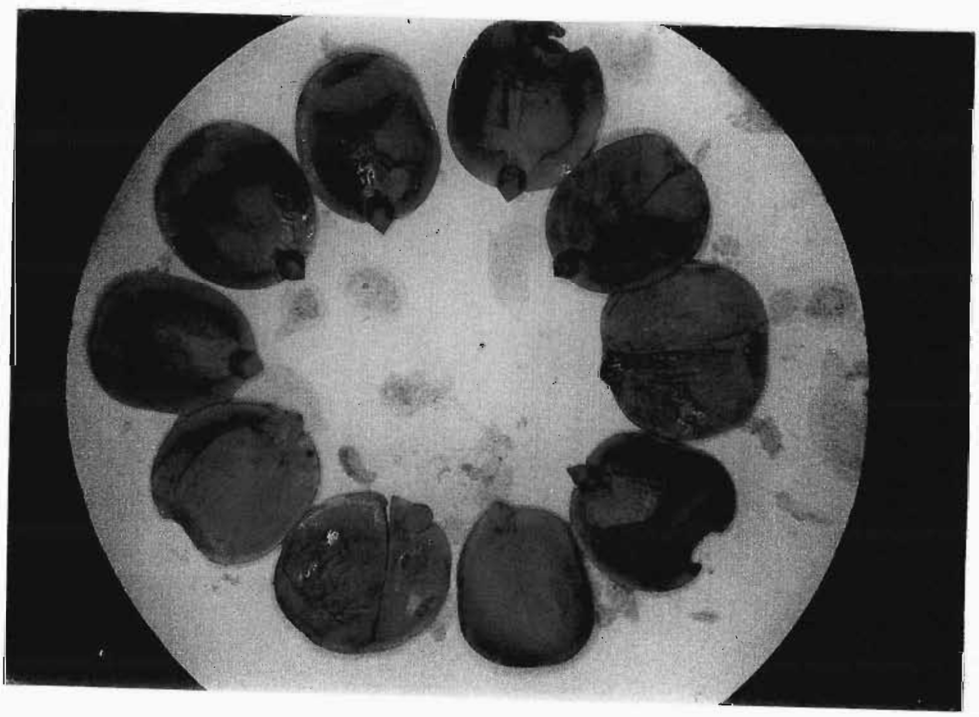


Plate 3.3. TTC viability test showing the staining affinity of *Erythrophleum lasianthum* seeds embryos and cotyledons.

Curtisia dentata showed 90 % viability with the TTC test. Plate 3.4 shows fully, partial and non stained *Curtisia dentata* seeds.

Plate 3.4. TTC viability test showing the staining affinity of *Curtisia dentata* seed embryos and cotyledons.

The results of TTC tests on *Zanthoxylum capense* and *Croton sylvaticus* are shown on Plates 3.5 and 3.6 respectively. The seeds were stained 100 %, thus the seeds might be of good quality.

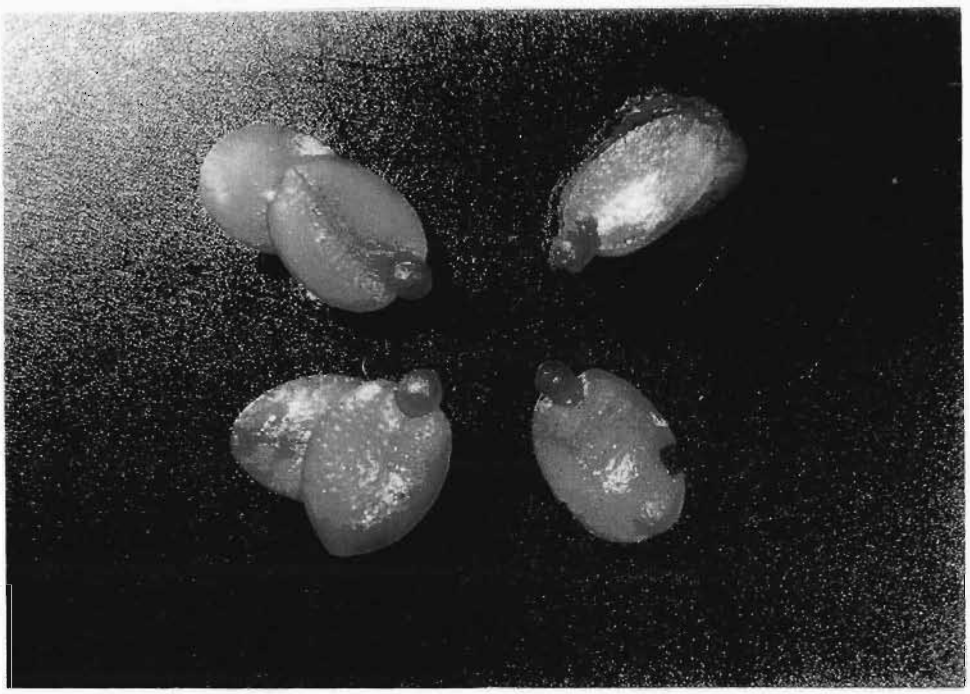


Plate 3.5. TTC viability test showing the staining affinity of *Zanthoxylum capense* seed embryos and cotyledons.

Plate 3.6. TTC viability test showing the staining affinity of *Croton sylvaticus* seed embryos and cotyledons.

The cotyledons of *Zanthoxylum capense* seeds were stained yellow-orange. A TTC-stained seed of *Cryptocarya woodii* (95 % viability) is shown in Plate 3.7.

Plate 3.7. TTC viability test showing the staining affinity of *Cryptocarya woodii* seed embryos and cotyledons.

Plate 3.8. A maggot parasitising the fruit/seed of *Protorhus longifolia*.

Photographic records of TTC tests on *Bersama lucens* and *Harpephylum caffrum* were not obtained due to equipment malfunction. The TTC test was not conducted on *Prunus africana* since it was difficult to identify the position where the embryo (radicle) was situated and was not conducted on *Warburgia salutaris* since the seed supply was very limited.

Table 3.3. The viability tests (n=20) of different seeds of different species.

Botanical Names	**Flotation Test** **% Viability**	**TTC Test** **% Viability**
Warburgia salutaris	not determined	not determined
Ekebergia capensis	95	80
Erythrophleum lasianthum	100	55
Curtisia dentata	95	90
Protorhus longifolia	95	95
Croton sylvaticus	100	90
Zanthoxylum capense	95	95
Ocotea bullata	100	75
Cryptocarya woodii	100	95
Prunus africana	95	not determined
Bersama lucens	95	100
Harpephylum caffrum	90	100

3.3.3. Germination Studies

The germination of a control (untreated seeds) of *Ekebergia capensis* started after 3 days and by 30 days, 60 % germination had been achie :d (Fig 3.1a). After hot water treatment, only 5 % germination occurred, while the remaining seeds were rotting and dying (Fig 3.1.a). Cracking of the seed coat gave rise to 100 % germination which was achieved after only 2 days. Sulphuric acid treatment for 20 or 30 minutes soaking caused 85 to 90 % germination which was achieved after 27 days (Fig 3.1.b). Germination after other acid treatments was reduced and the remaining seeds developed mould growth and became soft and died.

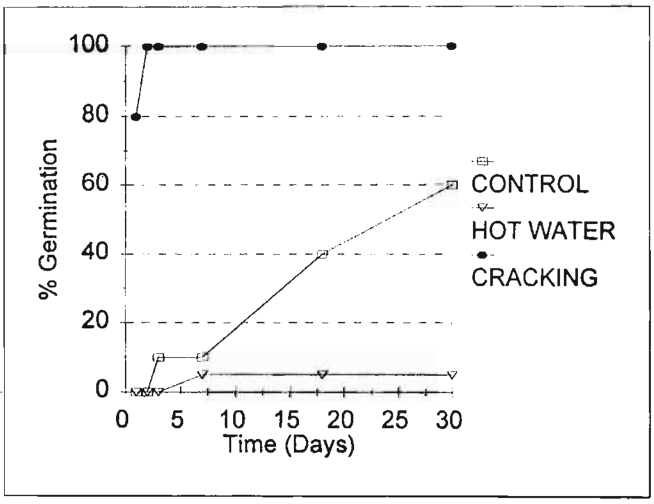


Figure 3.1. (a). Germination of *Ekebergia capensis* seeds after control, hot water and cracking pre-treatments of *Ekebergia capensis* seeds.

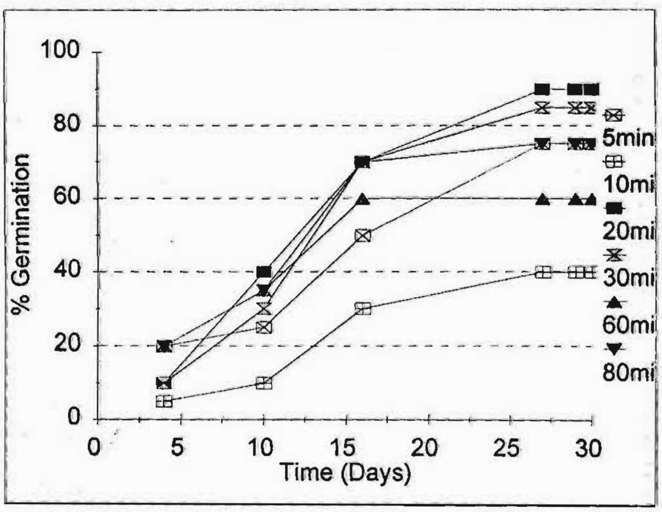


Figure 3.1. (b). Germination after 5 to 80 minutes soaking periods in sulphuric acid pre-treatments of *Ekebergia capensis* seeds.

Untreated, hot water and acid treated seeds of *Curtisia dentata* did not germinate. It was only after the cracking pre-treatment that a maximum of 35 % seed germination was achieved in 16 days (Fig 3.2.). Even though the overall percentage seed germination was low, the best treatment also appears to be cracking of the seed coat. All the acid pre-treatments resulted in the germination of no seeds at all.

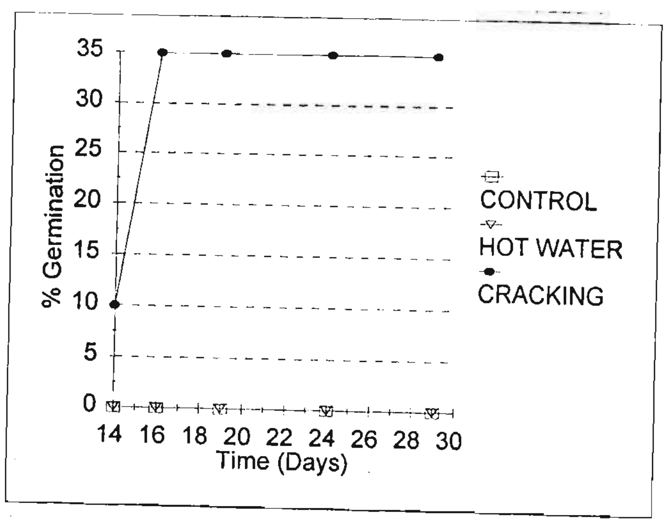


Figure 3.2. Germination after control, hot water and cracking pre-treatments of *Curtisia dentata* seeds.

