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POPULATION STRUCTURES OF *UAPACA KIRKIANA* (EUPHORBIACEAE) IN THE MIOMBO WOODLANDS OF MALAWI: STATUS AND MANAGEMENT PROSPECTS FOR FRUIT PRODUCTION

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NGULUBE, M. R. 2000. Population structures of *Uapaca kirkiana* (Euphorbiaceae) in the miombo woodlands of Malawi: status and management prospects for fruit production. A study to assess the population structures of *Uapaca kirkiana* Müll. Arg., an important indigenous fruit tree of African miombo woodlands, was undertaken in 19 sites covering 5 major silvicultural zones in Malawi. The species was well represented, with stems ha^{-1} ≥1 cm dbh exceeding 100 in 17 of the 19 sites. *Uapaca kirkiana* regenerates readily from seed and recruitment is high. Mortality is mostly attributed to dry season fires which frequently affect the woodlands. To promote successful recruitment and establishment of *U. kirkiana*, the woodlands should be subjected to annual burning early in the dry season to avoid litter fuel accumulation. Where density is high, thinning operations should be undertaken to open up the canopy to improve fruiting.

Key words: *Uapaca kirkiana* - population structures - miombo woodlands - indigenous fruit trees - natural regeneration - Malawi

NGULUBE, M. R. 2000. Struktur populasi *Uapaca kirkiana* (Euphorbiaceae) di dalam hutan jarang miombo di Malawi: prospek status dan pengurusan bagi pengeluaran buah. Kajian untuk menilai struktur populasi *Uapaca Kirkiana* Müll. Arg., sejenis pokok asli berbuah yang penting di hutan jarang miombo di Afrika, diusahakan di 19 tapak yang meliputi 5 zon silvikultur utama di Malawi. Spesies diwakili dengan garis pusat aras dada batang ha^{-1} ≥ 1 cm melebihi 100 dalam 17 daripada 19 tapak. *Uapaca kirkiana* tumbuh semula daripada biji benih dan penokokan adalah tinggi. Kematian kebanyakannya disebabkan oleh kebakaran pada musim kemarau yang selalu mempengaruhi hutan jarang. Untuk menggalakkan kejayaan penokokan dan penubuhan *U. kirkiana*, hutan jarang tersebut mestilah bergantung kepada kebakaran tahunan pada awal musim kemarau untuk mengelakkan penumpukan bahan api sarap. Operasi penjarangan mestilah dijalankan apabila kepadatan tinggi untuk membuka sudur bagi menggalakkan pembuahan.

Introduction

The distribution of the miombo woodlands of southern Africa corresponds roughly to the Zambezian Regional Centre of Endemism of White (1983). They are recognised for their floristic richness and the widespread occurrence of the tree genera *Brachystegia*, *Julbernardia* and *Isoberlinia* (Malaisse 1978). The woodlands cover large areas of Angola, Malawi, Mozambique, Tanzania, Zaire, Zambia and Zimbabwe and have for a long time been a useful source of various forest products and services for the subsistence needs of rural communities. Among the most important are edible fruits, many of which serve as food reserves during seasonal food shortages and in times of famine that frequently affect the region (Campbell 1987). The fruits are nutritionally rich in sugars, essential vitamins, minerals, vegetable oils and protein

(Malaisse & Parent 1985, Saka & Msonthi 1994). Utilisation and trade of fruits are integral components of local economies and culture and play important roles in household welfare (Kwesiga & Mwanza 1995, Lowore *et al.* 1995, Minae *et al.* 1995).

Miombo woodlands offer little commercial logging interest and as a result have attracted limited ecological and silvicultural attention (Lawton 1982). However, this view is rapidly changing and the importance of forest products other than timber — collectively referred to as non-timber forest products (NTFP) — is being widely acknowledged. As local peoples' resource needs and livelihood come to the forefront, miombo woodland management increasingly needs to revolve around producing a wide variety of NTFP. Indeed, efforts to manage miombo woodland resources have been revived and much intensified in the last few years though they still remain in their infancy. It appears that most silvicultural problems affecting miombo species relate to life cycle and growth phases prior to the sapling stage. In a number of miombo tree species, there are problems of seed dispersal and problems of seed dormancy and seedling check or die-back following germination. To these biological features must be added the environmental problems of the general harshness of the miombo climate and annual fires.

