Demand, propagation and seedling establishment of selected medicinal trees

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Short-listing of medicinal tree species for propagation was done through three criteria; number of bags sold, price per bag and mean scarcity value. There is a strong correlation between the mean scarcity values and number of bags sold per annum. On this basis, twenty three priority species were short-listed. Finally, seeds of only ten species were available and their propagation potential was investigated. Four species had moisture contents in the seeds of ≤ 20% and seven had moisture content of ≥ 50%. Seed viability was 75% for all species using flotation and triphenyl-tetrazolium chloride (TTC) tests. Only *E. lasianthum* had 55% viability using the TTC test. The high percentage seed viability across different species indicates their probable high germination vigour and quality. Cracking pre-treatment significantly increased germination across all species (62%). However, cracked seeds need to be thoroughly sterilised to avert fungal infestation. Acid and hot water pre-treatments decreased germination relative to the control (21%). Three species in controlled growth experiments showed that leaf area was the most significantly affected factor between species grown in sun and 40% shade conditions. However, it was impossible to classify seedlings as sun- or shade-loving. Some of the forest seedlings remain stunted until gaps in the canopy allow them to grow and establish themselves quickly. It could be appropriate to recommend low or medium light intensity for the establishment of such seedlings.

Keywords: Medicinal trees, exploitation, germination, seedling establishment.

Introduction

South Africa has a large number of plant species and their commercial utilisation can be of considerable benefit to the human population (Cunningham 1994). Plants, as primary producers, are basic primary resources upon which every being is dependent (Kokwaro 1983), but more specifically rural South Africans are dependent mainly upon indigenous medicinal plants for their health-care (Cunningham 1994; Kendler *et al.* 1992; Mander 1998).

The reliance on the use of indigenous medicinal plants has a long history (Halloin 1986, Cunningham 1988), and a large portion of the world's human population continues to rely chiefly on these plants for their primary health-care (Williams 1996).

The use of traditional medicine in South Africa (Cunningham 1988) has been practised by trained people like an *inyanga* (a traditional healer who administers herbs) or a *sangoma* (a diviner who mainly uses bones and to a lesser extent administers herbs) using sustainable strategies. Strategies were based on culture and traditional constraints such as taboos, religious controls, seasonal and social restrictions (Netshiluvhi 1996). The relatively small human population densities in the past also meant that exploitation levels were low.

Increased entry into a cash economy and rising unemployment have brought about the break-down of traditional conservation controls (Cunningham 1988). Commercial medicinal plant gatherers have emerged in response to urban demand which has resulted in medicinal plants being considered a common resource (Cunningham 1993; Netshiluvhi 1996). Popular indigenous plants with high economic value are coming under increasing exploitation pressure (Netshiluvhi 1996; Mander 1998). This has led to over-exploitation levels being much higher than predicted.

There are indications that customary controls are breaking down and legislation restricting the indiscriminate removal and damage of indigenous vegetation has been introduced (Williams 1992; Netshiluvhi 1996). However, legislation has failed to curb over-exploitation (Cunningham 1988) and only slowed down the rate of forest exploitation. Indigenous forest over-exploitation in KwaZulu-Natal (KZN) has escalated dramatically in recent years because legislation has been ineffectual as it has not been enforced.

Future replenishment of commonly utilised medicinal trees could be ensured by large scale planting using a firm scientific basis for the propagation (Gerstner 1946). Failure to do this has resulted in the pepper-bark tree (*Warburgia salutaris*), black stinkwood (*Ocotea bullata*), *Curtisia dentata* and more being declared endangered (Cunningham 1989).

In this study commonly utilised medicinal trees of KZN were prioritised in terms of their conservation needs. Cultivation requirements for successful germination and development for each species were investigated.

The aims of this study were to determine which woody plant species are being widely exploited in KZN; to investigate aspects of their seed biology relevant to the timing of germination and breaking dormancy, to investigate aspects of seed germination, *in situ* and *ex situ* seedling establishment and sapling growth that increase the probability of success.

