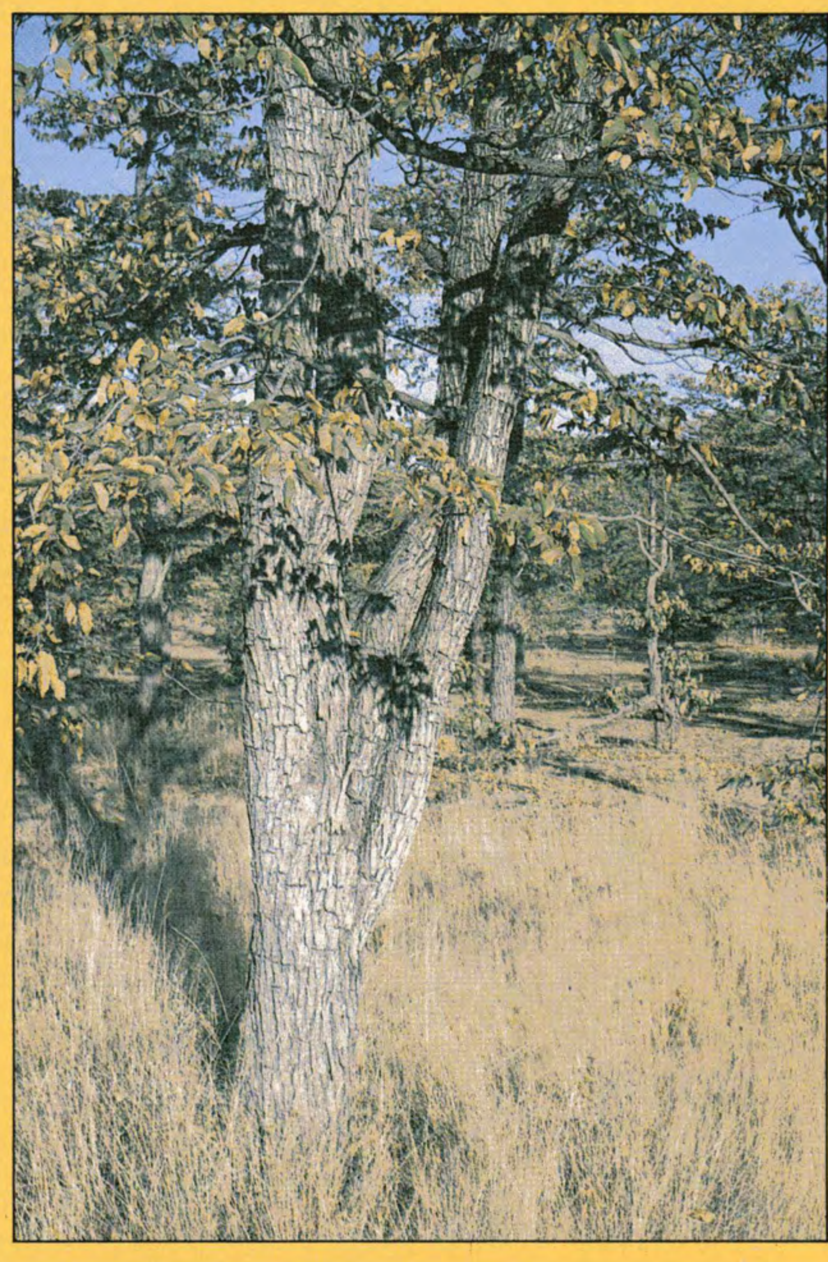
Bulletin

11

Colophospermum mopane
Annotated Bibliography and Review



J.R. TIMBERLAKE

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Colophospermum mopane
Annotated Bibliography and Review

by

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Introduction

Mopane (*Colophospermum mopane*) is a widespread and important tree species over much of sub-tropical Southern Africa, being found from coast to coast between the Tropic of Capricorn and 10^{o} South. Locally it can become dominant, forming an almost exclusive woodland, and in these places it can assume economic importance. It has also lent its name to a well-known woodland type, and is familiar to many who live or work in rural areas.