Over 50 indigenous tree species of the miombo ecosystem of southern Africa bear edible fruits (Campbell 1987). In Malawi, *Uapaca kirkiana* Müell. Årg. (a dioecious species) qualifies as one of the most valued indigenous fruit trees and its fruits have always been appreciated as NTFP (Ngulube *et al.* 1996). The fruits have high nutritional value and play an important dietary role (Sufi & Kiputo 1977, Palgrave 1981, Malaisse & Parent 1985, Saka & Msonthi 1994). Indeed, in recognition of its importance as a resource of great potential, it was declared a protected food tree in Barotseland (Western Province, Zambia) as early as the 1950s (Palgrave & Palgrave 1957). Throughout much of southern Africa, the fruits are collected from the wild and sold at the roadside and in town centres and city markets, serving as a significant rural source of income (Ngulube 1995). In recent years, the development of cottage wine industries in Malawi and Zambia has opened an attractive additional market for the fruit. Large quantities of fruits are now required to sustain these winery industries as well as to meet the growing demand for whole fruits in urban and city markets.

The state of knowledge on *U. kirkiana* as a vegetation component of the miombo woodlands of southern Africa is limited and largely inconsistent in form and representativeness (Ngulube *et al.* 1995). No definitive study has been traced on the population structures or dynamics of the species. In most field studies traced, attention is centred on vegetation communities — reference to *U. kirkiana* is only incidental, as a community member (Trapnell 1959, Rattray 1961, Lawton 1978, *et al.* 1982). Data on the population structures of *U. kirkiana* should provide a picture of the existing state of the species in the wild. As a basis for identifying appropriate *in situ* management options for the species, a pilot population-level study in the miombo communities throughout Malawi was therefore undertaken in 1995. The work reported in this paper is based on the results of the study and discusses possible management of *U. kirkiana.*

Materials and methods

Study sites

A total of 19 study sites covering 5 of the major silvicultural zones of Malawi (Hardcastle 1978) were selected based on a reconnaissance survey that identified both major concentrations of *U. kirkiana* and populations under extreme conditions of altitude and rainfall in Malawi. During selection, priority was placed on sites with minimal disturbance. Details of the sites and the various studies conducted in each are summarised in Table 1.

Table 1. Details of sites used for studies of *Uapaca kirkiana* population structures in the miombo woodlands in Malawi

Site	Zone*	Locality	Elevation (m)	Mean rainfall (mm)
Chimarilo, Kasungu	D	12°26'S, 33°33'E	1200	900
Chongoni, Dedza	E	14°19'S, 34°16'E	1632	1000
Mtangatanga, Mzimba	E	11°54'S, 33°43'E	1650	1000
Thazima, Rumphi	E	10°50'S, 33°35'E	1500	1000
Chikumbeni, Zomba	G	15°24'S, 35°19'E	900	1125
Chimpeni, Zomba	G	15°25'S, 35°19'E	750	1125
Malosa, Machinga	G	15°15'S, 35°19'E	900	1125
Michesi, Mulanje	G	15°48'S, 35°39'E	900	1125
Nandiwo, Mulanje	G	15°46'S, 35°43'E	950	1125
Sadzi, Zomba	G	15°24'S, 35°20'E	900	1125
Zomba Outer Slopes	G	15°23'S, 35°19'E	1000	1125
Livingstonia, Rumphi	J	10°38'S, 34°10'E	1371	1400
Misuku Hills, Chitipa	J	09°40'S, 334°4'E	1400	1400
Tsamba, Mwanza	J	15°20'S, 34°37'E	1000	1400
Uzumara	J	10°51'S, 34°07'E	1800	1400
Litende, Nkhata Bay	L	11°55'S, 34°04'E	500	1640
Kakwewa, Nkhata Bay	M	11°53'S, 33°59'E	1050	1450
Kaning'ina, Nkhata Bay	M	11°27'S, 34°02'E	1254	1450
Mazamba, Nkhata Bay	M	11°43'S, 33°55'E	1300	1450

* Hardcastle's (1978) silvicultural zones based on mean temperature and rainfall.

Population structure

Sampling coincided with the fruiting period of *U. kirkiana* (April–October 1995), facilitating identification of the male and female plants. At each site, a baseline on a set compass bearing was initiated at the site boundary. Along each transect, the first sample centre point was positioned 20–30 m inside the population (to avoid boundary effects) and thereafter, at 100 m intervals. Following the procedure described by Hall (1991), the 20 nearest trees (all species) to the sample centre points with dbh ≥10 cm were recorded. The genders of all *U. kirkiana* trees were identified and recorded where possible. From the centre point, the distance to the 20th tree was measured and any additional trees equidistant to the 20th nearest tree were recorded. Over the area occupied by the circle passing through the 20th tree, all *U. kirkiana*

≥2 m tall were recorded. Each *U. kirkiana* ≥1 cm dbh was measured and referred to a size class of <10 cm. Individuals <1 cm dbh but ≥2 m tall were referred to the "<1 cm dbh (sapling)" class.