Materials and Methods

Species availability and demand

The degree of utilisation (importance) of 140 medicinal trees in KZN was reviewed using existing literature. Because of this review, species that were well covered by the literature for their medicinal use and importance were short-listed. Personal interviews on 36 short-listed species were conducted at the Victoria street and Isipingo informal herbal markets in Durban. Forty plant gatherers were interviewed on the scarcity of those woody medicinal species. The scarcity ranking interviews (from at least eight responses) helped short-list the species further to 23. The demand assessment on the 23 species was based on the number of bags sold per annum, scarcity ranking (expressed in terms of the number of responses in which gatherers confirm that certain species are scarce) and price per bag. Using the variability of price and demand, species were

Table 1 The exploitation index and scarcity ranking of medicinal trees. Exploitation index was derived from Kendler *et al.* (1992), Brandenwyk and Brandenwyk (1974), Cooper and Swart (1992), Cunningham (1988; 1989; 1990), Morty and Johnson (1987), Pooley (1993), Scott-Shaw (1990) and van Wyk (1995). Scarcity ranking was calculated from the responses of 40 resourse users

Species	Exploitation index	Responses
Acacia caffra		1
Erythrina caffra		1
Vangueria infausta	Plenty	2
Ximenia caffra		2
Ximenia americana		2
Clausena anisata		3
Erythrophleum lasianthum	Vulnerable, declining	3
Vitex ventricos	Scarce	3
Pittosporum viridiflorum		4
Sclerocarya birrea	Heavily utilised	4
Adenia gummifera	In great demand, declining	8
Harpephyllum caffrum	Bark heavily utilised	8
Ilex mitis	Heavily utilised	8
Prunus africana	Heavily utilised, population declining	8
Turraea floribunda	Widely used in the past	8
Olea woodiana	Scarce	9
Albizia adianthifolia	Widely used, plenty	10
Albizia suluensis	Heavily utilised	12
Croton sylvaticus	Popular and heavily used, very scarce	12
Faurea macnaughtonii	Heavily utilised, population declining	12
Garcinia livingstonei	High demand	12
Protorhus longifolia	Heavily utilised	12
Zanthoxylum capense	Vulnerable	12
Balanites maughamii	Heavily utilised	15
Cassine transvaalensis	Bark is in high demand, vulnerable, declining	16
Cassine papillos	Bark is highly prized for 'muthi'	16
Ekebergia capensis	Heavily used, very high demand	18
Cassipourea gerrardii	Bark in great demand, declining	20
Bersama lucens	Very high demand, heavily exploited	22
Curtisia dentata	In great demand, large specimens rare, vulnerable, declining	24
Cryptocarya woodii	Widely used	26
Cryptocarya myrtifolia	Heavily utilised	26
Cryptocarya latifolia		26
Ocotea bullata	Vulnerable, population declining, 90% were over-exploited	28
Pterocelastrus echinatus	Heavily utilised, great demand, declining	30
Warburgia salutaris	Very high demand, it is nearly extinct	36

categorised into four groups and the mean scarcity value in each group was determined. The four groups were comprised of low number of bags (< 350)/low price (< R 100), low number of bags/high price (> R 100), high number of bags (> 350)/low price and high number of bags/high price. For each group, mean scarcity values (mean numbers of scarcity ranking responses - see Table 1) of species were calculated. The normality of the data was tested and the number of bags was logarithmically transformed. Also, a correlation matrix was constructed between the scarcity ranking, L_N (no. of bags) and price per bag. Finally, through seed availability, ten species had their propagation and growth potential investigated. Seeds of the eleventh species, *Warburgia salutaris* were not sufficiently available and only young seedlings were received from Silverglen nursery in Durban.

Seed moisture content and viability of selected species

Seeds were collected from different locations in KZN and only seeds of *E. capensis* came from Knysna.

Both seed moisture content and viability tests were performed. To limit the risk of microbial effects and fungal infection, the seeds associated with fermentation were removed from the fruit immediately after collection. Seeds were soaked in a 33% domesticated bleach solution for 20 minutes. Thereafter they were thoroughly rinsed and dried before storage in plastic bags with Benlate (insecticide) powder.

