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Description and Ecology of *Schinziophyton rautanenii* (Schinz) Radcl.-Sm. in Namibia

F. P. Graz

Department of Agriculture, Polytechnic of Namibia, P/Bag 13388, Windhoek, Namibia,
pgraz@polytechnic.edu.na

Abstract

The Manketti, Mongongo or Mangetti, Schinziophyton rautanenii *(Schinz) Radcl.-Sm. is an indigenous tree in Namibia, the fruit of which are of significant socio-economic value. The tree occurs in what appears to be even aged groves on deep sand, as part of the dry savanna woodlands. Natural regeneration in the woodland areas seems to be scarse, although some success has been achieved by planting truncheons.*

Introduction

Schinziophyton rautanenii (Schinz) Radcl.-Sm. (initially classified as *Ricinodendron rautanenii* by Dinter in 1885) is a deciduous, dioecious tree (Peters 1987), which belongs to the family *Euphorbiaceae* together with other genera like *Euphorbia* (Candelabra trees), *Spirostachys* (Tamboti) and *Croton* (Coates Palgrave 1983).

Although the tree is generally considered as rapid growing (Peters 1987), it has been declared a protected species in Namibia in terms of the existing forest legislation since 1952 (Erkkilä & Siiskonen 1992), probably because of its socio-economic importance.

In recent years the commercial exploitation of the nuts of the tree was investigated. Little information is available, however, on the ecology of the species and its management requirements so that the implications of such commercialisation are uncertain, and management is difficult to plan or implement.

This paper aims to review the information available for a detailed description of the species in Namibia. This description may in turn provide indications for policy development on suitable management or research activities and priorities.

Distribution and Occurrence

Distribution

Peters (1987) identifies a core area where trees are characteristically found in large groves or extensive stands as co-dominant or dominant tree. This core area is a relatively narrow belt across the subtropical latitudes of southern Africa. The northern border runs through Angola, Zambia and Mozambique, while the southern range limit runs through Northern Namibia (the Ohangwena, Okavango and Caprivi regions), Botswana, Zimbabwe and the Transvaal in South Africa (Lee 1973, Peters 1987).

Within the core area the species is densely grouped, few trees occurring more than 100m apart (Lee 1973). Where it becomes dominant the trees are usually spaced about 20m apart (Keegan 1982). Outside of the core area the tree appears to occur more or less occasionally or in small, localised stands (Peters 1987).

During their survey in Caprivi, Chakanga *et al.* (1998) found no co-dominant tree species where *Manketti* was recorded. Büschel (1999), on the other hand, reports that the species is found in mixed stands, i.e. mixed with other species and uneven in tree age and density. Büschel did not indicate associated species, however.

According to Keegan (1982), *S. rautanenii* is often associated with *Terminalia sericea, Baikiaea plurijuga, Burkea africana, Pterocarpus angolensis, Guibourtia coleosperma, Strychnos coculoides* and *Afzelia quanzensis* and members of the genus *Combretum*.

In accordance with its growth requirements (see later in text) *S. rautanenii* occurs in linear groves of a few hundred meters across and several kilometres long on the crest of fixed dunes in the Dobe and /Du/da areas of Namibia where the soils are sandy (Lee 1973; Helgren 1982). In other areas within its range the species may occur in irregular groves (Botelle 1999). The distribution of the species in Namibia is given in Figure 1.

Growth Requirements and Preferences

Soil Requirements

S. rautanenii is always found on deep sands of the Kalahari Sand Plateau (Palmer & Pitman 1972), never on calcrete or compacted soils, on clay or on areas subject to flooding (Lee 1973; Chimbelu 1983). The surveys reported on by Helgren (1982) found very high sand contents (around 94%) with clay around 1%. The organic matter content was less than 1%. The soils on which the species is found near Dobe are very poor in nutrients.