Natural regeneration

Information was collected on the regeneration of *U. kirkiana* within natural communities beneath or around mother trees. Two categories of regeneration were distinguished: less than 12 months old ("young" seedlings identified by the presence of the cotyledons) and more than 12 months ("old" seedlings <30 cm tall, no cotyledons present, but with an evident thickened root collar). Assessment was carried out within 5 m radius (an area of 79 m^2 $tree^{-1}$) of the base of each confirmed female (mother) tree. A total of five randomly selected female parent trees were assessed in each population. To facilitate thorough enumeration of the regeneration, each sample area was assessed by segments progressing clockwise around the tree.

Data handling and analysis

Individual trees of *U. kirkiana* were assigned to diameter classes of ≥1<10 cm, 10–15 cm, 16–20 cm, 21-25 cm, 26–30 cm and >30 cm according to the dbh (to the nearest cm) for summary and description purposes. For each site, the following parameters were summarised in tables:

- number of species represented in each site
- stocking (stems ha^{-1}) of all tree species ≥10 cm dbh
- stocking (stems ha^{-1}) of ≥1 cm dbh *U. kirkiana*

Data on the natural regeneration of *U. kirkiana* were summarised by regeneration category as follows:

- number of "young" seedlings ha^{-1} (<12 months old)
- number of "old" seedlings ha^{-1} (>12 months old)
- number of saplings ha^{-1} (dbh <1 cm)

Results

Gross population structure

In all the 19 sites, gross population structure of individuals ≥10 cm dbh was variable, with stocking ranging from 96 stems ha^{-1} to 1073 stems ha^{-1} (Table 2). The population structures are generally "balanced" — the numbers of individuals ha^{-1} >30 dbh being low (Figure 1). At 10 out of the 19 sites, *U. kirkiana* accounted for more than 50% of stems ha^{-1} ≥10 cm dbh (Table 2). At 14 sites, *U. kirkiana* accounted for most of the trees in small diameter classes (<21 cm dbh), its contribution increasing with decreasing dbh class (Figure 1).

Population structure and natural regeneration: Uapaca kirkiana

Uapaca kirkiana is well represented in all the 19 populations, with stems ha^{-1} >1 cm dbh exceeding 100 in most populations (Table 3). Typically, most of the stems are

Table 2. Stocking (stems ha^{-1}) of all species and contributions of *U. kirkiana* in natural communities in Malawi

Site	Zone	Number of species	Diameter (dbh) classes (cm)					
			10-15	16-20	21-25	25-30	>30	Total
Chimarilo	D	15	288 (38.9)	76 (15.8)	28 (28.6)	20 (20.0)	4 (100)	416 (44.2)
Chongoni	E	7	36 (63.9)	108 (41.7)	43 (58.1)	14 (50.0)	6 (33.3)	207 (49.3)
Mtangatanga	E	13	451 (65.9)	56 (50.0)	5 (0)	0 (0)	5 (0)	517 (62.9)
Thazima	E	13	307 (76.9)	93 (68.8)	58 (50.0)	9 (22.2)	16 (12.5)	483 (68.9)
Chikumbeni	G	26	85 (29.4)	95 (52.6)	63 (55.6)	24 (50.0)	19 (47.4)	197 (78.7)
Chimpeni	G	19	116 (6.0)	52 (28.8)	35 (34.3)	27 (25.9)	32 (21.8)	262 (18.3)
Malosa	G	14	114 (77.2)	94 (69.1)	94 (43.6)	35 (34.3)	35 (34.3)	372 (58.6)
Michesi	G	14	104 (31.7)	182 (24.4)	173 (27.7)	82 (21.9)	55 (14.5)	596 (26.1)
Nandiwo	G	20	141 (48.9)	113 (36.3)	107 (38.3)	31 (45.2)	31 (9.7)	423 (39.7)
Sadzi	G	27	54 (18.5)	44 (45.5)	39 (51.3)	18 (55.6)	22 (36.4)	177 (38.4)
Zomba	G	21	17 (23.5)	20 (25.0)	12 (41.7)	16 (68.8)	31 (58.1)	96 (44.8)
Livingstonia	J	11	134 (50.0)	157 (75.8)	131 (74.8)	31 (83.9)	4 (50.0)	457 (71.8)
Tsamba	J	8	484 (30.4)	221 (59.7)	31 (83.9)	10 (50.0)	0 (0)	746 (41.6)
Uzumara	J	14	784 (59.1)	242 (71.9)	31 (83.9)	16 (31.2)	0 (0)	1073 (62.3)
Misuku	J	14	400 (68.5)	105 (55.2)	53 (30.2)	16 (31.3)	16 (0)	590 (59.8)
Litende	L	12	145 (24.8)	155 (0)	100 (36.0)	91 (60.4)	63 (42.8)	554 (27.8)
Kakwewa	M	11	154 (23.4)	137 (59.5)	191 (52.3)	73 (87.7)	18 (0)	573 (50.8)
Kaning'ina	M	7	633 (83.1)	327 (71.9)	41 (87.8)	10 (100)	0 (0)	1011 (79.8)
Mazamba	M	16	134 (43.3)	80 (58.8)	56 (67.9)	35 (48.6)	13 (23.1)	318 (51.3)