Moisture content of 20 randomly selected seeds was determined. Hard coats (if present) were removed, and the seeds were dried at 90°C overnight. Water content of the seeds was expressed on a dry mass basis.

Seed quality and viability were assessed by flotation and triphenyl-tetrazolium chloride (TTC) tests. These test methods were adapted from Kioko *et al.* (1993), ISTA (1993) and Tietema *et al.* (1993). The proportion of the seeds that sank in the flotation test was taken as a measure of seed viability. The TTC test used a 0.1% TTC solution. The hard coats (if present) were removed from twenty seeds and their cotyledons were split open. Seeds were soaked in water (pH = 7.1) overnight before submerging them into the TTC solution. Water soaked seeds became hydrated thereby enhancing the diffusion rate of TTC solution. Seed embryos which stain pink are viable and those that stain red or non-stained are dead. The solution stains live tissue of the seed where there is respiration (oxidation/reduction). Differences between the two tests were assessed via a paired *t*-test to see if they had produced the same or different results. The TTC technique is suitable for assessing seed quality (McDonald & Copeland 1989) but time consuming if applied on large seed batches. Flotation is suitable for large seed batches (Kioko *et al.* 1993).

Seed germination

To prevent any potential reduction of seed viability during storage, germination tests were conducted immediately after the seeds were collected. The three pre-treatments were; hot water, mechanical scarification and sulphuric acid. The control was composed of seeds that were not pre-treated. Seeds were then monitored daily for germination.

The hot water pre-treatment was based on the procedure outlined in Wolf and Kamondo (1993). Seeds were kept overnight in water at 90°C and then put onto moist paper to germinate. Germination was taken as emergence of the radicle.

The acid pre-treatment involved soaking separate batches of seeds for 5, 10, 20, 30, 60 and 80 minutes in concentrated sulphuric acid. They were then washed for 30 minutes under running water, and germinated as above.

The third pre-treatment was cracking the hard coat of the seeds. The seeds were carefully cracked in a way that avoided damaging the developing embryo. The laboratory germination experiments were done at 25–28°C. Seeds of *P. longifolia* and *B. lucens* were not pre-treated because they do not have hard coats. *W. salutaris* was not tested because there were insufficient seeds.

Table 2a The turnover (plant items in 50 kg bags sold per annum by 40 traders and the price per bag) of the 23 medicinal tree species

Species	Turnover (no. of bags)	Price (R)
Zanthoxylum capense	151	65
Balanites maughamii	187	50
Ilex mitis	198	35–40
Adenia gummifera	201	45–50
Prunus africana	205	50–60
Olea woodiana	210	45–50
Harpephyllum caffrum	230	40–45
Garcinia livingstonei	273	40–50
Cassine transvaalensis	282	140
Ekebergia capensis	289	120
Protorhus longifolia	300	60
Erythrophleum lasianthum	339	120
Faurea macnaughtonii	363	45
Bersama lucens	423	50
Croton sylvaticus	480	50–60
Cryptocarya woodii	480	40
Cassipourea gerrardii	508	120
Cursisia dentata	672	45–50
Pterocelastrus echinatus	901	45
Ocotea bullata	930	50
Warburgia salutaris	1212	120 and above
Albizia adianthifolia	1368	40
Albizia suluensis	1372	50–60

Differences between species and treatments were tested via two-way ANOVA to see if there was any significant difference in germination vigour.

Seedling growth

Seedling growth was monitored under two conditions of full sun and partial shade (40% shade-cloth). Pinebark medium was used to raise seedlings until they could be transplanted into the potting-mix comprising four parts local red soil, two parts river sand, one part manure and two parts compost. Growth measurements commenced when seedlings were transferred to the potting mix (age varied among the species) and thereafter, they were taken weekly. Plant height, basal diameter and leaf area were measured. Leaf area was assessed from measurements of length and breadth of each leaf. The allometric relationship between the linear dimensions and leaf area was obtained from leaf prints using a dyline paper, and relating weight of print to area.