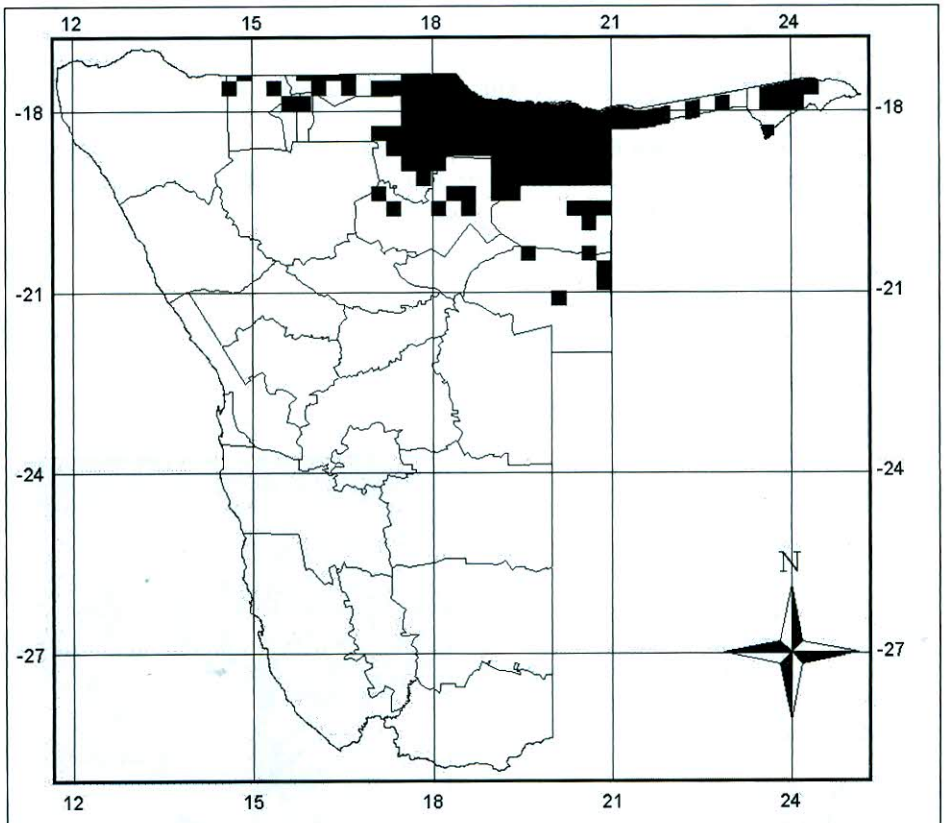

Figure 1. The distribution of *Schinziophyton rautanenii* in Namibia, showing the quarter degree squares where the species is found. Sources are combined from Botelle (1999), Records from the National Botanical Research Institute, Namibia, the National Forest Inventory (NFI 2000) and Namibian Tree Atlas Project (TAP 2000).

The distribution of *Manketti* groves in the Okavango region of Namibia as identified by Botelle (1999) very closely follows the fossil dunes and higher lying sandy plains identified by Graz (1999).

Climatic Conditions

The core area of the *Manketti* falls into the summer rainfall area. Keegan (1982) notes an average precipitation approximately 520mm per annum while Helgren (1982) cites 400mm per annum and Peters (1987) 200mm to 1000mm. Biesele *et al.* (1979) state that the species tolerates drought. It is evident from these sources that the species occurs in an extremely wide rainfall range and variability.

The maximum daily temperatures often exceed 30°C in the area where the species occurs (Keegan 1982; Chimbelu 1983). Although it tolerates light winter frost (Peters 1987) temperatures below 7°C kill young plants (Anon 1999).

The distribution of the tree in Namibia, as provided in Figure 1, coincides with the growing period zone 2 as identified by de Pauw *et al.* (1999). This zone has an average growing period of 105 days, and a dependable growing period of 86 days.[1]

Altitude

Peters (1987) reports that the altitude at which the species may be found ranges from 200m to 250m up-to 1220m; with the core area generally above 1200m (Chimbelu 1983).

Description

Growth form

S. rautanenii generally grows to a height of 7-12m (Lee 1973) although it may grow larger. Palmer & Pitman (1972) reported a tree of 24m height in the northern parts of Namibia.

The bole of the tree is stout and may reach a diameter of up to 1m (Palmer & Pitman 1972). As many as five trunks may grow adjacent to each other in a tight cluster (Peters 1987). The crown is broad and spreading (Lee 1973), with branches that are thickset (Peters 1987), stubby (Palmer & Pitman 1972) and contorted (Biesele *et al.* 1979). Figure 2 shows the tree during the dry season.

In Zambia, Chimbelu (1983) found that on disturbed land where spacing between trees was wide, trees had a short bole and many branches. These trees also tended to yield more fruit.

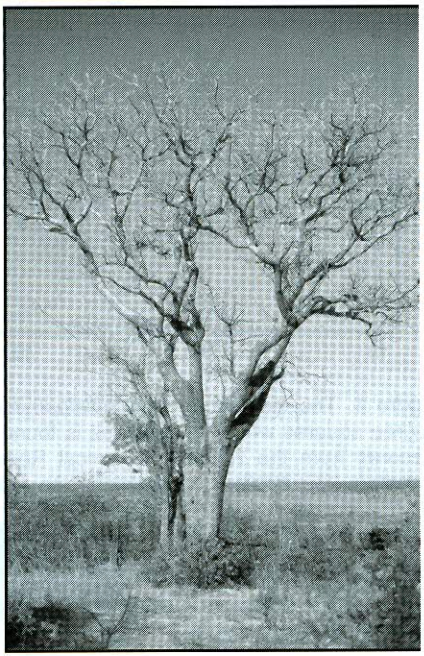

Figure 2: *Schinziophyton rautanenii* tree in Western Bushmanland, Namibia, during the dry season. Photo: F.P. Graz 1994.