The germination characteristics of *Erythrophleum lasianthum* were similar to those of *Curtisia dentata*. Control (untreated) seeds showed no germination after 30 days, but after hot water pre-treatment, 10 % seed germination was observed after 4 days (Fig 3.3.a) with no further increase. After cracking pre-treatment , 20 % seed germinated after 7 days and a maximum of 60 % seed germination was achieved after 10 days. The rest of the seeds were infected by moulds and rotted and died. After 5 minute soaking in sulphuric acid, 22 % germination was achieved and under 80 minute soaking, germination increased to 60% (Fig 3.3.b). The other acid pre-treatments yielded no germination.

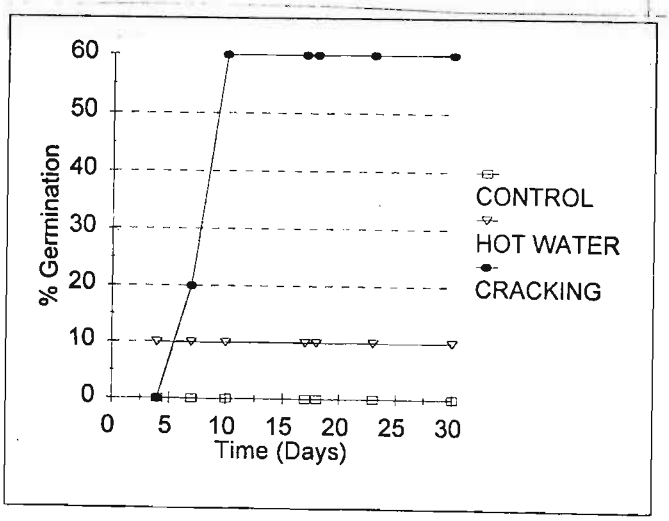


Figure 3.3. (a). Germination after control, hot water and cracking pre-treatments of *Erythrophleum lasianthum* seeds.

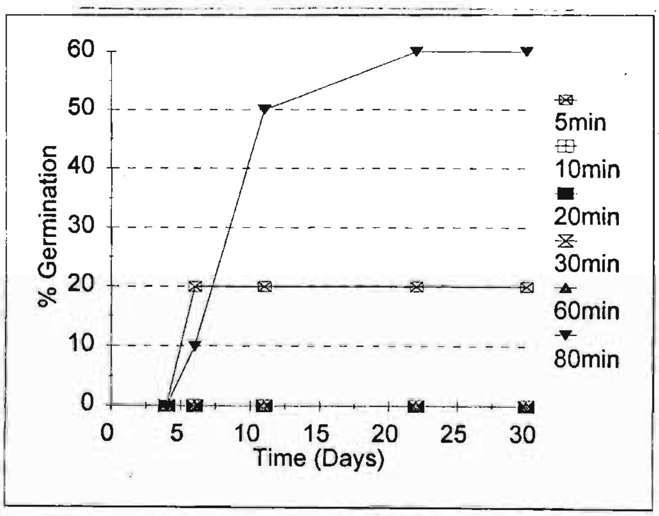


Figure 3.3. (b). Germination after 5 to 80 minutes soaking in sulphuric acid pre-treatments of *Erythrophleum lasianthum* seeds.

The germination of *Protorhus longifolia* (Fig 3.4) was observed to be very rapid. Since the seeds do not have a hard coat, they did not undergo any pre-treatment. Germination was 30 % after only one day and 100% germination had occurred after 3 days. The seeds of this species do not seem to have any germination problem if germinated immediately after collection. The only problem encountered when collecting those seeds was that almost all the seeds collected from the ground were infested by maggots (Plate 3.8). These seeds are vulnerable to maggots or any other parasites because they do not have a hard coat. This implies that seeds from the ground should not be collected for that reason.. Seeds collected from the tree have 100% germination.

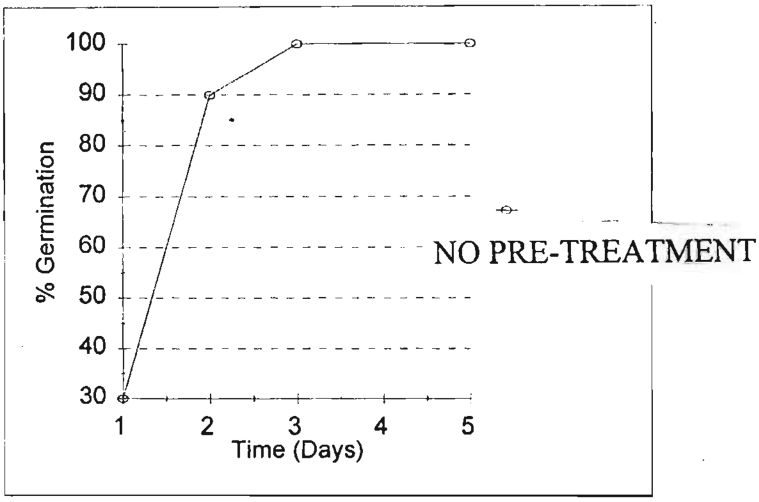


Figure 3.4. Germination without pre-treatments of *Protorhus longifolia* seeds.

The germination of untreated (control) seeds of *Prunus africana* started after 15 days and 10 % germination was achieved (Fig 3.5.a). Seeds pre-treated with hot water did not germinate. After cracking the seed coat, the germination reached 80 % after 5 days and 100 % germination occurred after 8 days. Of the acid pre-treatments, only 60 and 80 minutes soaking yielded germination (Fig 3.5.b). The cracking treatment appears to yield the highest germination percentage, and over a period of just a few days.

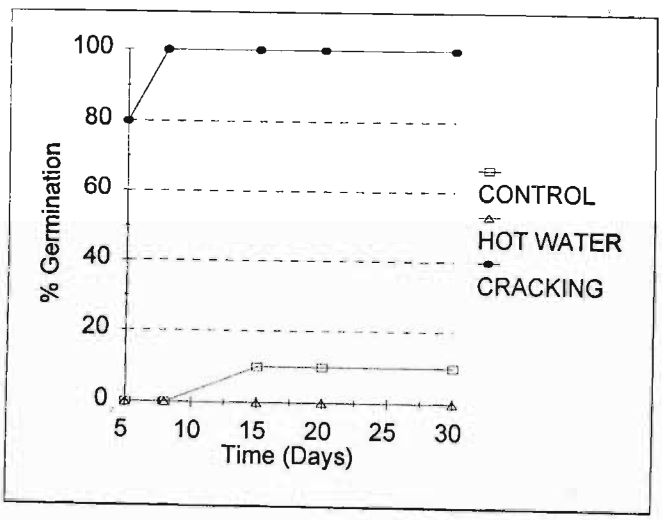


Figure 3.5. (a). Germination after control and hot ater and cracking pre-treatments of *Prunus africana* seeds.

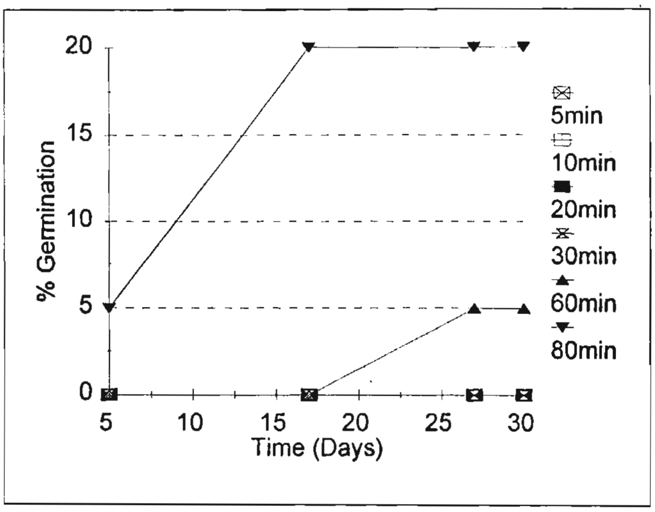


Figure 3.5. (b). Germination after 5 to 80 minutes soaking in sulphuric acid pre-treatments of *Prunus africana* seeds.

Neither control nor hot water pre-treated seeds of *Croton sylvaticus* germinated (Fig 3.6.a). After cracking the seed coat, 85% germination was achieved after 18 days. After 30 and 60 minutes soaking, in sulphuric acid, 5% germination occurred after 24 days (Fig 3.6.b), with other acid pre-treatments showing no germination. The cracking pre-treatment still appears to produce the highest percentage germination after just a few days.

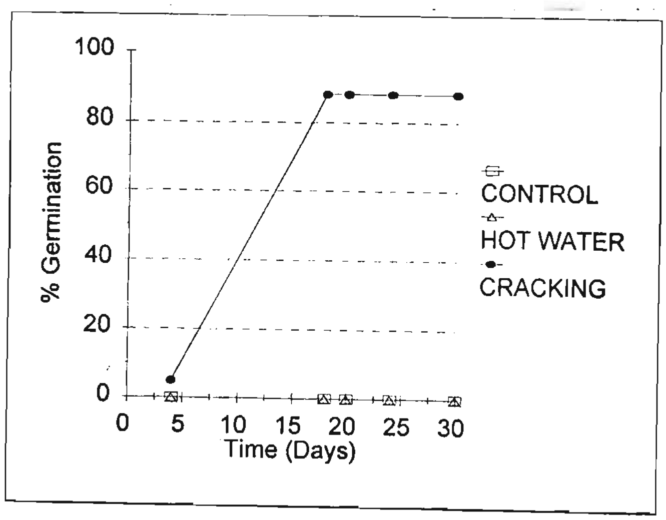


Figure 3.6. (a). Germination after control, hot water and cracking pre-treatments of *Croton sylvaticus* seeds.

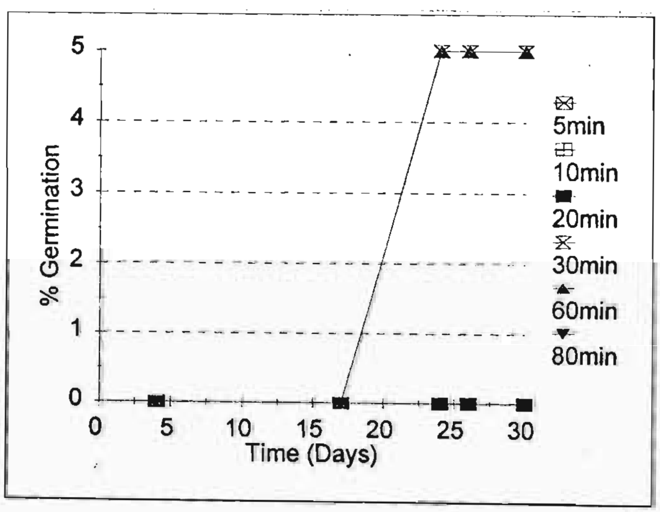


Figure 3.6. (b). Germination after 5 to 80 minutes soaking in sulphuric acid pre-treatments of *Croton sylvaticus* seeds.