Results

Species availability and demand

Of the 140 medicinal species identified in the literature, 36 were known to be medicinally useful and some mostly threatened in the KZN (Table 1). Also, the scarcity ranking responses were

Table 2b The demand (number of bags and price) and mean scarcity value of different species

Demand (No. of bags)	Low price, < R100	High price > R100
Low number, < 350	*A. gummifera*	*C. transvaalensis*
	B. maughamii	*E. capensis*
	G. livingstonei	*E. lasianthum*
	H. caffrum	
	I. mitis	
	O. woodiana	
	P. longifolia	
	P. africana	
	Z. capense	
	Mean scarcity value = 9.3	12.3
High number, > 350	*A. adianthifolia*	*C. gerrardii*
	A. suluensis	*W. salutaris*
	B. lucens	
	C. sylvaticus	
	C. woodii	
	C. dentata	
	F. macnaughtonii	
	O. bullata	
	P. echinatus	
	Mean scarcity value = 19.6	28

provided for further short-listing.

Thirty six species were further short-listed to twenty three through scarcity ranking of not less than eight. The turnover was variable across the 23 short-listed species (Table 2a). The lowest turnover was for *Z. capense* and the highest was for *A. adianthifolia*. Neither of these commanded particularly high prices.

Out of the 23 species, 12 had less than 350 bags (demand) sold with 39.1% of the species selling for less than R100 while only 13.1% for more than R100. Contrary to this, 11 species had more than 350 bags sold with 39.1% of species selling for less than R100 whereas 8.7% for more than R100 (Table 2b). To both levels, it showed that the scarcity increased with the price and vice versa. Also, with increased resource utilisation, there was an increased scarcity.

There was a strong correlation between scarcity and number of bags sold (Table 2c).

Table 2c Correlation matrix (r value) between bags sold, price and scarcity

	L_N Bags	Price	Scarcity
L_N	X	0.006 (n.s)	0.558
Price		X	0.117 (n.s)
Scarcity			X

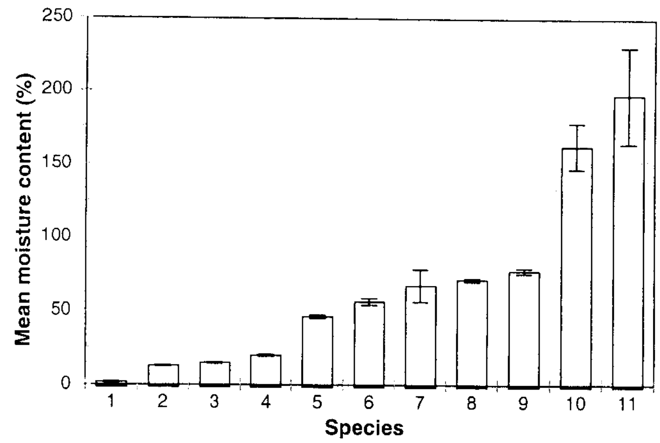

Figure 1 Mean seed moisture content (± standard error) of; 1. *E. lasianthum*, 2. *C. dentata*, 3. *O. bullata*, 4. *C. sylvaticus*, 5. *Z. capense*, 6. *C. woodii*, 7. *H. caffrum*, 8. *P. africana*, 9. *E. capensis*, 10. *B. lucens* and 11. *P. longifolia*.

Seed moisture content and viability

The species could be divided into two groups on the basis of seed moisture content. Four species had moisture contents of < 20% (i.e. *E. lasianthum, C. dentata, O. bullata* and *C. sylvaticus*), and the remainder had moisture contents of ≥ 50% (Figure 1). Seeds of both *P. longifolia* and *B. lucens* carried more water than their dry weights, with 197% and 162% moisture content, respectively.

Seed viability was greater than 75% for all species (irrespective of method), except for *E. lasianthum* which was 55% using TTC (Figure 2). There was no significant difference in results between the flotation and TTC viability tests ($T = 1.77$; $df = 9$; $p > 0.05$).

Seed germination

Significant differences exist between species and treatments ($p < 0.0001$) (Table 3). The LSD between species was 2.2, and between treatments was 2.0. Cracking pre-treatment significantly increased germination success across all species (62%), while all other treatments had decreased germination success relative to the control sample (21%).