[1] De Pauw and Coetzee (1999) define a growing period zone as the number of days during which precipitation exceeds half the potential evapotranspiration, plus the number of days to evapotranspire an assumed 100mm of water. In addition, the temperature during the whole period must exceed 6.5°C.

Leaves

The leaves are digitally compound and arranged alternately on branches (Peters 1987). They are comprised of three to seven leaflets, borne on hairy peduncles of up to 15cm (Palmer & Pitman 1972). The leaves of male trees are smaller than those of female trees (Botelle 1999), although no indication was given as to how much smaller.

The individual leaflets are broadly lanceolate to ovate, 5-13cm long and about 2.5 to 9cm broad with a blunt or rounded apex. The base is rounded or flat, but unequal (Palmer & Pitman 1972).

The abaxial surface (lower side) is lighter than the adaxial (upper), but both sides are covered with stellate hairs. Midrib and veins are covered with rust-coloured hair. Leaflet margin is serrate or occasionally lobed. Stipules are present (Palmer & Pitman 1972).

The margins of leaflets show small, dark, gland-like structures. These have not been mentioned in the literature, and their exact purpose is unclear. In her study of the tree, Dr. E. Solowey observed gland-like structures at the point where the leaflets meet. These have not been described in the literature (Solowey *pers. com*).

Leaves begin to sprout in September-October, before the first rain of the season. They are shed around May (Peters 1987).

Flowers

The species is dioecious (Palmer & Pitman 1972; Coates Palgrave 1983; Botelle 1999), with sex ratios of male : female more or less 1:1. This ratio was estimated by Lee (1973) in the Dobe and /Du/da areas, and by Botelle (1999) for the Mpungu district (Okavango region), Namibia.

The flowers are borne in slender, loose sprays or paniculate cymes of up to 12cm long. The female cymes or sprays are shorter than those of the male trees, and produce fewer flowers (Coates Palgrave 1983).

Flowers are whitish (Palmer & Pitman 1972) or yellow and have a diameter of about 10mm. The sepals are densely covered with stellate hairs, the latter ranging in colour from golden to rust-brown, and are stellate. The petals are fused to form a wide tube (Coates Palgrave 1983)

The flowers are produced in early summer (Lee 1973), in October to November (Coates Palgrave 1983) or early December (Peters 1987), before the first rains (Palmer & Pitman 1972).

Fruit

The fruit of *S. rautanenii* are ellipsoidal drupes (Keegan 1982) approximately 35mm long and 25mm in diameter. In Zambia, Chimbelu (1983) found significant differences in fruit size associated with differences in location.

Unlike many other species, the *Manketti* fruit ripens after falling to the ground in April or May (Helgren 1982; Arnold *et al.* 1985). With ripening the colour turns from the original yellow to a reddish brown, although the mesocarp may be dried out to a powdery texture by August (Lee 1973) so that only the endocarp is visible.

The fruit itself is comprised of five distinct layers, as follows.

The exocarp is thin, but sturdy (Biesele *et al.* 1979), and is pale green when the fruit falls from the tree. When the fruit dries the surface appears slightly wrinkled (Biesele *et al.*1979). The exocarp is often eaten by insects by the end of the first season (Peters 1987).

The mesocarp (pulp) is about 2 – 5mm thick (Biesele *et al.* 1979), green or red in colour, and has a dry, spongy texture (Lee 1973).

The endocarp is about 3 – 7mm thick and extremely hard and woody (Biesele *et al.* 1979), forming a tough shell around the testa and nut once the flesh is removed, the endocarp weathers to a pale buff-grey (Lee 1973). The shell is pitted, and has an indentation at the broad end (Lee 1973).

Irregular canals permeate the endocarp. One of these is especially well formed and runs from a deep gutter at the abscission scar to the germule region at the lower end of the fruit. Within this gutter is a strand of tissue that may be acting as a wick for rainwater. This seems to offer a mechanism to help germination (Biesele *et al.* 1979).

The testa (seed coat) is about 1mm thick (Lee 1973) and woody (Keegan & van Staden 1981). It is strongly attached to the endosperm which it encloses (Biesele *et al.* 1979).

The endosperm, nut or kernel is roughly the shape and size of a small hazel nut, and creamy yellowish to white in colour (Lee 1979). It contains about 57% lipid and 26% protein. The embryo, embedded in the endosperm, is about 20mm long, with thin, papery cotyledons and (Keegan 1982)

The proportion which each of these parts contribute to the total mass of the fruit is given in Table 2.