Control seeds of *Ocotea bullata* showed initial germination after 13 days and ended up with 25 % germination after 16 days (Fig 3.7). Germination after hot water pre-treatment was 10 % after 16 days. The rest of the seeds rotted and died. After cracking the seed coat, 75 % germination was achieved in 8 days and germination increased to 90% after 16 days. The acid treatment was not conducted since there were insufficient seeds. The cracking treatment still produces the highest percentage germination over a few days.

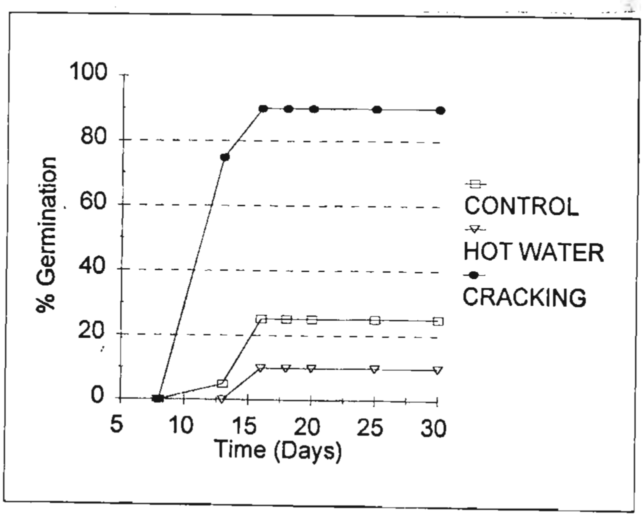


Figure 3.7. Germination after control, hot water and cracking pre-treatments of *Ocotea bullata* seeds.

Control and hot water pre-treated seeds of *Cryptocarya woodii* showed no germination, whereas after cracking the coat, seeds started germinating after 8 days and ended up with the maximum of 60% germination after 40 days (Fig 3.8). The remaining ungerminated seeds did not show any sign of rotting or fungal infection. The cracking treatment was the most effective since it produced the highest percentage germination. Acid pre-treatments did not achieve any germination.

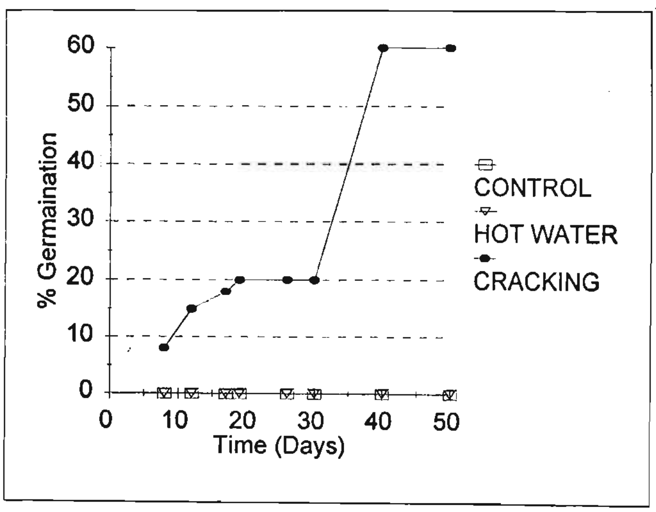


Figure 3.8. Germination after control, hot water and cracking pre-treatments of *Cryptocarya woodii* seeds.

Bersama lucens did not germinate under any test conditions even though their moisture content was very high (Table 3.2) and viability assessed by TTC test was high (Table 3.3.) It is possible that the seeds were collected while still immature, as according to Pooley (1993), the mature shiny red seeds are exposed when the fruit ruptures. The seeds were collected from the fruits before rupturing and this might have had an influence on germination.

Cracked seeds of *Harpephylum caffrum* failed to germinate while on the moist paper towels in petri-dishes. It was only when those seeds were planted in local soil firmly packed in a germination tray that they germinated erratically. It became very difficult to measure their germination as it was erratic and on a different medium from the standard one used to test almost all the other species. It took 30 to 50 days for many seeds to germinate.

Germination of *Zanthoxylum capense* was not achieved by any pre-treatment. However, germination of 80% has been achieved by the staff of Silverglen Nature Reserve by planting unpre-treated seeds in pinebark.

Germination studies were not conducted on *Warburgia salutaris* seed because seeds were not available. The few seeds collected were sown at Silverglen using pinebark.

The germination style of the three species; *Cryptocarya woodii*, *Prunus africana* and *Ocotea bullata* is hypogeal whereas that of 7 species; *Erythrophleum lasianthum*, *Ekebergia capensis*, *Curtisia dentata*, *Croton sylvaticus*, *Zanthoxylum capense*, *Warburgia salutaris* and *Protorhus longifolia* is epigeal.

3.4. DISCUSSION

Even though desiccation sensitivity was not tested, water content measured could be able to show whether some seeds were either recalcitrant or orthodox behaviour. The extremes of water water contents were measured in; *Erythrophleum lasianthum*, *Protorhus longifolia* and *Bersama lucens* (Table 3.2). The low water content of *Erythrophleum lasianthum* suggests that it shows true orthodox behaviour. The very high water contents of *Protorhus longifolia* and *Bersama lucens* suggest that they may show recalcitrance. The seeds were very fresh and besides they do not have a hard coat. With the exception of *Curtisia dentata* and *Ocotea bullata*, the other seed had water contents ≥20 % , and so may show recalcitrant characteristics.

Both flotation and TTC were used as tests of viability. In a number of species, the two techniques showed equivalent results and on others they showed different results (Table 3.3). The best example of a clear difference of viability between flotation and TTC tests was of *Erythrophleum lasianthum*. The difference might have been brought about by the hardness of the seeds which also had some cracks on them. Flotation test does not seem to be more reliable than TTC. Flotation test can only assess the quality of the seeds in terms of being full or empty, it cannot always show seeds which are viable or vice versa. For example, seeds of *Zanthoxylum capense*, *Cryptocarya woodii* and *Ekebergia capensis* were found floating after 24 hours of soaking, but when opened, they were all full. Interestingly enough, floating seeds of *Ekebergia capensis* also germinated. TTC test seemed to be a more reliable test (in terms of indicating the ability of seed to germinate) than flotation test as it stains portions or the entire seed which is respiring (undergoing oxidation-reduction process). Even though at some stage such oxidation-reduction process might be caused by fungi, TTC test should be recommended to laboratory workers.

Germination and viability results were similar in some species and different in others. The species with similar germination and viability results are *Ekebergia capensis*, *Erythrophleum lasianthum*, *Protorhus longifolia* and *Croton sylvaticus*. The species which show different results were; *Curtisia dentata*, *Bersama lucens*, *Cryptocarya woodii* and *Harpephyllum caffrum*. The difference could have been probably brought about by dormancy or by germination conditions physically damaging the seeds or enhancing microbial infection. In case of *Bersama lucens*, it is probably that the seeds did not germinate because they were still immature. *Cryptocarya woodii* ungerminated seeds were not infested by fungi and did not rot. They have a dormancy imposed by a mechanism other than a hard seed coat. In some species like *Bersama lucens* and *Croton sylvaticus* the ungerminated seeds became infested by fungi and moulds, indicating that they were dead.

Pre-treatments were applied to seeds in order to enhance germination. Some of these pre-treatments result in high germination and an early onset of germination. However, hot water and acid pre-treatments seemed to achieve low germination on other seed types. It was only on *Erythrophleum lasianthum* seeds where 60 % germination was achieved in each of those pre-treatments. The comparable germination results of hot water and acid pre-treatments were also speculated by Danthu *et al* (1995), but both of these pre-treatments showed variable results when tested on seeds of *Adansonia digitata*. The effectiveness of sulphuric acid in germination was successful on hardseededness of *Adansonia digitata* (boabab tree) where over 90 % germination was achieved in 6-8 days after 12 hours of immersion (Danthu *et al*, 1995). This is an implication that hot water and acid pre-treatments should have been applied for other periods of time of soaking until the optimal period for maximum germination results could be identified.

Generally, the cracking pre-treatment led to high germination. Since a hard seed coat is also known to afford immunity to fungal infections (Halloin, 1986), cracking pre-treatment might also encourage fungal infestation. This was observed on *Harpephyllum caffrum* and *Curtisia dentata* seeds which had some moulds growing on them. Apart from this problem, cracking pre-treatment appears to yield the highest percentage germination. In order to reduce fungal infestation after cracking pre-treatment, seeds without hard coat should have been sterilised and the paper towels should also have been changed on daily bases. Such could have led to different germination results. The other problem of cracking the seeds can lead to excessive imbibition of their tissues which may also lead to their asphyxia and necrosis (Danthu *et al*, 1995). Reasonable moist paper towels could be used in order to avoid excessive imbibition.

In conclusion; from the water contents recorded without conducting desiccation sensitivity, it seems most of the seed types could possibly be recalcitrant. The flotation test was found to be unreliable, but it gives a general guideline for a large amount of seeds to be sown within a very short period of time. TTC test seems to be the best method of assessing quality and viability of the seed, it can be recommended to laboratory workers who work on small number of seeds. The pre-treatment which appears useful and more effective than others is cracking because there is no chemical involved. It can also be administered by indigenous people in the country side without any danger of being affected by chemicals. Hot water and acid pre-treatments can be very destructive to the embryo (miniature plant), hence they cannot be recommended to indigenous people. According to Fu *et al* (1995) and Egley (1989), concentrated sulphuric acid may rapidly desiccate tissues and cause stress resulting in cell separations.

CHAPTER FOUR

SEEDLING GROWTH STUDIES

4.1. INTRODUCTION

Basically, the term 'growth' means an irreversible increase in size or volume accompanied by biosynthesis of the new protoplasmic constituents. According to Ting (1982), the term 'growth' means the quantitative aspect of development representing an increase in number and size of cells. Such is evident on the increment of size of leaves, stems and height of the plant in general.

The growth of a plant is dependent on many factors both internal (hormones, nutrient status) and external (environmental conditions). Their morphological features also vary according to conditions they are exposed to at a given time. In particular, light intensity (sun and shade) plays a very important role on the growth of plants during seedling establishment. The morphologies of the same species under sun and shade conditions are never the same. It is through photosynthesis that light constitutes the primary source of all forms of biological energy (Hart, 1988; Wareing and Phillips, 1978). Plants show adaptations to incident light energy. Too little radiation results in low rate of photosynthesis and low growth rate of plants. The plant species developing under low radiant energy, tend to develop large thin leaves with high chlorophyll content per leaf area. High levels of radiation can effect through two processes. High radiation can lead to excitation of the photosynthetic electron transport pathway, in excess of the rate of utilisation of reducing power. This can cause damage, particularly to photosystem II, a process known as photo-inhibition. At a higher level of organisation, high radiation loads give rise to high leaf temperatures, leading to high transpiration rates. Most species developing under high radiation adapt to such condition by developing small erect leaves, with low chlorophyll content per unit area which is also a protection against photo-inhibitory damage. Different species show different adaptive plasticities, and such has also been emphasised by Hart (1988). Basically, the rate of photosynthesis is relative higher in the sun than in the shade. Most of the medicinal trees considered in this study are mostly forest species, and so shade adaptations as seedlings might be expected. However, the objective of this study was to find the best propagation conditions, so this study grew seedlings under high light (greenhouse) treatment as well as shade.