Figures in parentheses refer to the contribution of *U. kirkiana* expressed in percentages (%) in relation to the rest of the species.

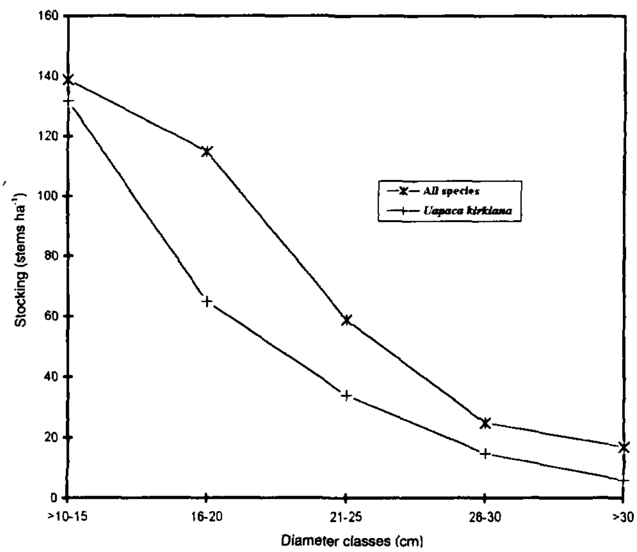

Figure 1. Mean stocking density of miombo species and the contribution of *Uapaca kirkiana* in 19 sampled sites

concentrated in small diameter classes. The sex ratio of mature *U. kirkiana* individuals ≥10 cm dbh in all the 19 natural populations was about 1:1 and significant departures from this ratio (at Chikumbeni, Chimpeni, Malosa, Michesi, Nandiwo and Uzumara) all resulted from a higher proportion of the male trees (Table 3).

Assessment results of natural regeneration of *U. kirkiana* demonstrated the presence of seedlings and saplings within the populations (Table 4). The density of seedlings ha^{-1} was generally much higher than that of saplings and poles (Figure 2). The high mortality of seedlings indicates a low proportion developing into saplings. Similarly, the rarity of poles suggests that most saplings do not progress into this category.

Association with other species

Species richness is generally low and mostly dominated by *Brachystegia* and *Julbernardia* species. The dominance of the Caesalpinioideae is characteristic of the surveyed sites, although their contribution to stocking varies widely within and between the sites (Table 5). As associates of *U. kirkiana*, a total of 49 species (Table 5) of which 16% are *Brachystegia* species were recorded. *Brachystegia boehmii, B. longifolia, B. spiciformis, Cussonia arborea, Faurea speciosa, Ochna schweinfurthiana, Parinari curatellifolia* and *U. sansibarica* were the most common, each being represented in more than 50% of the 19 sites (Table 5). Of the species recorded at each site, those with reported ectomycorrhizae (ECM) association occurred with higher frequencies than AM or non-mycorrhizal species.