Table 2: The composition of a normal *S. rautanenii* fruit after *Lee (1973) and †Keegan (1982)

Part of Fruit	% of Total Weight
Exocarp (skin)	12.5* (10†)
Mesocarp (Flesh)	26.7* (20†)
Endocarp	51.8* (60†)
Testa and Nut	9.0* (10†)
	100 = 10g†

The free end of the fruit often has a small point, while the stalk end has an abscission scar (Biesele *et al.* 1979).

Lee (1973) describes two abnormalities of the *Manketti* nut, that have also been noted by (Botelle 1999). The first oddity concerns approximately 5% of fruit which are extra large and contain two kernels. See Figure 3 for a comparison of the fruit. The other abnormal form only contains a vestigial, inedible kernel and is generally lighter than normal nuts. This abnormality may be caused by the fall of immature nuts before the kernel has been able to develop. The number of spoilt nuts produced seems to vary between groves. Some groves have a high proportion of these nuts of up to 10% (Lee 1973).

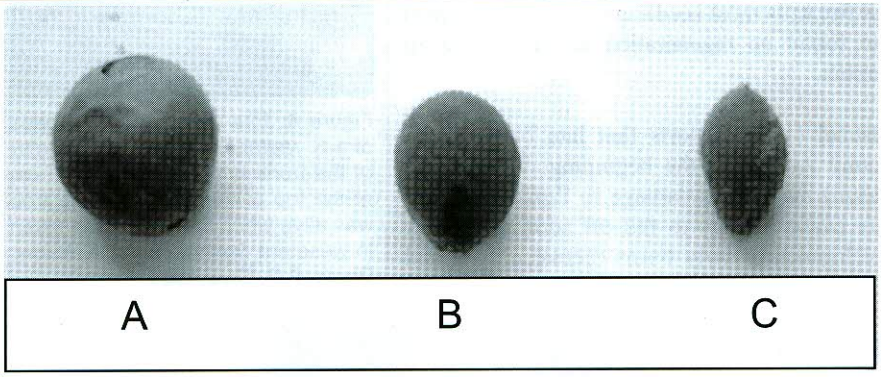

Figure 3: A: fruit with two kernels; B: fruit with single kernel; C: kernel

Bark and Wood

Mature trees have a smooth green or golden bark (Palmer & Pitman 1972) which has a tendency to peel in thin strips (Keegan 1982). Young twigs are covered with short, soft, white or red hairs that disappear with age (Palmer & Pitman 1972).

The wood of *S. rautanenii* is yellowish, light and soft (Palmer & Pitman 1972), having a wavy grain and coarse texture. It is comparatively strong for its weight

(Coates Palgrave 1983). Coates Palgrave recommends that the wood should be sawn immediately after cutting and dried as rapidly as possible to prevent discoloration.

Demography

The effect of fire

Adult trees may often be observed with fire scars on their trunks, as shown in Figure 4. While this indicates that trees may cope with a certain amount of fire damage, no conclusions can be drawn on the long-term effects of fire frequency, season and intensity on the demography.

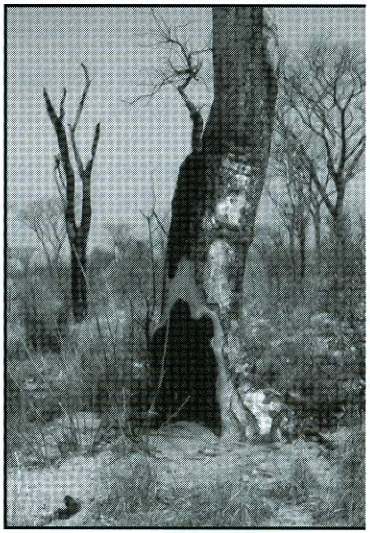

Figure 4: Fire damage at the base of a *S. rautanenii* tree. The diameter of the trunk is approximately 70 cm at the top of the fire scar. The tree was alive when the photo was taken in wesetern Bushmanland, Namibia. Photo: F.P. Graz 1994.

Geldenhuys (1977) reports that seedling establishment is favoured by complete protection, although the data available to him were not conclusive. Discussion with residents of western Bushmanland (Namibia) confirms that fire kills most seedlings. Chimbelu (1983) also found no regeneration in burnt areas in Zambia.

Büschel (1999) reports that late burns (from around August to the beginning of the rainy season) may cause damage to flower buds, or may cause flowers to fall off soon after their development. Early burns (between June and August) cause little damage to flower buds.

Pests and diseases

Parker (1978) reports that various fungi and insects attack the seed and wood of the tree.