Seedling growth

Propagation of seedlings under sun or shade conditions had little effect on seedling basal diameter growth. Only two of the ten

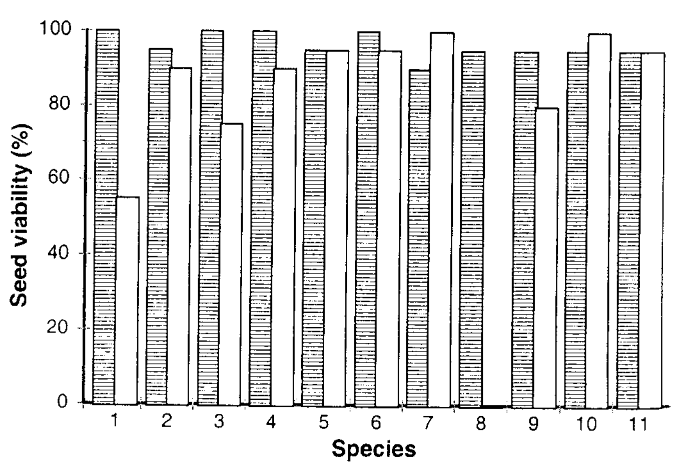

Figure 2 Seed viability of different species (as in Figure 1), using TTC (non-shaded) and flotation (shaded) techniques.

Table 3 Mean (n = 4) germination percentage of seeds from different tree species after application of different pre-treatments (mean ± standard error). (LSD between species was 2.2 and between treatments was 2.0)

Species	Control	Cracking	Hot water	5 min H_2SO_4	10 min H_2SO_4	20 min H_2SO_4	30 min H_2SO_4	60 min H_2SO_4	80 min H_2SO_4
Croton sylvaticus	0	83 (4.79)	0	0	0	0	0	5 (2.89)	5 (2.89)
Cryptocarya woodii	0	60 (8.17)	0	0	0	0	0	0	0
Curtisia dentata	0	35 (10.41)	0	0	0	0	0	0	0
Ekebergia capensis	60 (4.08)	100	5 (2.89)	73 (2.50)	40 (4.08)	90 (4.08)	85 (2.89)	60 (4.08)	75 (6.45)
Erythrophleum lasianthum	0	60 (4.08)	10 (4.08)	20 (4.08)	0	0	0	0	60 (4.08)
Harpephyllum caffrum	15 (5.77)	88 (2.50)	0	0	0	0	0	0	0
Ocotea bullata	25 (2.89)	90 (5.79)	0	0	0	0	0	0	0
Protorhus longifolia	100	0	0	0	0	0	0	0	0
Prunus africana	10 (5.79)	100	0	0	0	0	0	5 (2.89)	20 (4.08)
Zanthoxylum capense	0	0	0	0	0	0	0	0	0

species, *E. capensis* and *E. lasianthum*, had a significantly smaller basal diameter ($p \leq 0.05$) under shade conditions (Table 4). Significant differences between sun and shade treatments were apparent in the seedling height of four species; *C. sylvaticus*, *C. dentata*, *E. capensis* and *P. longifolia*. For *C. woodii* and *P. longifolia*, sun condition resulted in reduced seedling height whereas the opposite applied for *C. dentata* and *E. capensis*.

Leaf area was the attribute of seedling morphology that was most significantly affected in the sun and shade. Four species had a higher leaf area in shade, *C. sylvaticus*, *C. dentata*, *P. longifolia* (its leaves in the sun developed necrosis and died) and *P. africana* (its leaves died after being affected by insects). Species with greater leaf area in the sun treatment were, *E. capensis*, *E. lasianthum* (all leaves were lost under 40% shade cloth) and *O. bullata* (Table 5). Only *P. longifolia* had significant growth differences (in height and leaf area) in favour of the shade.