Table 3. Stocking (stems ha^{-1} ≥1 cm dbh) and sex ratio of *U. kirkiana* in natural communities in Malawi

Site	Zone	Diameter (dbh) classes (cm)							
		≥1<10	10-15	16-20	21-25	26-30	>30	Total	Sex ratio
Chimarilo	D	44	112	12	8	4	4	184	0.9
Chongoni	E	109	23	45	25	7	2	211	1.1
Mtangatanga	E	405	297	28	0	0	0	730	1.0
Thazima	E	1086	236	64	29	2	2	1419	0.3
Chikumbeni	G	24	25	50	35	12	9	155	1.3
Chimpeni	G	0	7	15	12	7	7	48	1.3
Malosa	G	38	88	65	41	12	12	256	1.3
Michesi	G	75	33	48	48	18	8	230	1.3
Nandiwo	G	148	69	41	41	14	3	316	1.8
Sadzi	G	0	10	20	20	10	8	68	0.9
Zomba	G	292	4	5	5	11	18	335	1.0
Livingstonia	J	16	67	119	98	26	2	328	1.1
Misuku	J	389	274	58	16	5	0	742	1.0
Tsamba	J	132	147	132	26	5	0	442	0.7
Uzumara	J	311	463	174	26	5	0	979	1.3
Litende	L	0	36	0	36	55	27	154	1.0
Kakwewa	M	9	36	82	100	64	0	291	1.1
Kaning'ina	M	87	526	235	36	10	0	894	1.0
Mazamba	M	245	58	47	38	17	3	408	1.0

Figures in parentheses refer to the contribution of *U. kirkiana* expressed in percentages (%) in relation to the rest of the species.

Table 4. Regeneration (numbers ha^{-1}) of *U. kirkiana* in natural populations assessed in Malawi

Site	Zone	Regeneration category			
		Young seedlings (cotyledons present)	Old seedlings (seedlings <30 cm tall)	Saplings (> 50 cm tall < 1 cm dbh)	Total regeneration
Chimarilo	D	9646	1322	726	11694
Chongoni	E	27336	19384	687	47407
Mtangatanga	E	25166	10437	794	36397
Thazima	E	4970	21670	748	27388
Chikumbeni	G	1528	7194	874	9596
Chimpeni	G	-*	-	905	905
Malosa	G	3910	6229	503	10642
Michesi	G	3976	3380	449	7805
Nandiwo	G	-	2319	299	2618
Sadzi	G	-	4326	874	5200
Zomba	G	-	-	792	792
Livingstonia	J	1829	23022	788	25639
Misuku	J	398	11597	469	12464
Tsamba	J	37177	2783	268	40228
Uzumara	J	9675	22266	271	32212
Litende	L	20278	31412	865	52555
Kakwewa	M	17097	7157	713	24967
Kaning'ina	M	3340	5815	738	9893
Mazamba	M	1286	26830	1119	29235

*Not assessed due to dry season fire which had affected the sites prior to enumeration.

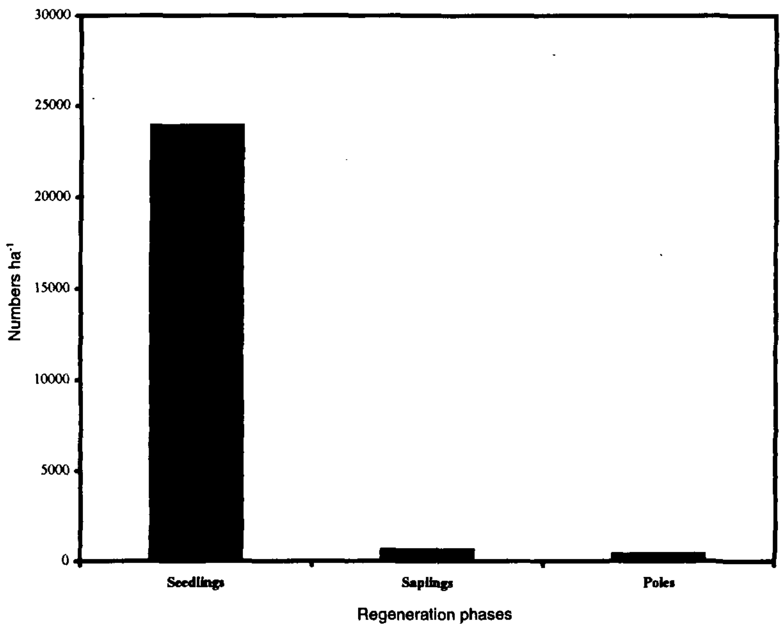

Figure 2. Overall regeneration capacity of *U. kirkiana* in 19 sampled populations in Malawi

Table 5. Tree species recorded occurring in association with *U. kirkiana* in natural communities in Malawi