Growth, according to Ting (1982), is commonly estimated from the measurements of length, leaf area or weight (fresh and dry weights). The best method of measuring growth is through the total measurement of dry weight. However, this requires destructive harvesting, and in this study there was insufficient material to undertake repetitive dry weight measures. Thus increase in plant size as measured by height, stem diameter and leaf area, was taken as an indication of dry matter increase. Leaf area has been emphasised as a very useful index (Ting, 1982) since most of the photosynthates are manufactured in the leaves, and leaves act as sinks for water and nutrients. In this study, two treatments were imposed; sun and shade. This was done to observe the influence on each of the species studied with the knowledge that plants adapt differently to different environments. The other factors; water and soil were kept as uniform as possible for all species.

4.2. MATERIALS AND METHODS

4.2.1. Growth Media

For each species, ten seedlings were grown under high light conditions in the greenhouse and a further ten seedlings were grown under partial shade (40% shadecloth).

Vermiculite or pinebark were used for germinating seeds up to a height where they could be transplanted into the potting mix for establishment and growth. The potting mix consisted of 4 parts local soil; 2 parts river sand; 1 part cow dung and 2 parts compost. Growth measurements were initiated when seedlings were transferred to the potting mix (the age varied among the species) and were subsequently taken every seven days. Growth was assessed in terms of height, stem diameter and total leaf area.

4.2.2. Growth Measurements

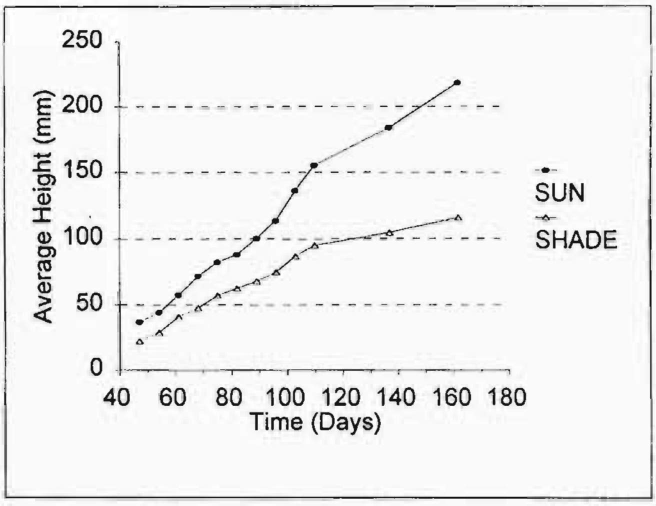
The height was measured using a 300mm clear ruler. The point of reference for the measurements of the height was the position where the cotyledons were attached to the seedling stem, because this does not change in height. The final point of the height was at the terminal bud of the developing seedling.

The leaf area was an estimation because use of the available leaf area meter was destructive. The seedlings could not be destroyed as a number of consecutive measurements were to be taken. The leaf area was assessed from measurements of length and breadth in millimetres. The allometric relationship between the linear dimensions and leaf area was obtained from leaf prints using a dyeline paper, and relating weight of print to area. Stem diameters were measured in millimetres (to 0.1 mm) using a venier-calliper. Repeated measurements were made on the same position of the stem where the initial measurements were taken. The point of reference was just below the cotyledon position in case of species showing epigeal germination and just above the cotyledon in case of species showing hypogeal germination. Differences between treatments in some variables was tested using the t-test.

4.3. RESULTS

4.3.1. Growth Studies

The growth in terms of height, leaf area and stem diameter of *Ekebergia capensis* appeared to be higher in the sun than in the shade (Figs. 4.1.a, b and c). Tables 4.1, 4.2 and 4.3 show that there was a significant difference in the height, leaf area and stem diameter at the end of the experiment. The seedlings under both sun and shade conditions looked healthy, even though those in the sun had a significant higher growth than those in the shade. In the beginning up to the 105th day, the growth in terms of leaf area of *Ekebergia capensis* was the same (Fig. 4.1.b), but after that the seedlings in the shade treatment had almost all their leaves eaten by *Charaxes brutus natalensis* worms. There was a rapid recovery as many leaves were produced within a short period. Generally, seedling establishment was quicker in the sun than in the shade. All the seedlings survived until the end of the experiment (Table 4.4).



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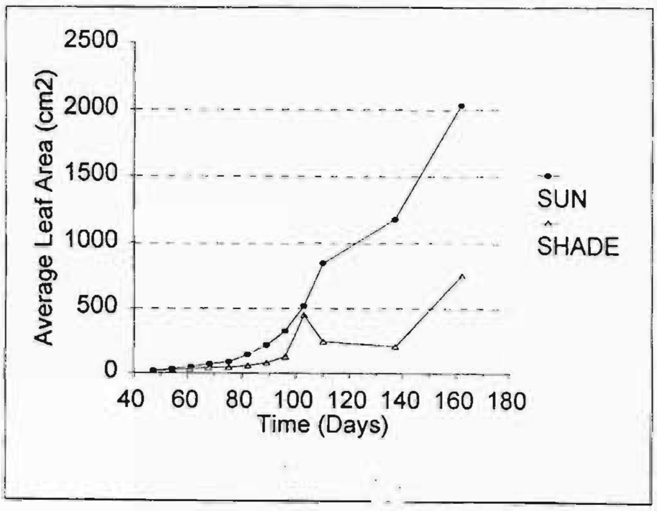

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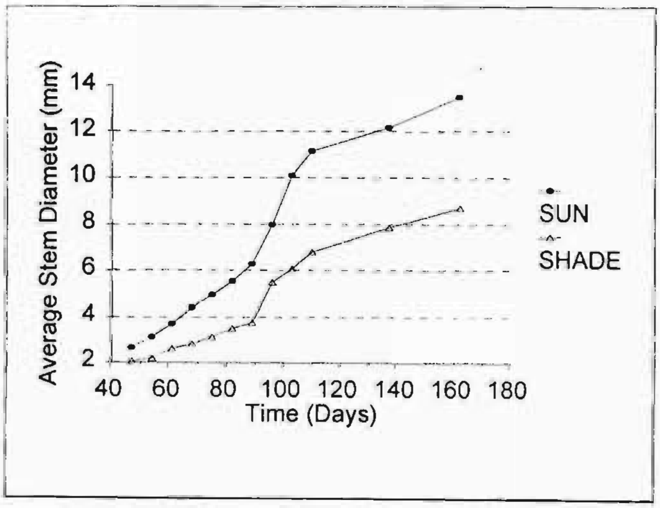
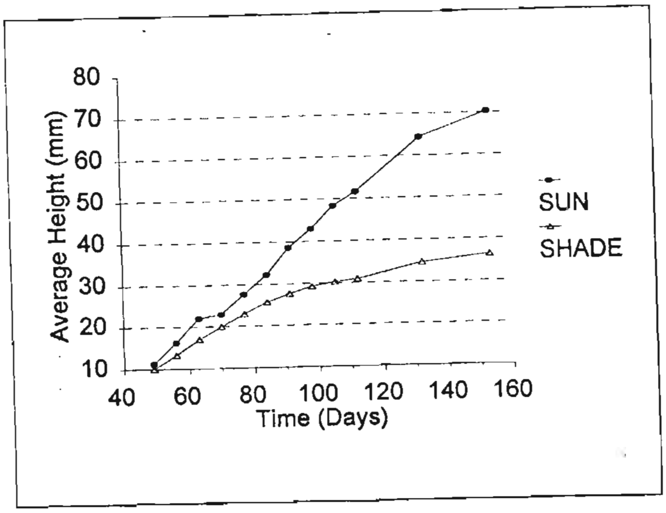


c.

Figure 4.1. The growth of *Ekebergia capensis* seedlings in sun and under 40% shadecloth as indicated by differences in (a) height, (b) leaf area and (c) stem diameter.

The average height and leaf area for *Curtisia dentata* were greater in the sun than in the shade, but there was a similar growth of stem diameter in the sun and the shade (Figs. 2.a, b and c). The stem diameter of seedlings in the sun became stable but there was a sharp increase of growth of stem diameter in the shade (Fig. 4.2.c) and then became stable. There were significant differences in growth of *Curtisia dentata* in terms of the height and leaf area (Tables 4.1 and 4.2), but not in terms of stem diameter (Table 4.3). The seedlings in the shade looked healthier than those in the sun even though those in the sun were significantly taller than those in the shade. The seedlings in the shade had broader leaves with distinctive sharply pointed serrated leaves. 60 % of the seedlings in the sun survived while 100 % seedlings survived in the shade (Table 4.4).

a.



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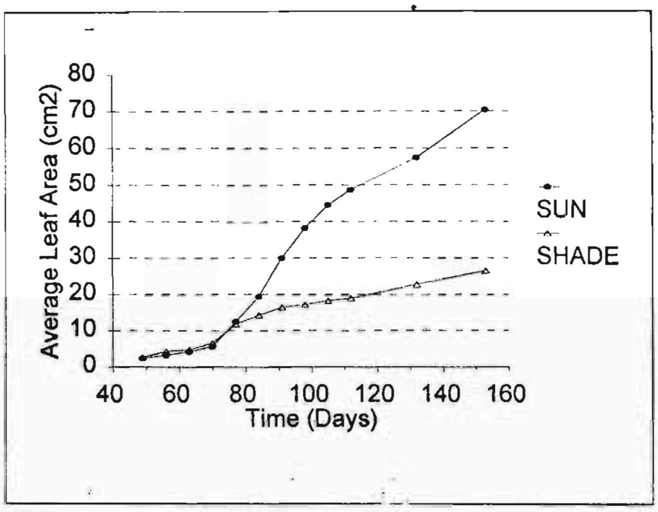

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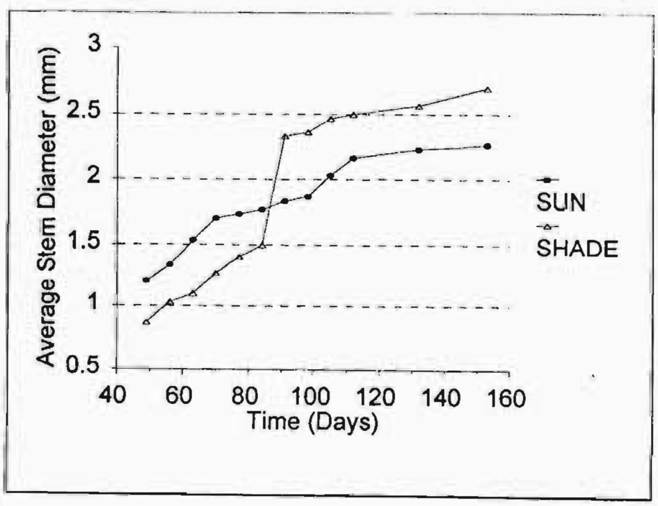
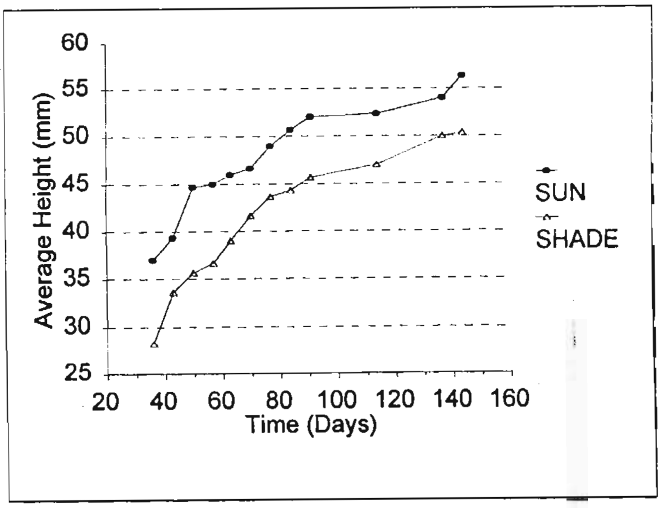


Figure 4.2. The growth of *Curtisia dentata* seedlings in sun and under 40% shadecloth as indicated by differences in (a) height, (b) leaf area and (c) stem diameter.