Discussion

Species availability and demand

There was a strong relationship between supply and demand (scarcity and number of bags sold per annum). More medicinal resources were used while their mean scarcity did increase. The mean scarcity also did increase with the increase in purchasing price. This is apparent on species of higher demand such as *W. salutaris*, *O. bullata*, *C. dentata* (Cunningham 1988; Cooper & Swart 1992). The latter three species were the top most purchased per annum (Mander 1998) and frequently demanded. Those species are according to Cunningham (1990), Brandenwyk and Brandenwyk (1974) and Morty and Johnson (1987) seriously threatened. Over-exploitation of those species is wide-spread throughout KZN (Cunningham 1991). At the informal herbal markets visited in 1995, few traders had such specimens. It shows that those species are no longer available outside the protected areas. More than a decade ago, the degree of ring-barking on *O. bullata* was estimated to be 90 to 100% (Morty & Johnson 1987). Because of its higher scarcity in KZN and Swaziland, *O. bullata* is increasingly being harvested from Transkei (Williams 1996). A decade ago, *W. salutaris* was on the verge of extinction around KZN (Cunningham 1988). This species treats at least twelve different types of diseases (Netshiluvhi 1996). Its importance and multi-purposefulness make it the most wanted and useful species in the country. It is likely that excessive

Table 4 Mean (n = 10) seedling height, leaf area and basal diameter of medicinal trees growing in sunlight and shade ± standard error (SE) and the age of the seedlings at the final measurement

Species	Height (mm)		Leaf area (cm^2)		Basal diameter (mm)		Age (days)
	Sun	Shade	Sun	Shade	Sun	Shade	
Croton sylvaticus	27 (6.50)a	25 (4.40)a	7 (1.50)a	30 (5.50)b	1.1 (0.20)a	0.9 (0.20)a	80
Cryptocarya woodii	26 (11.00)a	40 (14.50)b	17 (7.00)a	12 (4.00)a	0.9 (0.25)a	0.9 (0.20)a	70
Curtisia dentata	70 (9.50)a	36 (4.00)b	23 (3.00)a	70 (8.50)b	2.3 (0.15)a	2.7 (0.35)a	130
Ekebergia capensis	478 (72.50)a	331 (35.50)b	2635 (337.00)a	1665 (255.50)b	13.5 (0.55)a	8.7 (0.90)b	160
Erythrophleum lasianthum	58 (3.00)a	53 (4.00)a	104 (26.00)a	0 (0)b dried leaves	3.9 (0.15)a	2.2 (0.05)b	140
Ocotea bullata	80 (7.00)a	67 (6.50)a	111 (14.5)a	51 (5.00)b	2.8 (0.25)a	2.4 (0.05)a	100
Protorhus longifolia	84 (17.00)a	120 (19.50)b	12 (3.00)a	132 (38.50)b	3.2 (0.30)a	5.1 (0.20)b	135
Prunus africana	70 (5.50)a	71 (2.50)a	17 (5.00)a	94 (3.50)b	19. (0.05)a	2.4 (0.15)a	100
Warburgia salutaris	87 (3.50)a	90 (7.50)a	150 (24.50)a	217 (5.00)a	2.8 (0.30)a	2.7 (0.20)a	170
Zanthoxylum capense	33 (2.50)a	35 (3.50)a	22 (5.00)a	16 (3.50)a	1.0 (0.10)a	0.9 (0.05)a	60

harvesting for bark, root and stem specimens also contributed to its relatively high scarcity. Harvesting for bark and roots is according to Williams (1996) the most lethal way of resource extraction.

However, there were a low demand and value for *P. africanum* which, according to Cunningham (1991), is also heavily utilised. It seems that *P. africanum* has a limited distribution and this could be the reason for its low use and value. Similarly, distribution of *C. transvaalensis*, *E. capensis* and *E. lasianthum* is mostly restricted to northern KZN. Other species like *H. caffrum*, *P. longifolia*, *A. adianthifolia* and *C. sylvaticus* were freely accessible around KZN with a fairly high supply. The latter have a fast growth rate (Pooley 1993; Cunningham 1991). According to Cunningham (1988), supply of fast growing species with a wide distribution could easily be sustained.

Generally, it appears that the degree of exploitation of most commonly used medicinal species has been documented. Evidence about their exploitation strongly warrants their cultivation. If properly implemented, cultivation *in situ* and *ex situ*, hopefully, could substantially reduce species over-exploitation and such is well documented in Mander (1998).