Species	Mycorrhizae	Ck	Cm	Cp	Cg	Kk	Kn	Lt	Lg	Ms	Mz	Mc	Mk	Mt	Nw	Sz	Tb	Tz	Uz	Za	Total (All sites)
Albizia antunesiana	AM*	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	3
Anisophyllea pomifera	AM	-	-	-	-	3	-	2	1	-	2	-	1	-	-	-	-	-	-	-	9
Brachystegia boehmii	ECM**	-	3	1	-	3	-	-	-	1	-	-	2	-	-	1	-	4	2	1	18
Brachystegia floribunda	ECM	-	2	-	-	-	-	-	-	-	-	-	1	6	-	-	3	-	3	-	15
Brachystegia longifolia	ECM	1	1	-	2	3	1	4	-	1	6	-	-	-	-	2	-	-	3	-	24
Brachystegia manga	Not traced	-	-	-	-	-	-	-	-	-	-	3	-	-	5	-	-	1	-	-	9
Brachystegia microphylla	ECM	-	-	-	-	-	-	-	-	-	1	1	-	6	1	-	-	-	-	-	9
Brachystegia spiciformis	ECM	2	-	-	3	2	4	2	3	-	5	-	2	5	-	4	1	1	2	-	36
Brachystegia taxifolia	Not traced	-	-	-	-	-	-	-	-	-	1	-	-	6	-	-	-	-	1	-	8
Brachystegia utilis	ECM	1	5	-	-	-	-	6	1	2	1	4	-	-	-	-	-	-	-	-	20
Bridelia micrantha	AM	1	-	1	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	1	6
Burkea africana	Not traced	1	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	3
Catunaregam spinosa	Not traced	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	2
Combretum molle	AM	1	-	1	-	-	-	1	-	-	1	1	-	5	1	-	-	1	-	1	13
Cussonia arborea	AM	1	1	1	1	1	-	-	-	1	1	-	-	6	1	1	2	-	1	1	19
Dalbergia nitidula	AM	1	1	1	-	-	-	-	-	-	1	1	1	-	-	1	-	-	-	1	8
Diospyros kirkii	AM	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	2
Diplorhynchus condylocarpon	AM	1	-	-	-	-	-	-	-	1	-	1	-	-	1	4	-	-	-	-	8
Dombeya rotundifolia	Not traced	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	3
Entada abyssinica	AM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Erica benguelensis	Not traced	-	-	-	-	1	-	1	-	-	-	-	-	6	-	-	-	-	-	-	8
Ekebergia benguelensis	Not traced	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	1	-	3
Erythrina abyssinica	AM	-	-	1	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	1	7
Faurea saligna	AM	1	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	3
Ficus sur	Not traced	-	-	-	1	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	3
Faurea speciosa	Not traced	-	1	1	-	-	1	-	1	-	1	1	-	-	1	1	1	1	1	1	12
Flacourtia indica	Not traced	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	3

Table 5. (*continued*): Tree species recorded occurring in association with *U. kirkiana* in natural communities in Malawi

Species	Mycorrhizae	Ck	Cm	Cp	Cg	Kk	Kn	Lt	Lg	Ms	Mz	Mc	Mk	Mt	Nw	Sz	Tb	Tz	Uz	Za	Total (All sites)
Hymenocardia acida	AM	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	3
Isoberlinia angolensis	ECM	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	2	-	5
Julbernardia globiflora	ECM	1	-	1	-	-	-	-	1	-	-	1	-	-	2	1	-	1	-	1	9
Julbernardia paniculata	ECM	-	6	6	-	-	-	-	-	-	-	-	-	6	-	-	-	1	-	6	25
Lannea discolor	AM	1	1	1	-	-	-	-	-	-	-	1	-	-	1	2	-	-	-	1	8
Markhamia obtusifolia	AM	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Memecylon flavovirens	Not traced	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	1	1	-	4
Monotes africana	ECM	–	-	-	-	-	-	-	-	1	-	-	2	5	1	-	-	1	1	-	11
Ochna schweinfurthiana	Not traced	-	1	1	-	1	-	-	1	1	1	1	1	-	-	1	-	-	-	1	10
Ozoroa reticulata	Not traced	1	-	1	1	-	-	-	-	1	-	-	-	-	1	1	-	-	1	1	8
Parinari curatellifolia	AM	1	-	1	1	1	1	1	2	1	4	1	3	6	1	2	1	2	3	1	33
Pericopsis angolensis	ECM	1	-	1	-	-	-	2	-	1	1	1	-	-	1	3	-	-	-	1	12
Protea petiolaris	Not traced	-	1	-	-	-	-	-	-	-	-	-	1	6	-	-	-	-	-	-	8
Pseudolachnostylis maprouneifolia	AM	1	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	4
Rhus natalensis	Not traced	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2
Pterocarpus angolensis	AM	1	-	1	-	-	-	1	-	1	-	1	-	-	1	-	-	-	-	1	7
Syzygium guineense	AM	-	-	1	-	-	-	-	-	-	1	-	-	-	-	2	-	1	-	1	6
Uapaca kirkiana	ECM	6	6	3	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	3	108
Uapaca nitida	ECM	1	-	-	-	-	-	1	1	-	-	2	-	-	2	2	-	-	-	-	9
Uapaca sansibarica	ECM	2	1	-	-	3	6	1	1	6	-	-	1	-	-	6	6	-	-	-	33
Vangueria infausta	Not traced	1	-	1	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	1	5
Vitex doniana	Not traced	1	-	1	-	-	-	-	-	-	-	1	-	-	-	4	-	-	-	1	8