Regeneration and establishment

The groves described by Biesele *et al.* (1979) were made up of even aged trees, while Büschel (1999) reports uneven aged stands in the Okavango region of Namibia. It is therefore unclear if regeneration occurs continuously or in cohorts, as seems to be the case with *Pterocarpus angolensis*, another woodland species (Graz 1996). Seedlings seem to grow better in moderate shade than in full sun or deeper shade (Graz unpublished data), suggesting that the species does not colonize open areas, as does

P. angolensis, but rather establishes itself in areas where some woody vegetation occurs. This must, however, be verified in the field.

Chimbelu (1983) reports an average 259 stems of regeneration per hectare for part of his study area in Zambia. He referred to this density as poor, and considers this to be due to the exploitation of the nuts by humans and animals. However, since the natural cue for germination has not been established (see later in text), this conclusion may be a little premature, and higher reproduction rates may be found in other years.

Fruit Production

S. rautanenii requires between 15-25 years to reach maturity, before it will bear fruit (Peters 1987; Lee 1973). However, Mizrahi (quoted by Taylor & Kwerepe, 1995) has found that trees may produce a crop within four years if they are irrigated. Palmer & Pitman (1972) report that fruit are produced in large quantities, and may sometimes lie "knee-deep" under the trees. Peters (1987) provides a more quantitative estimate of fruit yield of between 200 and 800kg per hectare, while Keegan (1982) mentions 1t of nuts per hectare for some stands north of Tsumeb in northern Namibia.

Peters (1987) considers such variations in yield to be primarily due to differences in tree density, rather than because of differences in the production potential of trees. Mwamba (1996), on the other hand, reports that fruit yield increases linearly with tree age and size.

Annual fruit production is dependent on the quantity, frequency and duration of rainfall during the key months of October to March. Too much, as well as too little rain will reduce yield (Botelle 1999). Lee (1973) reports that yields will be higher in the year following good rains.

Fruit production is influenced to some extent by weather conditions. High winds may cause a reduction in yield by shaking the fruit from the trees prematurely. Yield is also affected by consumption by mammals, birds, and insects, and by fungal attacks (Botelle 1999). As mentioned previously, fire may damage flowers thus reducing potential yield.

Seed Dispersal

Lee (1973) reports numerous saplings under the canopies of mature trees in the Dobe and /Du/da area, but little regeneration elsewhere. It is not clear if this implies a lack of dispersal agents or specific germination and growth requirements. Graz (unpublished data) found that light significantly affected the height of seedlings grown in controlled nursery conditions.

Once the fruit have fallen they may be ingested by elephant (*Loxodonta africana*) (Bainbridge 1965), porcupine (*Hystrix africaeaustralis*) (Parker 1978), ostrich (*Struthio camelus*) and kudu (*Tragelaphus strepsiceros*) (Biesele *et al.* 1979).

The nuts are generally not digested by elephant and are excreted in the dung (Lee 1973). Many are still viable, and end up in a nutrient rich substrate that will retain moisture (Bainbridge 1965). No reference was found to indicate the survival of seed ingested by the other mammals.

It must be noted that the numbers of elephant, kudu and ostriches have declined dramatically in most parts of the Namibian section of the core area in recent years. This may limit the dispersal of seed in the future.

Human activity also plays a role in the distribution of seed, as fruit may be dropped along tracks between groves and villages, These trees do not seem to grow to maturity, however (Biesele *et al.* 1979).

Germination

A large portion of the nuts remain dormant for at least a year (Peters 1987). This is not induced by the hard endocarp, but probably due to other mechanisms (Keegan *et al.* 1998). Such mechanisms are not expanded on by Keegan *et al.* (1998). Kumar (1978) reports that seeds remain viable for at least two years.

The breaking of the dormancy has been subject to a number of studies (Biesele *et al.* 1979; Keegan & van Staden 1981; Keegan 1982; Keegan *et al.* 1989; Shikongo in prep). The ethylene treatment tested by several of these authors seems to have had the highest degree of success in germinating seed artificially. Keegan *et al.* (1989) suggest that ethylene might serve as a signal for sufficient moisture as experienced during the onset of the wet season.

Biesele *et al.* (1979) tested mechanical scarification, grinding off the tip of the testa until the endocarp became visible. After imbibing water, the seed still required a few weeks before the radicle started to emerged.

Chimbelu (1983) reports that livestock chew the soft part of the fruit and discard the stone. Termites then feed upon these discarded pits. He suggests that the combined impact of livestock and termites may enhance the capacity of the seeds to germinate. If this is the case, the decline in elephant, kudu and ostriches in northern Namibia (see "Seed dispersal" above) may also affect regeneration through the animals' effect on germination. This needs to be verified, however. The possibility of replacing parts of the ecological role of game animals with domestic cattle should also be investigated.

Shikongo (in prep) has achieved some improvement in germination by soaking seeds in water treated with smoke. His results have not been conclusive and further investigations are planned in this regard.