Perhaps because it is confined to the Zambezian floral domain and is not found in other parts of Africa or the tropics, literature and information on the species is rather scant and scattered. For example, surprisingly little is known on growth rate, silviculture and nutrient content of what is an important browse species. Successful management of mopane woodland will depend to a great extent on an understanding of the ecology of the species, why it occurs where it does, how it responds to cutting or browsing, and how its value could be enhanced. Given the limited funds and human resources available in the region for such investigations, it is important that available information is brought together and reviewed, thus reducing the likelihood of 're-inventing the wheel'. This bibliography and review sets out to do that, and it is hoped that it will also stimulate further research into what is a most fascinating and versatile species.

Review

BOTANY

1. Taxonomy

Colophospermum Kirk ex J. Léonard is a monotypic genus in the subfamily Caesalpinioidae of the family Leguminosae (or Fabaceae), a genus first described by Léonard in 1949, and is normally classified as belonging to the Tribe Caesalpinieae Benth. (Ross 1977). The generic name comes from the Greek, meaning "resinous seed", an allusion to the numerous scattered resin-glands which cover the seed (Ross 1977), although De Winter *et al.* (1966) say it comes from the Greek meaning "seed inhabiting the light". The only species in the genus is *C. mopane* (Kirk ex Benth.) Kirk ex J. Léonard, a tree occurring in Southern Africa. The specific epithet is derived from the vernacular name (De Winter *et al.* 1966). John Kirk collected the two type specimens (syntypes) in Shiramba and Lupata in Mozambique during Livingstone's expeditions in the last century.

Previously *C. mopane* was placed in the genus *Copaifera* L. (*Copaifera mopane* Kirk ex Benth.), along with *Copaifera conjugata* (Bolle) Milne-Redh. (now *Guibourtia conjugata* (Bolle) J.Léonard) and *Copaifera coleosperma* Benth. (now *Guibourtia coleosperma* (Benth.) J.Léonard), to which it is closely related. *C. mopane* was also placed in the genus *Copaiba* O. Kuntze for a while around the turn of the century.
[Refs. 20, 31, 62, 71, 77, 83, 84, 85, 86, 92, 122, 129, 133, 134]

2. Description

C. mopane is a small to medium-sized tree, usually 5-12(20) m high with an erect narrow crown, although it is sometimes found as an irregularly deciduous 1-2 m high shrub (see Section 11). In large specimens trunk diameter can reach 1 m, but normally the diameter of mature trees is around 50-80 cm. The largest tree recorded from Zimbabwe is 24 m tall and 169 cm dbh, near Chiredzi in the southern lowveld (L.J. Mullin, personal communication). The bark is dark grey or brown, rough, and longitudinally fissured. The slash (a cut through the trunk bark into the wood below) is pink to red, laminated and fibrous. The leaves, which appear at the beginning of the rains, are alternate, with a single pair of characteristic large triangular leaflets, often termed "butterfly-shaped". Leaves are deciduous but sometimes remain on the tree into the dry season. During the heat of the day the leaflets can be found folded together, providing little shade. Young leaves are reddish-brown and glossy, later becoming matt green. The petiole is 1.5-4 cm long and glabrous. The leaflets are asymmetric and articulated basally, 4.5-9 cm long by 2.5-5 cm wide, the inner margins slightly convex. There are 7-12 prominent nerves arising from the point of attachment, but no midrib. Numerous scattered pellucid gland-dots are found on the lamina, which is said to smell of turpentine when crushed. The stipules are up to 5 x 3.5 mm, ovate in shape, and soon deciduous. (Palgrave 1956; Fanshawe 1962; Palmer & Pitman 1972; Wyk 1972; Ross 1977; Palgrave 1981.)