Scoring: 1 representing stocking of <20 stems ha^{-1}, 2 for 21–40 stems, 3 for 41–60 stems, 4 for 61–80 stems, 5 for 81–100 stems and 6 for > 100 stems ha^{-1}.

Site acronyms: Ck, Chikumbeni; Cm, Chimarilo; Cp, Chimpeni; Cg, Chongoni; Kk, Kakwewa; Kn, Kaning'inan; Lt, Litende; Lg, Livingstonia; Ms, Malosa; Mz, Mazamba; Mc, Michesi; Mk, Misuku; Mt, Mtangatanga; Nw, Nandiwo; Sz, Sadzi; Tb, Tsamba; Tz, Thazima; Uz, Uzumara; Za, Zomba.

*AM: arbuscular mycorrhizae; **ECM: ectomycorrhizae; - absent.

Mycorrhizal associations from: Högberg (1982, 1989), Högberg & Piearce (1986), Högberg & Alexander (1995).

Discussion

A management perspective for Uapaca kirkiana

Uapaca kirkiana has a long history of use as a resource within southern Africa — particularly as a source of fruit. Despite its importance and abundance in the miombo region, accelerating deforestation (Hyde & Seve 1993) and the rarity of domesticated stands (Ngulube, *et al.* 1996) underline the need for active conservation. Around the many expanding centres of population within the natural range, extensive replacement of forest by arable and tree crops has been responsible for substantial reductions in its populations. Nevertheless, its resource value persists and great attention continues being focused on this rather than the ecological factors associated with the exploitation of the resource. Sustainability of a reliable income flow requires maintenance of the tree resource upon which this flow is based. If *U. kirkiana* is depleted through over-exploitation, inappropriate harvesting procedures or poor management policies, not even improved marketing processes will make any distinct difference.

Sporadic collection of *U. kirkiana* fruits for domestic use will have little impact on the long-term stability of its natural population structures and dynamics. However, as a valuable market fruit, intense annual fruit harvesting for commercial purposes may have serious ecological impacts. Over-exploitation or destructive harvesting of the *U. kirkiana* fruits is therefore likely to reduce the recruitment rate, thereby altering the population size-class distribution over time.

This study has revealed that *U. kirkiana* is well represented (Figure 1) in all the woodlands assessed — accounting for more than 50% of stems ha^{-1} ≥10 cm dbh (Table 2). The woodlands are dominated by the Caesalpinioideae and the most common associates of *U. kirkiana* are those with reported ectomycorrhizae association (Table 5), an important feature of miombo woodland ecology (Högberg & Alexander 1995). *Amanita, Cantharellus, Lactarius* and *Russula* are the major fungi genera which typically form ectomycorrhizas within the miombo woodlands, renowned for the production of a variety of mushrooms widely collected and consumed or sold as a source of cash during the wet season.

Where a management authority is identifiable, the initial need is to characterize stand structure of *U. kirkiana* in terms of the gender and sizes and monitor these over time. The immediate conservation objective should be to promote desirable stocking levels of both genders. The present demographic information suggests a natural stocking of 100–500 individuals ha^{-1} ≥10 cm dbh could be expected in areas where *U. kirkiana* is well-represented (Table 3). Most of the stems are concentrated in small diameter classes and the population structures conform to typical reversed J-shaped curve (Figure 1) — suggesting a stable size class distribution pattern with successful natural regeneration and regular reproduction. High mortality at this level will set the stage for only a proportion of the juvenile population attaining a mature size to occupy the limited space available in the woodland community.