Lee (1973) reports that the mechanical action of raindrops partially buries the fruit that remain on the ground during the summer. The implications of this for germination is unknown, although it may be assumed that such a layer of soil will retain more moisture around the seed.

The survival of seedlings has not been clearly documented. While Botelle (1999) records some seedlings in the Okavango region of Namibia, he does not give an indication of survival potential. According to a resident of western Bushmanland in Namibia, there are many seedlings at the end of a growing season, but most, if not all are killed by fire.

Root development

In view of the poor soils on which the species grows, and the low water holding capacity of these soils, root development is looked at separately.

When the seed has germinated, the emerging radicle grows very slowly, has no root hairs and does not noticeably taper off (Biesele *et al.* 1979; Stanford, 1979). When it is 50-100mm long, 5-12 true roots emerge in a ring from immediately above the root-tip, resembling a Medusa's head. When these roots are 20-50mm long the plumule starts to emerge (Biesele *et al.* 1979).

Nursery trials have shown that much of the development of seedlings takes place underground. Although relatively little height growth took place, the potted seedlings developed a sturdy taproot. The initial rootlets that form behind the root tip remain visible, but do not show much thickening (Figure 5) (*pers obs*).

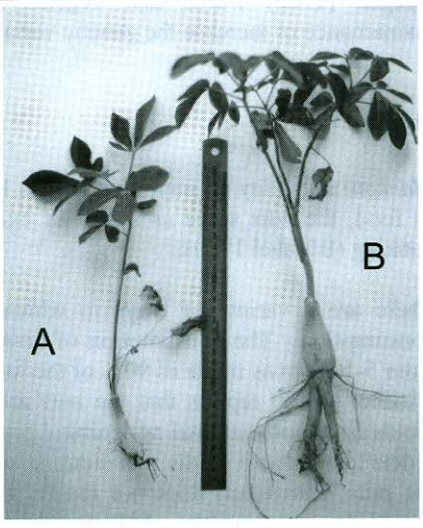

Figure 5: Root development of seedlings in a nursery environment, after 4 weeks (A) and 16 weeks (B). Photo: F.P. Graz 2000.

Although adult trees still have a distinct taproot most lateral roots appear to run close to the soil surface (Timberlake & Calvert 1993) probably enabling the plants to make the most of infiltrating water.

In their studies of micorrhizal infection of roots in the field, Mateke *et al.* (1999) found only very little presence of vesicular and arbuscular colonization of the roots. They also found that the amount of infection varies with season.

Vegetative Propagation

Chimbelu (1988) reports some success with the planting of truncheons. He reports that the Luchazi people of Zambia are familiar with this technique. Botelle (1999) suggests that truncheons may be used to propagate plants closer to villages to improve access to the resource. However, the possibilities for such development are limited due to the site requirements of the species, specifically looking at soil requirements. On the other hand, if a specific sex ratio and mingling of male and female plants is required, the planting of truncheons may result in higher production. This needs to be investigated.

Keegan (1982) warns that vegetative propagation will not provide for the maintenance or increase the genetic variability.

Uses

Manketti nuts play an important role in local, rural economies. Apart from their use as food, the nuts serve as a unit of exchange, and the shells are used as fuel for cooking (Büschel 1999).

There are a variety of ways in which the kernel or pulp may be prepared for consumption. The consumption of nuts varies between people and season ranging from 5-10% to as much as 90% of the total dietary intake of local people (Lee 1973). Büschel (1999) reports that the nuts are used more intensively during years when yields from conventional agricultural crops have been poor. Keegan (1982) provides a detailed analysis of the nutritious value of the nuts. According to Keegan (1982), the pulp (mesocarp) does not readily decompose and is edible even if it already turned dry and crumbly. This permits the consumption of the fruit for six to eight months after they have fallen to the ground, even after the new crop has fallen as reported by Lee (1973) and Peters (1987).

The pulp may be processed into a potent beer (Palmer & Pitman 1972; Büschel 1999) because of the relatively high sugar contents of the pulp (Swart 1991). More recently there appears to have been a shift in the importance of the fruit in the diet of rural people. While Lee (1973) notes that up to 90% of food intake is based on *Manketti*, du Plessis (1999) reports that the use of fruit is now concentrated on the production of Kashepembe, a very potent local alcoholic drink. The remaining nuts are almost a by-product. According to Palmer & Pitman (1972) the kernels may yield about 63%

of a yellow, edible oil that is used in soups. There are currently attempts to market oil extracted from the kernel (du Plessies 1999).

The wood of the tree is very light, and may be used for floats, dart and drawing boards, crates, insulating material or coffins (Palmer & Pitman 1972). Büschel (1999) also reports that the wood is used for the construction of ox drawn sledges, which are used for transporting of goods in sandy areas. In his study in Zambia, Chimbelu (1988) further determined that the wood is used for building, furniture, musical instruments, toys, curios and fishing gear.