Average height, stem diameter and leaf area of *Erythrophleum lasianthum* were greater in the sun than in the shade (Figs. 4.3.a, b and c). So many leaves were shed in the shade without new ones being produced that the seedlings eventually died. In the shade, only 10 % seedlings survived. These differences in growth were significantly different at the final measurement (Tables 4.1, 4.2 and 4.3). Generally, the growth of the surviving *Erythrophleum lasianthum* was better in the sun than in the shade. 80 % survived in the sun (Table 4.4), but they also kept on losing leaves with few new more leaves being produced.



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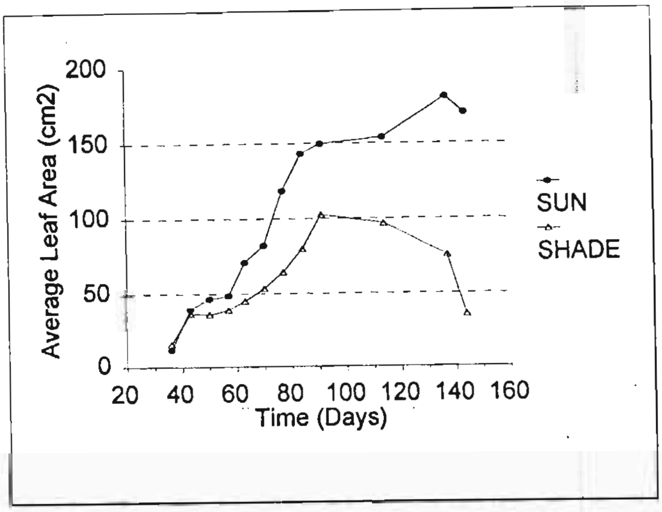

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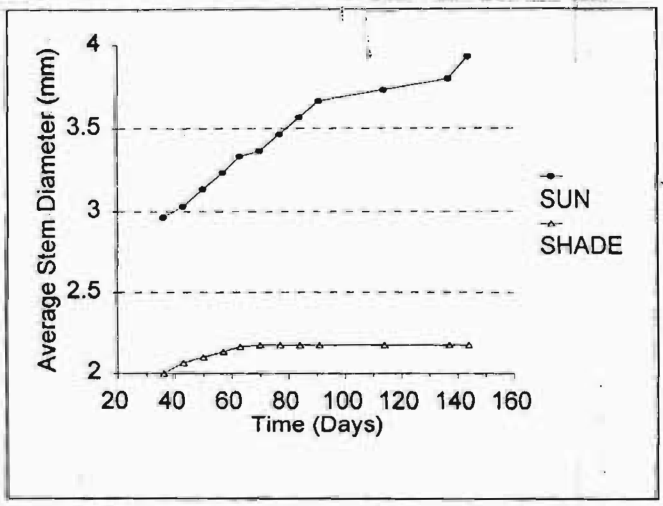
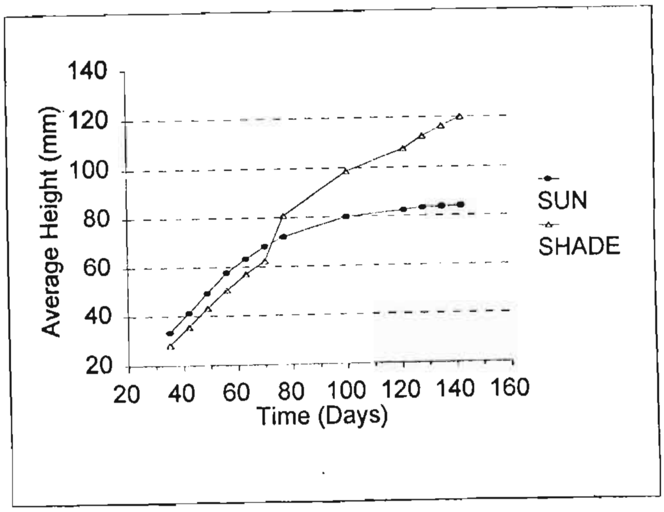


c.

Figure 4.3. The growth of *Erythrophleum lasiathum* seedlings in sun and under 40% shadecloth as indicated by differences in (a) height, (b) leaf area and (c) Stem diameter.

In the case of *Protorhus longifolia*, the growth in terms height, stem diameter and leaf area was greater in the shade than in the sun (Figs. 4.4.a, b and c). Tables 4.1, 4.2 and 4.3 show that the different in growth in those conditions was significant. Almost all the seedlings (sun and shade) did well initially, but later on seedlings in the sun developed some brown spots from the edges to the entire leaf. The seedlings (sun) then became stunted with relatively short leaves as opposed to their known long leaves. Later on, all the seedlings died (Table 4.4). Seedlings in the shade grew well and they also appeared healthy.



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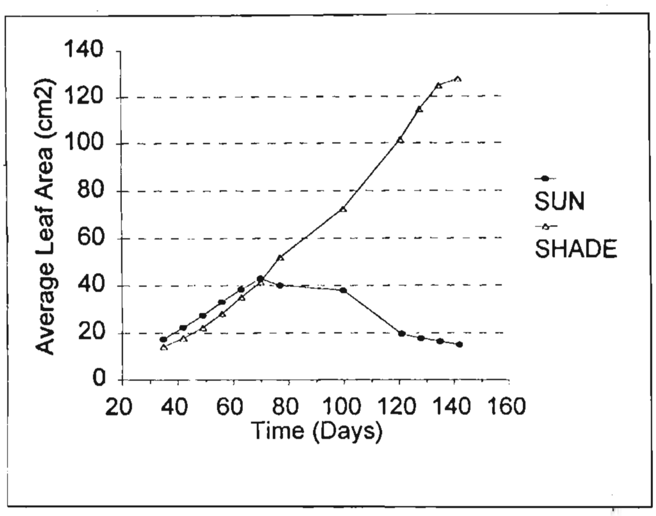

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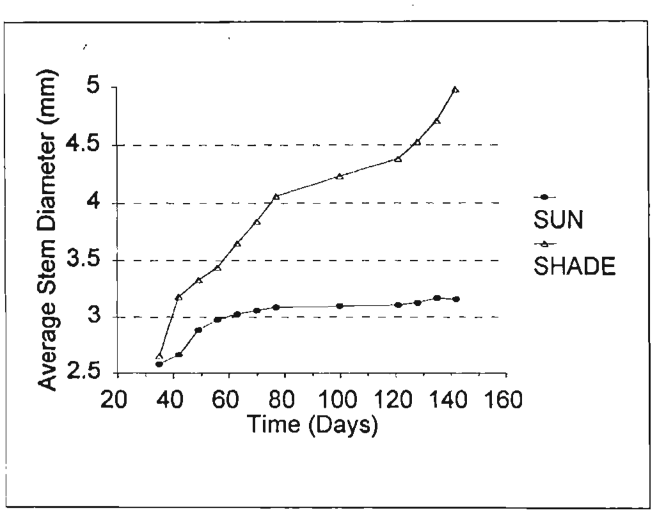
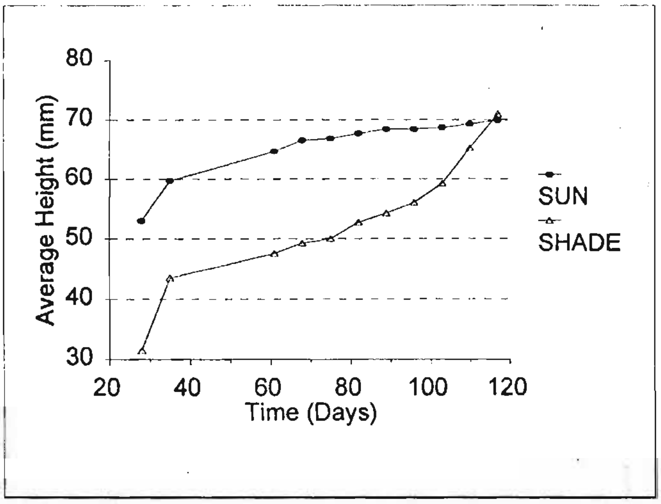


c.

Figure 4.4. The growth of *Protorhus longifolia* seedlings in sun and 40% shadecloth as indicated by differences in (a) height, (b) leaf area and (c) stem diameter.

Growth of *Prunus africana* was higher in the shade than in the sun in leaf area and stem diameter (Figs. 4.5.a, b and c). The difference in height and stem diameter at the end of the experiment was not significant (Tables 4.1 and 4.3) whereas that in leaf area was significant (Table 4.2) in favour of the shade. Most of its leaves were lost with very few produced. The finely serrated leaves in the shade looked very broad and generally, all the seedlings looked healthy in the beginning. The seedlings in the sun developed brownish spots on their leaves and there was a continual leaf loss without leaf production. Later on, they all dried out and died (Table 4.4). According to Tables 4.1-4.3 a slightly better establishment seems to be in the shade than in the sun.