The high tree density (Table 3) suggests a large and intense seed shadow, although the seed shadow of individual trees seems small — a dispersal distance of 8 m has been reported (Malaisse 1978). There is no dormancy mechanism and once dispersed, the seed germinates readily which is a rather atypical feature for a miombo woodland species (Ngulube & Mkandawire 1997) as most of its close associates are legumes (Table 5) with explosively dehiscent pods and strongly expressed seed dormancy. Coincidence of fruit maturation and fall with the wet season (Ngulube 1996) maximises prospects that moisture will be available for germination. Once germinated, the young seedling must survive a 6–7 months harsh dry season. Most *U. kirkiana* regeneration is suppressed by any dry season fires, but there is resprouting (Hans *et al.* 1982), a reflection of adaptation to the fire environment (Bond & van Wilgen 1996).

This study suggests good stocking of "young" and "old" regeneration in natural populations (Table 4) — consistent with the 2039 ("young") and 1183 ("old") individuals ha^{-1} reported by Mwamba (1992) for Kanona Forest Reserve, Zambia. Regeneration success may be expected to vary with site depending mainly on the frequency and intensity of dry season fires. Nevertheless, the high numbers of "old" regeneration (Table 4) typify a species resilient to perturbation (Peters 1996). The low number of seedlings developing into saplings (Figure 2) indicates that the seedlings are highly vulnerable, but once the sapling stage is attained, mortality rates decline. High seedling mortality is, however, offset by subsequent good fruiting and high germination rates of *U. kirkiana* in its natural communities. This is evidence of a relatively large seedling bank from which recruitment is being effected into the sapling stage. As *U. kirkiana* is well represented in the miombo woodlands involved in the present study (Table 2), the relatively high recruitment rate, and the expectation of an existing large seedling bank is therefore not surprising.

Management practices in miombo woodlands do not at present include any scheduled action to favour the regeneration or growth of any particular species (Dewees 1996). The conditions which promote the germination and establishment of *U. kirkiana* in these woodlands have therefore not been formally investigated. A broad approach is desirable to ascertain the fate of dispersed seeds as an integral part of the demographic picture. For comparison with an apparently low nursery success rate ((Ngulube *et al.* 1997), it will be useful to know the proportion of seed under natural conditions which fails to germinate rather than succumbing to predation. Sites with depleted *U. kirkiana* populations should be rehabilitated through encouragement of natural regeneration. Initial strict fire control will promote regeneration as long as there are relict living root stocks or nearby seed sources (Anonymous 1929). Extended periods of rigorous protection would, however, be unnecessary if any burning was controlled and early.

The density and size-class structure data presented in this study provide a baseline for monitoring the impact of fruit harvesting on the natural population of *U. kirkiana* at each site. For sustained management, there is need to assemble yield data of the fruit resource being produced in these natural populations and amounts being exploited. In this respect, the major need is to obtain a reasonable estimate of the total quantity of the fruit resource produced, followed by implementation of a monitoring scheme on the extraction rates over time and formula to maintain population structures of an appropriate kind. One approach to assembling these data is to train local collectors to weigh or count fruits produced by marked sample trees during their normal harvest operations. Impact of differing harvest intensities on the population status of the species is required to clarify the most feasible exploitation levels. Periodic regeneration surveys should provide data on the dynamics of the seedling and sapling phases of the species in natural populations. As long as densities remain above "threshold values" and no major problems are detected in harvest assessments, then the exploitation levels are ideal. If, however, the densities are lower, corrective steps should be undertaken to reduce exploitation levels.

Uapaca kirkiana is gregarious (Ngulube 1996) and fruit yield is adversely affected by the high stocking densities and canopy closure — dominant trees being more productive than intermediate-sized or small and suppressed trees (Hans 1981, Mwamba 1995). In such cases, management prescriptions should focus on improving fruit production through appropriate thinning regimes with an objective of opening up the canopy. In this respect, removal of associated species (Table 5) or aged *Uapaca* individuals (dbh >30 cm) should be considered first. Indeed, increased fruit yields of *U. kirkiana* have been reported in Zambia following thinning operations (Mwamba 1995). To maximise fruit yields, a population sex ratio in favour of the female individuals would be an appropriate management option — provided conspecific male to female dispositions are properly designed — enabling male individuals to serve several females (around them) within the population. Based on the Zambian results (Mwamba 1995), a conspecific distance of 4–6 m seems appropriate and crowns should not touch. However, the extent to which fruit set and yield are influenced by the population sex ratio remains unknown.

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