Chimbelu (1988) mentions that parts of the stem, roots and leaves of the tree are used for medicinal purposes, but provides no further information regarding the ailments that are treated. The shoots of young *Manketti* trees form an important source of water and nutrition for migrating wildlife in Botswana (Albertson 1998).

Management Issues

Mwamba (1989) recommends that the dioceous nature of the species and its environmental requirements be considered in management of the resource. He does not provide possible management strategies, however.

While the sex of adult trees is readily determined during the flowering season, no reference was found on the sexing of seedlings. This would be vital for the artificial establishment of stands.

While Chimbelu (1983) addresses the management of the tree in his thesis, he is concentrating primarily on consultative management approaches rather than actual management practices or techniques.

From the literature it becomes evident that the effect of inter- and intra-species competition as well as the effect of fire on seedling survival need to be clarified before management strategies can be considered.

Conclusion and Recommendations

Most of the available literature deals with either the socio-economic importance of the *Manketti* nuts, or the artificial germination of seed. Further studies dealing with the regeneration or the general ecology of the species are sparse or have not been published.

No literature dealing with the growth and development of the species could be found, and questions such as: "For how long will a tree produce nuts? What is the longevity of the trees or the general viability of the seed" or "What is the role of fire?" seem to

have been neglected. These questions, together with a variety of others dealing with the demography and management issues, are important if management strategies are to be considered.

Management is only possible if certain basic knowledge is available. Apart from specifying the uses of the trees or their fruit, necessary information also includes:

- Optimum sex ratio
- Optimum intermingling of male and female plants
- The potential planting density
- Factors that cue germination
- Longevity of the individual plants
- Pollinators and their ecology
- Age and size relationships
- Productivity of individual trees
- Requirements of regeneration in terms of fire protection and the protection from animals.

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References

ALBERTSON, A. 1998. Northern Botswana Veterinary Fences: Critical Ecological Impacts. URL: http://www.stud.ntnu.no/~skjetnep/owls/fences/index.html. Accessed 19 April 2000.

ANON. 1999. The Mongongo/Manketti Nut *Ricinodendron rautanenii (Schinziophyton rautanenii)*. URL: http://www.naturalhub.com/natural_food_guide_nuts_uncommon_Ricinodendron_rautanenii.htm. Accessed 19 April 2000.

ARNOLD, T.H.; WELLS, M.J. & WEHMEYER, A.S. 1985. *Khoisan food plants: Taxa with potential for future economic exploitation.* Plants for arid Lands. Royal Botanic Gardens, Kew.

BAINBRIDGE, W.R. 1965. Distribution of seed in elephant dung (*Acacia, Ricinodendron, Hyphaene*). *Puku* 3:173-175.

BIESELE, M.; BOSQUET, J. & STANFORD, G. 1979. *A Kalahari food Staple: Ricinodendron rautanenii*. In Goodin, J.R. & Northington, D.K (eds). *Arid*

land plant resources. International Center for Arid and Semi-Arid Land Studies, Texas Tech Univ. Lubbock. pg 341-355.

BOTELLE, A. 1999. *Estimating Manketti Nut Yields in the forest of Western Kavango, Namibia..* CRIAA SA-DC, Windhoek.

BÜSCHEL, D. 1999. *A Study of Resource Utilisation: A case from Namibia, Mpungu Constituency, Kavango District, Northern Namibia.* CRIAA SA-DC Report, Windhoek, Namibia.

CHAKANGA, M.; KORHONEN K. & SELÄNNIEMI T. 1998. *Forest Inventory for Caprivi Region.* NFFP, Directorate of Forestry, Windhoek.

CHIMBELU, E.G. 1983. *The availability, use and Management potentials of Mungongo (Ricinodendron rautanenii, Schinz): A Case study of the Southern Shungu Region, Zambia.* Ph.D. Thesis, State University of New York.

CHIMBELU, E.G. 1988. *Developing Zambian tree resources through community needs and values*. In: Lungwanga G & Sinyangwe I (eds). *Utilizing Local Resources for Development.* Proceedings of the 9th PWPA Conference, Eastern, Central and Southern Region. held at Musungwa Lodge, Zambia, July, 1988 (Lungwangwa, G. & Sinyangwe, I. eds.). 1990, Zambia. pp. 66-75,

COATES PALGRAVE, K. 1983. *Trees of Southern Africa.* Struik Publishers, Cape Town.

DE PAUW, E.; COETZEE, M.E.; CALITZ, A.J.; BEUKES, H. & VITS, C. 1999. Production of an Agro-Ecological Zones Map of Namibia (first approximation), Part 1: Condensed Methodology. *Agricola* 10:1-7

DE PAUW, E. & COETZEE, M.E. 1999. Production of an Agro-Ecological Zones Map of Namibia (first approximation), Part 2: Results. *Agricola* 10:8-68.