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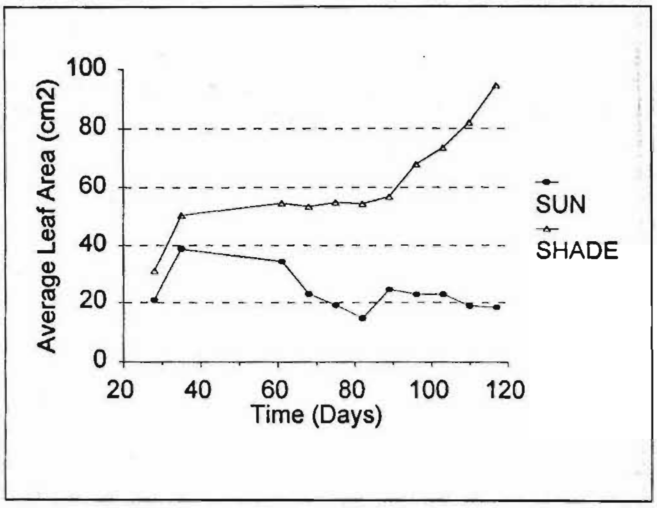

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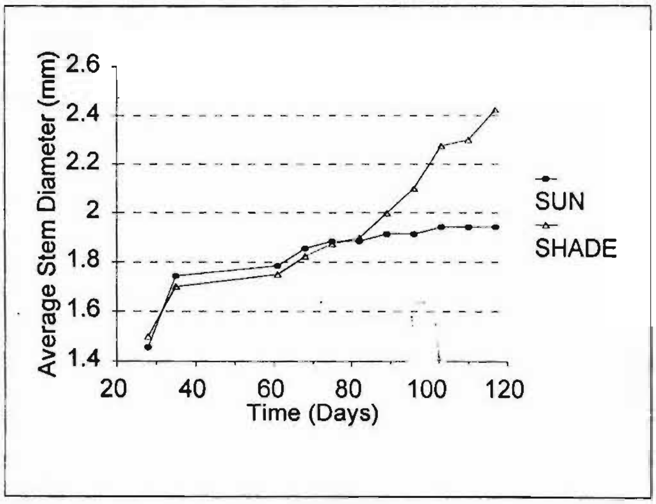
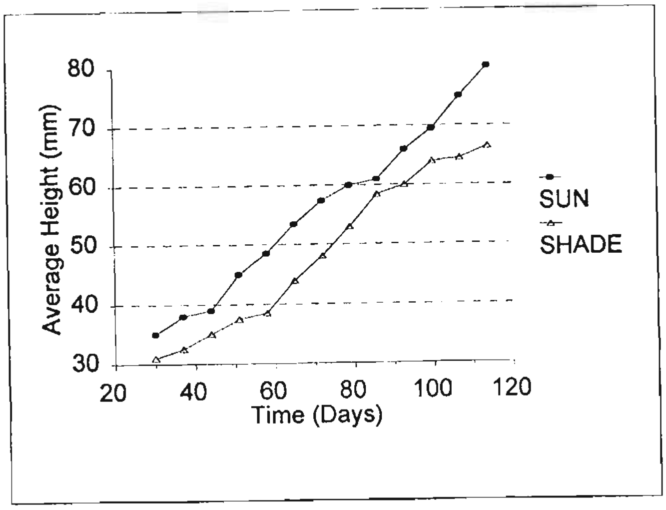


c.

Figure 4.5. The growth of *Prunus africana* seedlings in sun and 40% shadecloth as indicated by differences in (a) height, (b) leaf area and (c) stem diameter.

For *Ocotea bullata*, all parameters of growth were higher in the sun than in the shade (Figs. 4.6.a, b and c). The difference between the sun and shade specimens in height and stem diameter at the final measurement was not statistically significant (Tables 4.1 and 4.3), but the difference in leaf area was significant (Table 4.2). It appears the growth of *Ocotea Bullata* is slightly faster in the sun than in the shade. Leaves in the shade were observed to be broader than those in the sun, but the growth rate seemed to be slow in the shade as it took a long time for new leaves to be produced. Difference in growth was probably brought about different adaptations to different conditions since 100 % seedlings were retained until the end of the experiment (Table 4.4).



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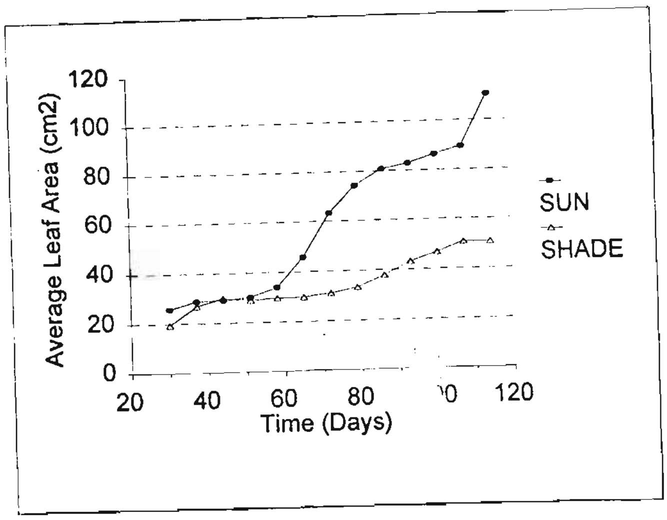

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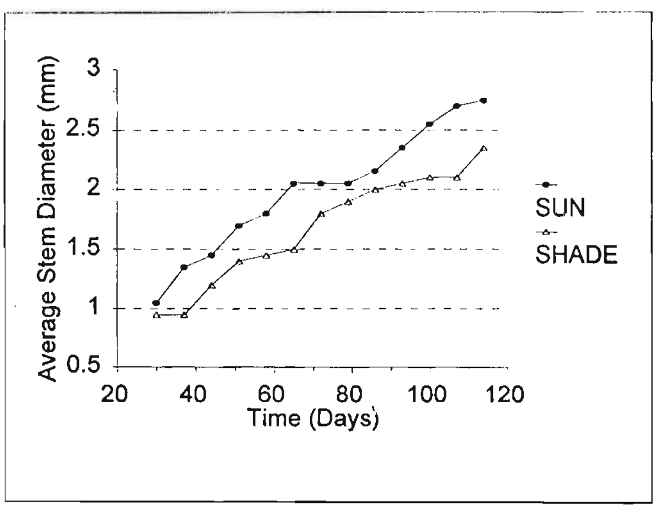

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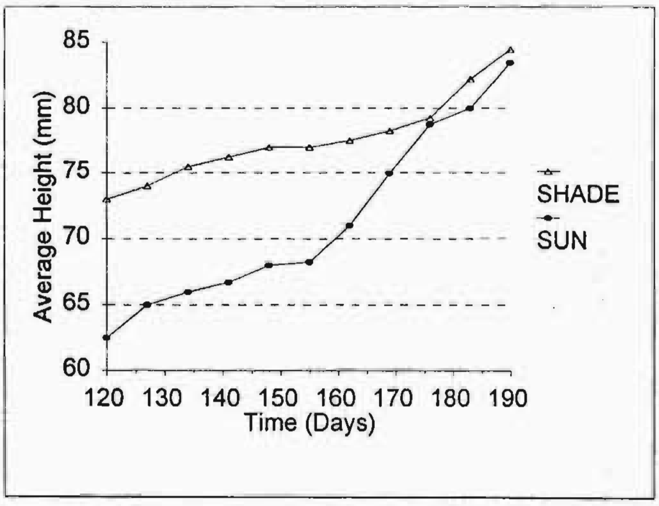
Figure 4.6. The growth of *Ocotea bullata* seedlings in sun and 40% shadecloth as indicated by differences in (a) height, (b) leaf area and (c) stem diameter.

In terms of height, the growth of *Warburgia salutaris* was initially higher in the sun than in the shade, but by the end of the experiment, there was no difference (Fig. 4.7a and Table 4.1). Although leaf area appeared to be increasing faster in the sun treatment (Fig. 4.7b) the difference had not reached a statistical difference by the end of the experiment (Table 4.2). There were no significant differences in stem diameter between treatments (Fig. 4.7c, Table 4.3). All the seedlings in the shade looked a bit more healthier than those in the sun. Some seedlings in the sun had their leaves turning yellow. There was no death of the seedling up to the end of the experiment (Table 4.4).



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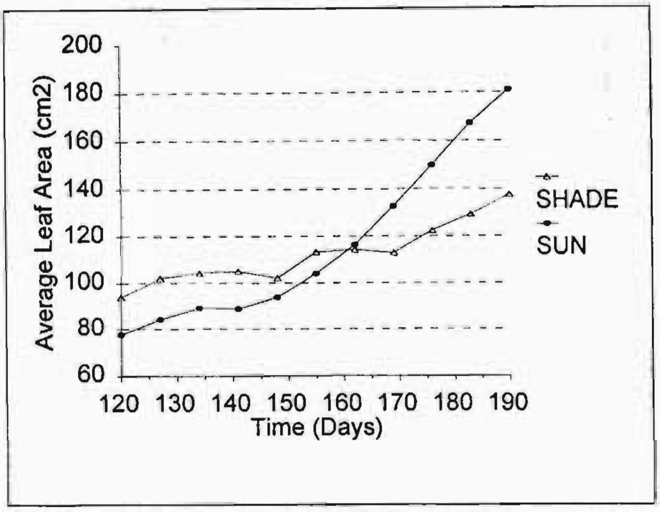

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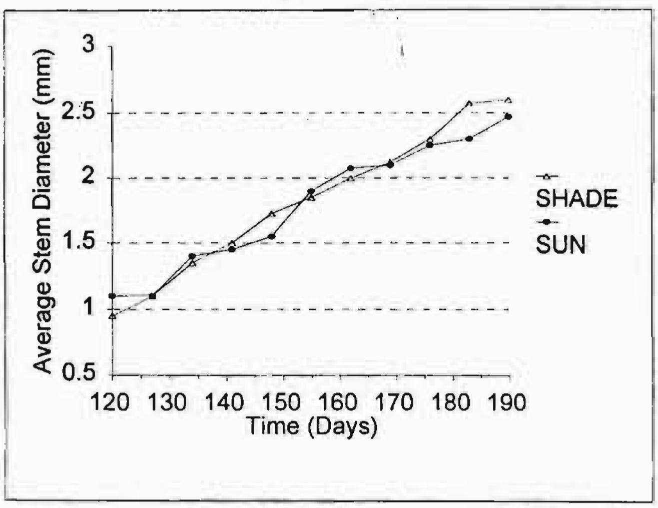
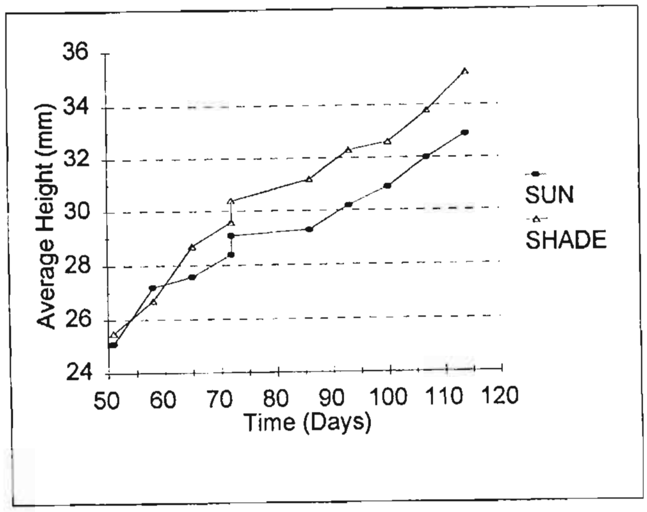


c.