Seed quality and germination

Of the species that were tested, *B. lucens, C. woodii, E. capensis, H. caffrum, P. africana, P. longifolia* showed recalcitrant behaviour with moisture contents of ≥ 50%. *E. lasianthum* showed an orthodox behaviour. It is recommended that recalcitrant seeds be germinated immediately after collection because they tolerate only little post-shedding drying (Bradweer 1989, Justice & Baas 1978). According to Bewley (1986), Egley (1989) and Kozlowski (1972), seeds with a high moisture content are susceptible to fungal infection. The death of some of the seeds, and poor germination, may be the result of such infections.

TTC and flotation techniques showed equivalent results and that seeds tested were of good quality. However, respiration of fungi and bacteria generate heat in the seeds (Halloin 1986) and as such may yield misleading TTC seed viability results. For that reason, germination is probably the ultimate seed quality test.

The different pre-treatments resulted in varying germination success. Germination under the cracking pre-treatment was successful in about 75% of the species. The same pre-treatment produced equivalent germination success in *Acacia karroo* and *A. robusta* (Choinski & Tuohy 1991). However, unsatisfactory germination results, or long germination duration, could have been caused by chemical dormancy, fungal infections, or immature seed embryos like those of *B. lucens*. According to Halloin (1986), only seeds with hard coats are immune to fungal infections. Consequently cracked seeds should be thoroughly sterilised and monitored daily for any sign of fungal infection. Insect parasitism is also a serious problem to seed propagation mostly in other African species (Hart 1995; O'Connor 1995; Beeson & Lea 1992). Ripe seeds of *W. salutaris* are also susceptible to parasitism by a fruit-fly (Johnson *et al.* 1995). For that reason, precautions to reduce parasitism should be considered for a considerable germination yield.

Seeds have secondary metabolites that may be poisonous and prevent fungal infection (Bewley 1986). Cracking and soaking of the seeds seems to enhance the leaching of metabolites and growth hormones and that may induce the chances of fungal infection by delaying germination. It also appears that poor seed germination of *Z. capense* was attributed to such cracking and soaking. However, at Silverglen nursery, the uncracked seeds of the latter germinated successfully. In another study, Campbell and Matthewson (1992) and Afolayan *et. al* (1997) had reported that water-cleaned seeds of *Atriplex nummularia* did not germinate. It was only after gibberellic acid (growth hormone) was added, that seeds germinated successfully (Campbell & Matthewson 1992).

In this study acid pre-treatment produced poor germination in 81.8 % of all the species. Only *E. lasianthum* achieved 60% germination after soaking the seeds in sulphuric acid for 60 minutes. The poor germination was probably attributed to the permeable seed coat and sensitivity of the embryos to sulphuric acid. Concentrated sulphuric acid, may consequently dessicate tissues and eventually cause cell separation (Fu *et al.* 1995; Egley 1989). In some cases seeds that pass through the digestive tracts of herbivores tend to germinate easily (Choinski & Tuohy 1991; Beeson & Lea 1994; Mucunguzi & Oryem-Origa 1996), but in others they did not (Miller 1994). Long term incubation in sulphuric acid adversely affected seed embryos of *Acacia* (Choinski & Tuohy 1991) while short term (30 minutes) achieved higher germination success (Tietema *et al.* 1993). On the contrary, satisfactory germination success was achieved on hard seeds of *Adansonia digitata* after a long term incubation (Danthu *et al.* 1995). However, in this study, poor germination might be the result of the prolonged period of soaking (up to 80 minutes). It seems that the nature of the seed coat and sensitivity of embryos to acid determine whether long or short term incubation will inhibit or enhance germination.