DU PLESSIES, P. 1999. *Report on the Manketti Stakeholder Workshop held on 9th July, 1999.* CRIAA SA-DC, NTFP 1, Windhoek.

DYER, R.A. 1975: *The Genera of Southern African Flowering Plants.* Department of Agricultural Technical Services, Pretoria; ISBN 0 621 02854 1.

ERKKILÄ, A. & SIISKONEN, H. 1992. Forestry in Namibia 1850-1990. *Silva Carelica* 20 244p.

GELDENHUYS, C.J. 1977. The Effect of Different Regimes of Annual Burning on Two Woodland Communities in Kavango. *South African Journal of Forestry* 103:32-42.

GRAZ, F.P. 1996. *The management of a Pterocarpus angolensis population under the influence of land use and fire.* M.Sc. Thesis, University of Stellenbosch, South Africa.

GRAZ, F.P. 1999. A Preliminary Terrain Feature Classification of the Okavango Region, Namibia. *South African Journal of Surveying and Geo-Information* 1:123-129.

GRAZ, F.P. in prep. The development of *Schinziophyton rautanenii* Seedlings in relation to Shading.

HELGREN, D.M. 1982. Edaphic Context of the Mongongo" (*Ricinodendron rautanenii*) in the Northwestern Kalahari. *South African Journal of Science* 78:131-132.

KEEGAN, A.B. 1982. *Dormancy and Germination of the Manketti Nut, Ricinodendron rautanenii.* Ph.D. Thesis, University of Natal, Pietermaritzburg.

KEEGAN, A.B, & VAN STADEN, J. 1981. Dormancy and Germination of the Manketti Nut *Ricinodendron rautanenii* Schinz. *South African Journal of Science* 77:262-264.

KEEGAN, A.B.; KELLY, K.M. & VAN STADEN, J. 1989. Ethylene Involvement in Dormancy Release of *Ricinodendron rautanenii* Seeds. *Annals of Botany* 63:229-234

KUMAR, V 1978. *Studies of Mungongo Seed Germination.* TIRC/NCSR Res. Pap. No. 9, Tree Improvement Research Center, National Council for Scientific Research, Kitwe, Zambia.

LEE, R.B. 1973. Mogongo: The Ethnography of a Major Wild Food Resource. *Ecology of Food and Nutrition*, Vol 2, 307-321

MATEKE, S.; MCGONIGLE, T. P. & SINCLAIR, R. C. 1999. Mycorrhizal Contribution to the Establishment of Fruit Trees in Southern Africa. In Devlin J.F. & Zettel T. (eds) *Ecoagriculture: Initiatives in Eastern and Southern Africa.* pp 131-148.

MWAMBA, C.K. 1996. *Status report on domestication and commercialization of non-timber forest products in agroforestry systems.* Tree Improvement Research Centre, National Council for Scientific Research, Kitwe, Zambia

NFI, 2000. National Forestry Inventory data base, Directorate of Forestry, Windhoek, Namibia. Data extracted April 2000

PALMER, E. & PITMAN, N. 1972. *Trees of Southern Africa.* Vol. 2; Balkema, Cape Town.

PARKER, E.J. 1978. *An Annotated List of Problems which Affect some Zambian Wild Fruit Trees*. Tree Improvement Research Center, National Council for Scientific Research, Kitwe, Zambia. TIRC/NCSR Res. Pap. No. 6

PETERS, C.R. 1987. *Ricinodendron rautanenii* (Euphorbiaceae): Zambezian Wild Food Plant for All Seasons. *Economic Botany* 41:494-502.

SHIKONGO, S. in prep, M.Sc Thesis, University of Namibia.

STANFORD, G. 1979. Preliminary findings on germination of Mongongo seeds. *Plant Propag*. 25:2-4.

SWART, W.J. 1991. Good Living – The Bushman Way. *Trees in South Africa, Oct. 1990-Mar. 1991*. p. 46-49.

TAP, 2000. Namibian Tree Atlas Project. National Botanical Research Institute, Windhoek, Namibia. Data extracted April 2000

TAYLOR, F.W. & KWEREPE, B. 1995. *Towards the domestication of some indigenous fruit trees in Botswana.* In: Maghembe J.A.; Ntupanyama Y. & Chirwa P.W. (eds.) *Improvement of indigenous fruit trees of the Miombo woodlands of southern Africa.* ICRAF, Nairobi.

TIMBERLAKE, J.R. & CALVERT, G.M. 1993. Preliminary Root Atlas for Zimbabwe and Zambia. *The Zimbabwe Bulletin of Forestry Research* No. 10, Zimbabwe Forestry Commission.