Figure 4.7. The growth of *Warburgia salutaris* seedlings in sun and 40% shadecloth as indicated by differences in (a) height, (b) leaf area and (a) stem diameter.

Growth of *Zanthoxylum capense* in terms of height appeared to be higher in the shade than in the sun (Fig. 4.8a) while growth of leaf area and stem diameter appeared to be faster in the sun than in the shade (Fig. 4.8b and c). However, at the final measurement, the differences between the treatments were not significant (Tables 4.1, 4.2 and 4.3). The seedlings in the shade appeared to have bigger leaflets and longer internode distances compared with those in the sun. Fewer, but larger leaflets were produced in the shade while in the sun more but smaller leaflets were produced. This reduction in leaflet size will increase heat dissipation and so decrease transpiration rates. All the seedlings in both treatments survived (Table 4.4).



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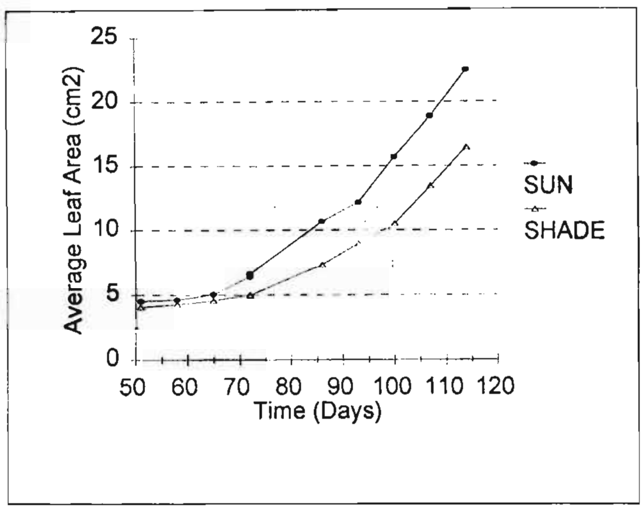

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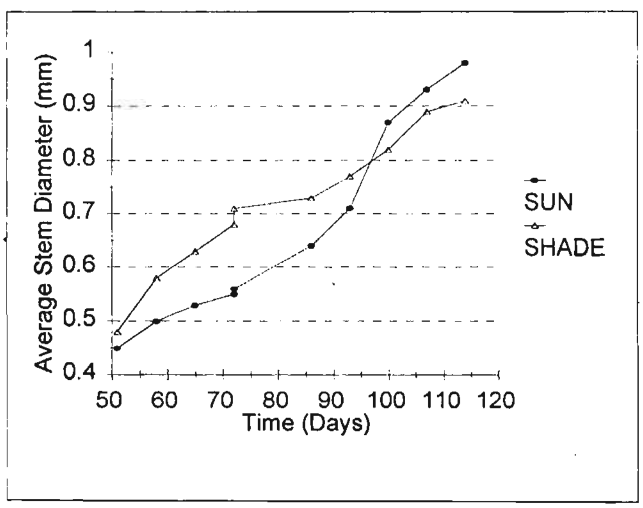


c.

Figure 4.8. The growth of *Zanthoxylum capense* seedlings in sun and 40% shadecloth as indicated by differences in (a) height, (b) leaf area and (c) stem diameter.

The height and stem diameter growth of *Croton sylvaticus* would appear to be slightly higher in the sun than in the shade (Fig.4. 9a and c) but statistically there was no significant difference between the two treatments at the end of the experiment (Tables 4.1 and 4.3). Even though at the beginning of the experiment, the growth in terms of leaf area production was not significantly different, at the end of the experiment there was a significant difference (Table 4.2). Although there was high mortality, particularly in the sun (Table 4.4), the remaining seedlings were observed to be doing well with new leaves being rapidly produced. At the end of experiment, all the surviving seedlings in all conditions produced broad leaves with relatively thick stems. It appears the seedlings of *Croton sylvaticus* take time to establish themselves because at the end of the experiment, the remaining seedlings in both treatments looked healthy.

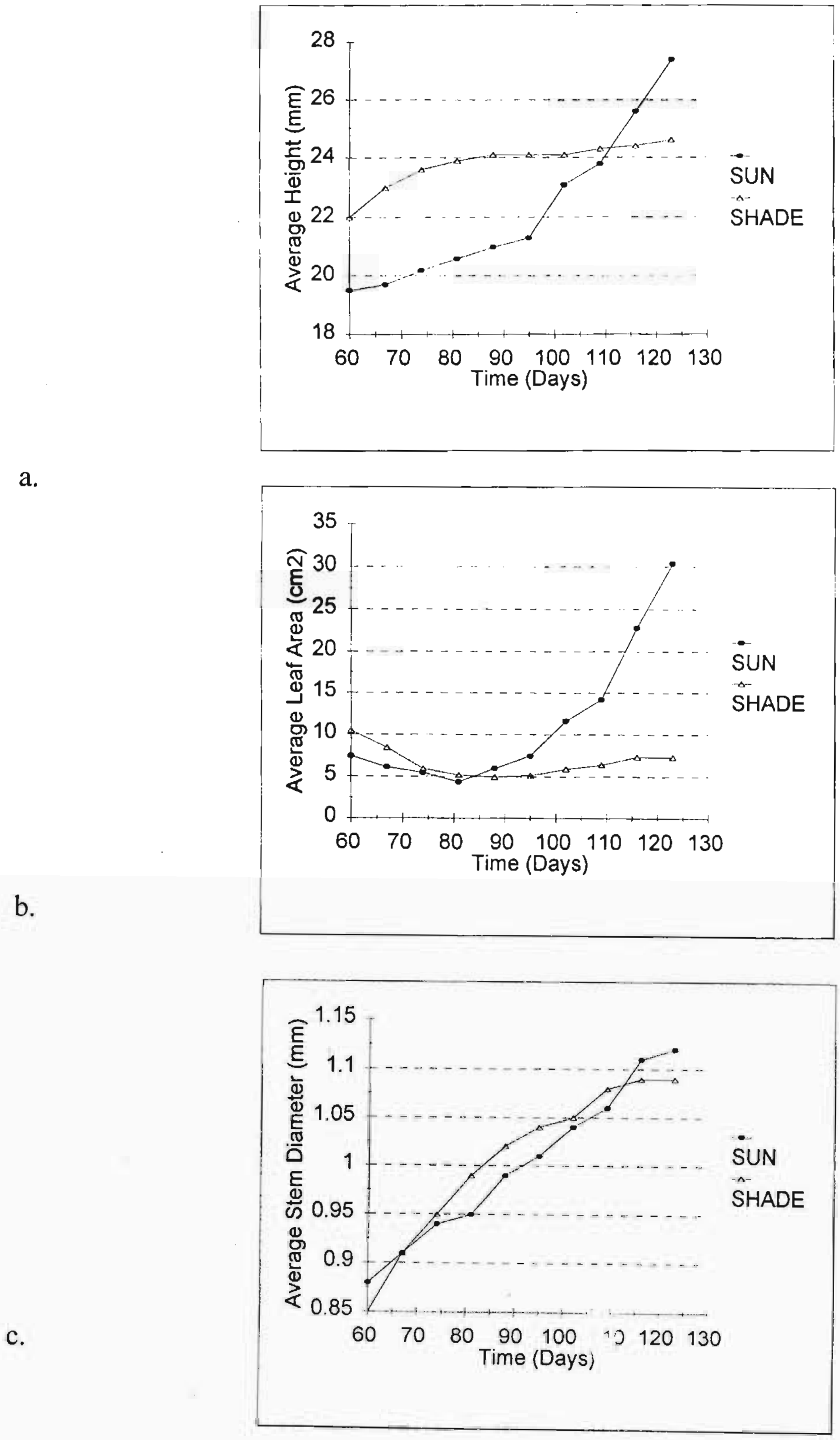
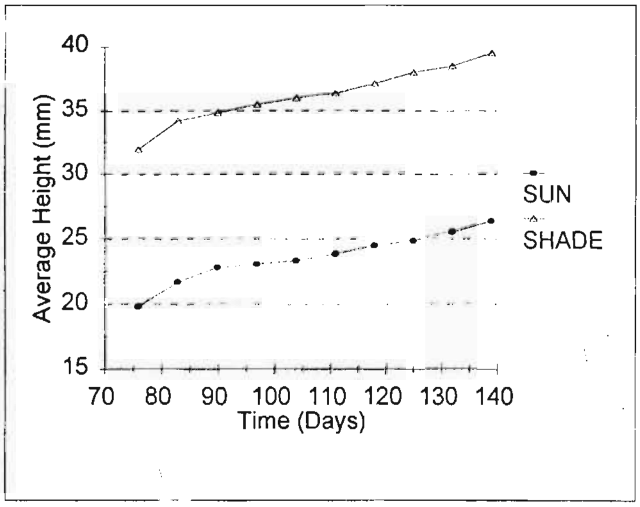


Figure 4.9. The growth of *Croton sylvaticus* seedlings in sun and 40% shadecloth as indicated by differences in (a) height, (b) leaf area and (c) stem diameter.

Growth of *Cryptocarya woodii* in terms of height and leaf area appears to be higher in the shade than in the sun (Fig. 4.10a and b) whereas growth in terms of stem diameter appears similar in both treatments (Fig. 4.10c). However, statistical analysis shows no significant difference in these parameters at the final measurements (Tables 4.1 and 4.2). There was also no statistical significant difference in stem diameter (Table 4.3). All the seedlings appeared to be doing well in both treatments, the only slight difference being that in the shade leaves looked dark green and healthier than those in the sun. All the seedlings survived until the end of the experiment (Table 4.4).



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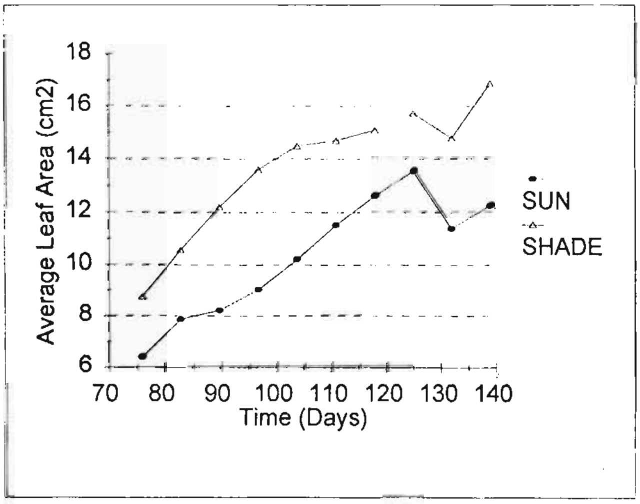

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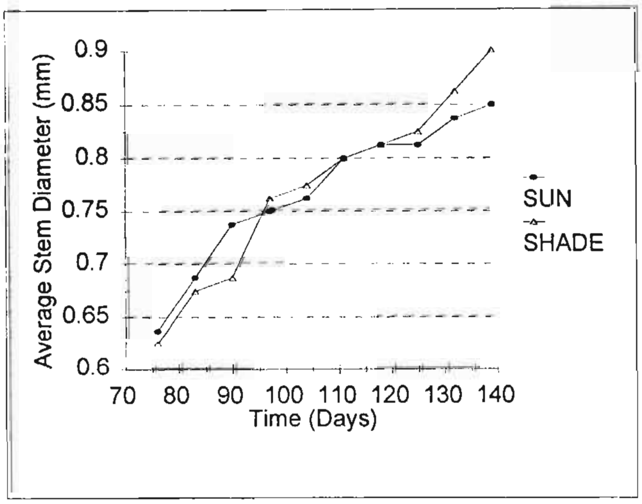

c.