Poor germination of seeds submerged in hot water reflected similar results as those of *Acacia* species obtained in Tietema *et al.* (1993). Seed embryos of most seed types appeared to be too sensitive to heat and eventually died. The poor outcome was probably exacerbated by the nature of their coat. Mimosaceae and Caesalpiniaceae are most suitable for higher temperatures (Mucunguzi & Oryem-Origa 1996; Beeson & Lea 1992) since they have hard (woody) seed coats. Temperature held between 80°C and 100°C for 5 to 15 minutes successfully stimulates germination of most hard seeds from various habitats (Cocks & Stock 1997), but, temperatures of 120°C and more inhibit germination in certain fynbos taxa (Musil & Martin 1991). However, all the species in this study, except *E. lasianthum* could not germinate under higher temperature (90°C heated water) pre-treatment. It seems that most seeds were detrimentally affected by raised temperatures. According to Hodgkinson and Oxley (1990) germination response to higher temperatures could differ significantly between species and this appears to be true in this study. Submerging hard seeds of different species in hot water (90°C) for different periods (like 5, 10, 15, 30 and up to 60 minutes) may help to obtain threshold temperature. In this study this was not done, instead seeds were incubated for 24 hours until the water cooled down. It appeared that a continuous incubation has a detrimental effect on seeds.

Seedling growth

Basal diameter growth of the seven tree species was not significantly affected by the degree of exposure to sun and shade. *E. capensis* showed higher growth in the sun, probably because it is fast growing (Pooley 1993; Pitman & Palmer 1972). Differences in the height of seedlings were apparent for four species (*C. woodii, C. dentata, E. capensis* and *P. longifolia*); two (*C. woodii* and *P. longifolia*) did well in the shade whereas another two (*C. dentata* and *E. capensis*) did well in the sun. With the exception of *E. capensis* and *C. sylvaticus*, all other species are slow growing (Carr 1994; Pitman & Palmer 1972; Pooley 1993).

Leaf area showed the most significant differences in growth. Seven species (*C. sylvaticus, C. dentata, E. capensis, E. lasianthum, O. bullata, P. longifolia* and *P. africana*) had significant differences in leaf area, with four (*C. sylvaticus, C. dentata, P. longifolia* and *P. africana*) in favour of the shade while three (*C. woodii, E. capensis* and *E. lasianthum*) were in favour of the sun.

Seedlings that did not develop well in the sun showed faster leaf loss than leaf production. Some developed necrotic patches on their leaves.

Only two species (*E. capensis* and *P. longifolia*) showed consistent results across the growth variables when contrasting sun and shade growth. For *E. capensis*, growth at basal diameter and leaf area were highest in sun condition, while the opposite applied for *P. longifolia*. Two other species, *W. salutaris* and *Z. capense* demonstrated no significant differences between sun and shade conditions. Four species (*C. sylvaticus*, *C. woodii*, *O. bullata* and *P. africana*) each had significant growth differences for one variable only, usually leaf area. *Curtisia dentata* provided an ambiguous characterisation with highest leaf area in shade, but significantly greater height in sun condition.

In another study, seedlings of *Acacia karroo* had higher survival and higher density under shade cloth and low irradiance conditions (O'Connor 1995). Such conditions are probably the best for seedling establishment of different species. Some seedlings may be shade tolerant but need to wait for gaps in the canopy to develop into an adult tree (Ting 1982). This idea was supported by Ellison *et al.* (1993) when he reported that certain high shade-tolerant species appeared to require gaps (light) for establishment. In the Tsitsikamma and Diepwalle forest gap studies, it was observed that quite a number of different seedlings (probably all shade-tolerant) established themselves within created gaps (van Wyk & Netshiluvhi 1997). Irrespective of whether a tree species is shade- or sun-tolerant, seedlings may be adapted to any suitable micro-habitats for their development and establishment. It appears that edaphic factors are a strong influence during the development of seedlings. Appropriate soil type for a specific species gives good establishment results (Tietema *et al.* 1993). It is possible that the results in this study reflect different requirements for each species. Lack of mycorrhiza or nitrogen- fixing bacteria could be another reason why certain species did not establish themselves well.

Generally, this study encourages resource users to be more positive towards cultivation of the scarce essential medicinal species *ex situ* and *in situ*. Silverglen nursery in Chatsworth, Durban, is also empowering and teaching the resource users (*inyanga*, *sangomas*, traders and gatherers) to grow medicinal trees on a large scale.

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