Figure 4.10. The growth of *Cryptocarya woodii* seedlings in sun and 40% shadecloth as indicated by differences in (a) height, (b) leaf area and (c) stem diameter.

Table 4.1. Mean seedling height (mm) of medicinal trees growing in sunlight and shade ± standard deviation, and the age of seedlings (d) at the final measurement.

Species	**Sun**	**Shade**	**Significance Level**	**Age**
Ekebergia capensis	478 ± 145	331 ± 71	*	160
Curtisia dentata	70 ± 19	36 ± 8	*	130
Erythrophleum lasianthum	58 ± 6	53 ± 8	ns	140
Protorhus longifolia	84 ± 34	120 ± 39	*	135
Prunus africana	70 ± 11	71 ± 5	ns	100
Ocotea bullata	80 ± 14	67 ± 13	ns	100
Warburgia salutaris	87 ± 7	90 ± 15	ns	170
Zanthoxylum capensei	33 ± 5	35 ± 7	ns	60
Croton sylvaticus	27 ± 26	25 ± 9	ns	80
Cryptocarya woodii	26 ± 22	40 ± 29	*	70

Significance level of difference between sun and shade treatments, (t-test) is indicated as: ns, not significant; *, significant at $p \leq 0.05$.

Table 4.2. Mean seedling leaf area (cm^2) of medicinal trees growing in sunlight and shade ± standard deviation; and the age (d) of the seedlings at the final measurement.

Species	**sun**	**shade**	**Significance Level**	**Age**
Ekebergia capensis	2635 ± 674	1665 ± 511	*	160
Curtisia dentata	23 ± 9	70 ± 17	*	130
Erythrophleum lasianthum	104 ± 52	0 ± 0	*	140
Protorhus longifolia	12 ± 6	132 ± 77	*	135
Prunus africana	17 ± 10	94 ± 7	*	100
Ocotea bullata	111 ± 29	51 ± 10	*	100
Warburgia salutaris	150 ± 49	217 ± 10	ns	170
Zanthoxylum capense	22 ± 10	16 ± 7	ns	60
Croton sylvaticus	7 ± 3	30 ± 11	*	80
Cryptocarya woodii	17 ± 14	12 ± 8	ns	70

Significance level of difference between sun and shade treatments, (t-test) is indicated as: ns, not significant; *, significant at $p \leq 0.05$.

Table 4.3. Mean seedling stem diameter (mm) of medicinal trees growing in sunlight and shade ± standard deviation; and the age (d) of the seedlings at a final measurement.

Species	sun	shade	Significance Level	Age
Ekebergia capensis	13.5 ± 1.1	8.7 ± 1.8	*	160
Curtisia dentata	2.3 ± 0.3	2.7 ± 0.7	ns	130
Erythrophleum lasianthum	3.9 ± 0.3	2.2 ± 0.1	*	140
Protorhus longifolia	3.2 ± 0.9	5.1 ± 0.4	*	135
Prunus africana	1.9 ± 0.1	2.4 ± 0.3	ns	100
Ocotea bullata	2.8 ± 0.5	2.4 ± 0.1	ns	100
Warburgia salutaris	2.8 ± 0.6	2.7 ± 0.4	ns	170
Zanthoxylum capense	1.0 ± 0.2	0.9 ± 0.1	ns	60
Croton sylvaticus	1.1 ± 0.4	1.09 ± 0.6	ns	80
Cryptocarya woodii	0.85 ± 0.5	0.9 ± 0.4	ns	70

Significance level of difference between sun and shade treatments, (t-test) is indicated as: ns, not significant; *, significant at $p \leq 0.05$.

Table 4.4. Percentage of seedlings surviving in the sun and shade until the end of the experiment.

Species	**Sun**	**Shade**
Ekebergia capensis	100	100
Curtisia dentata	60	100
Erythrophleum lasianthum	80	10
Protorhus longifolia	20	90
Prunus africana	40	100
Ocotea bullata	100	100
Warburgia salutaris	100	100
Zanthoxylum capense	100	100
Croton sylvaticus	20	60
Cryptocarya woodii	100	100

4.4. DISCUSSION

Growth of seedlings in sun and shade treatments was assessed in terms of height, leaf area and stem diameter. Seedling growth assessed in terms of stem diameter and height, did not show many significant differences. Stems of most seedlings at their early establishment stages seemed to take a long time to grow significantly in terms of stem thickness. One of the species where a significant difference of stem diameter thickness did occur was *Ekebergia capensis* (Table 4.3). Differences were apparent in this species probably because it is fast growing. Generally, the difference in thickness of stem diameter if it occurred, could be observed only after a long period of time because of the slow growth. The height of seedling was expected to be different under the two treatments, but only

40 % of the species showed significant differences (Table 4.1) whereas 60 % of the species did not. This is implies that most of the seedlings are of slow growing species in terms of height and stem thickness. Of the 4 species where height differences did occur, in *Protorhus longifolia* and *Cryptocarya woodii*, growth was better in the shade, and in *Ekebergia capensis* and *Curtisia dentata*, growth was better in the sun. The natural habitat of *Protorhus longifolia* is both open and closed forests, hence this *Protorhus longifolia* might have been well adapted to the closed environment. But the natural habitat of both *Ekebergia capensis* and *Curtisia dentata* are closed forests. For *Ekebergia capensis*, it appears it can also do well in the open forest because its seedlings looked healthy both in the sun and shade.

The best determinant of assessing growth appeared to be leaf area, a concept also supported by Ting (1982). Seven of the ten species showed a sun-shade significant differences on leaf area (Table 4.2). Of these, 4 had significant growth in the shade, and 3 had significant growth in the shade.

The species that did not develop well in the sun showed leaf loss faster than leaf production (rather than smaller leaves). Many species (including some of those for which treatment did not effect leaf area production) developed necrotic patches on the leaves in the sun.

Most of the species tested in this study are forest species and might be expected to perform better as seedlings in the shade. Tree seedlings may be shade tolerant but need to wait for gaps in canopy to develop into adult trees, therefore must respond quickly to this change in light. Of the species that did perform better under sun environment, at least four of them (*Erythrophleum lasianthum* and *Ekebergia capensis*) grow well in more open conditions and so their superior performance in the sun is not surprising. However, even the sun-grown specimens of *Erythrophleum lasianthum* did not do very well, and it is acknowledged that this species does not grow well in pots (Nichols, pers. comm.).

In conclusion; generally, the growth in terms of height and stem diameter of different seedlings did not show many significant differences. They appeared to be not very meaningful measurements in time frame of this study. It was leaf area where many different species showed significant differences between sun and shade treatments. This suggests that some of those species might be obligate shade plants since most of the parent trees are forest species (Table 2.5, Chapter 2). Nursery staff at Silverglen nursery recommended that seedlings from wild species should be raised in the shade. In the shade treatment, non of seedlings developed spots on their leaves whereas for example *Erythrophleum lasianthu*, *Prunus africana* and *Protorhus longifolia* did in the sun treatment. The shade treatment generally appeared to be suitable for seedling establishment, with 4 of the 10 species showing better growth, and 3 unaffected. However, it is difficult at this stage to conclude that only a shade treatment should be employed because 3 out of 7 species performed better in the sun treatment. It seems more data is needed over a longer period of time in order to observe if these significant differences of growth between the sun and shade treatments are maintained and affect longer term survival.

CHAPTER 5

SUMMARY AND RECOMMENDATIONS

A comprehensive inventory of KwaZulu Natal trees used for medicinal purposes was constructed to provide basic information in terms of uses, parts used, past conservation status and current scarcity. This was used as a tool for the analysis of the conservation status of the species especially in relation to their level of utilisation. A shorter list of 23 species was then compiled from this based upon an assessment of the degree of exploitation relative to their scarcity. Of these potentially vulnerable species, 12 were selected for further experimental study. In this way, relevant biological data regarding species propagation could be focused on species which are likely to disappear from the wild through excessive harvesting of declining populations.

Germplasm is one of the ways to conserve declining populations of species, but in this study seed propagation (*ex situ* conservation) was conducted on the 12 species. Moisture content of the seeds of most of the species, with the exception of *Erythrophleum lasianthum* , *Curtisia dentata* and *Ocotea bullata*, was ≥ 20 % which is a characteristic (but not a diagnostic characteristic) of a recalcitrant seed. Moisture content determination is very useful because it gives a guideline as to whether certain seed types have recalcitrant or orthodox characteristics if seeds are to be stored. Desiccation sensitivity is the best way of assessing whether seeds are either recalcitrant or orthodox. In this study it would have been desirable to assess desiccation sensitivity, but it could not be done because very few seeds were available.

The best germination results for seeds with hard coats were achieved using the cracking treatment. Cracking of outer coverings is strongly recommended for enhancing germination. Hot water and acid treatments, which frequently reduced germination, are not recommended unless more trials are undertaken to establish optimal soaking period for high germination. With the exception of *Erythrophleum lasianthum*, the viability assessment using TTC, and germination tests was equivalent. Flotation was found to be an unreliable test of viability. It was observed that most of the seeds which did float were full and viable. TTC and germination tests are strongly recommended when determining the quality and the viability of the seed.

Although growth in height and diameter did not show much difference between sun and shade, leaf area growth during seedling establishment was generally found to be slightly better under shade treatment than under sun treatment. With this limited data, it is difficult to recommend a suitable environment for seedlings. It cannot be unequivocally stated that certain species grow well under shade simply because they are forest species. Some forest tree seedlings wait for a gap in canopy that will let light to shine on them and then they grow rapidly. Light energy enhances growth of many plants because of the increased rate of photosynthesis. None-the-less, seedlings of many forest species are damaged by excessive radiation. Growth studies should be continued up to the optimal stage when the species would be mature enough for medicinal harvest. This will need quite period of observations which could be as long as 5-10 years. This cultivation of species under controlled conditions in laboratories and greenhouses should also be studied in comparison with the species growing in the wild. The difference in growth and health of the species in greenhouse and in the wild might be interesting to note because many herbalists recommend wild specimens rather than those raised in the greenhouse (under controlled conditions). Herbalists believe wild plants produce more powerful medicine than those grown under cultivation. Thus, screening for medicinally active compounds in species growing in the wild compared with the cultivated ones could be important when recommending growth conditions.

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