The root system is generally shallow, around 30-120 cm in depth (Thompson 1960), although on deep soils roots can go down to 2 m (Timberlake & Calvert 1993). Lateral roots are well developed, and a tap root is sometimes present, possibly dying back as the tree gets older (Henning 1976). Nitrogen-fixing root nodules have not been found (Grobbelaar & Clarke 1972; Corby 1974). The fine roots are endomycorrhizal (Högberg & Piearce 1986).

The inflorescence is a slender raceme or panicle up to 7 cm long, consisting of small greenish-white or greenish-yellow wind-pollinated flowers appearing irregularly from December to March (Zimbabwe and South Africa). There are 4 sepals, the outer slightly larger than the inner, reflexed in flower, with no petals. Stamens number 20-25 with free filaments. The ovary is around 2 mm long with a lateral style and an expanded stigma.

The pods are compressed and yellowish-brown, 3.5-6 cm long by 2-3.2 cm wide, reniform or obliquely semi-circular, and indehiscent, with numerous scattered resin glands on the surface. They are light and papery, and readily dispersed by wind. The seeds are large and compressed, 1.4-2.5 cm, usually reniform and corrugated, with numerous small, sticky, reddish glands.

TABLE 1. Vernacular names of *Colophospermum mopane*.

Vernacular names	Source
balsam tree	20,77,78,83,122
butterfly tree	20,52,77,78,85,92,122
chanate (Portuguese)	77
chanya (Kunda)	83
ilipane, lipane (Ndebele)	83,86
ipane, iphane (Ndebele)	36,83,86
lupanye (Nsenga)	83
massamba, massanha, m'tssanho (Mozambique)	77
messanha, messano (Nhúnguè)	37,77
mopane, mopani (Tswana, Eng.)	20,31,36,52,78,83,84, 85,86,92,122,133
mopanie (Afrikaans)	20,84,122,133
mophane (Tswana)	71,85
mupane, mupani (Bisa, Lala, Senga, Lozi, Tonga, Venda, Lambya, Ambo)	20,31,77,83,85,86,122
musania (N)	31
musara, musaru (Ndau)	36,83,86
musharo (Shona)	83,86
mutanari (Venda)	85
mutiati (Angola)	77
mwane, mwani (Kaonde, Tonga, Lozi, Ila, Nkoya)	31,36,83
nshanantsi (Tonga)	20,122
nxanatsi (Sotho)	85
omufiadi (Ovambo)	85
omutati, omuntati (Herero)	85,122
red Angola copal	122
Rhodesian ironwood	20,77,78,83,85,122
Rhodesian mahogany	85,122
shanatse, shanatsi (Shona)	36,83
tsanya, sanya (Nyanja)	83
turpentine tree	20,77,78,83,85,92
unteate (Angola)	77
xanate (Mozambique)	77

[Refs. 19, 20, 28, 31, 36, 37, 38, 43, 45, 47, 52, 62, 71, 77, 78, 82, 83, 84, 85, 86, 92, 105, 115, 122, 129, 133, 134]

3. Vernacular names

Mopane has a range of common or vernacular names. The commonest is, of course, "mopane" (and derivatives), probably derived from the Tswana vernacular name (De Winter *et al.* 1966; Palmer & Pitman 1972). This name is also reported in vernacular usage from southern Zambia, Zimbabwe and South Africa. In Mozambique the most common name is "chanate". Although a few English names are recorded, in most cases the tree, and the vegetation type in which it is dominant, is referred to as "mopane". Table 1 gives the recorded vernacular names.
[Refs. 20, 28, 31, 36, 37, 52, 69, 71, 77, 78, 83, 84, 85, 86, 122, 129, 133, 134]

4. Life cycle and phenology

Mopane is irregularly deciduous, with the leaves turning yellow or red-brown with the onset of the dry season around May. Many dry or dead leaves remain on the tree or shrub until blown off, and are a valuable source of browse for animals. Trees are generally leafless from August to October, when new fresh leaves, reddish-brown and glossy, sprout with the first rains. Regrowth of leaves is possible if young leaves are removed soon after the start of the growing season (Guy *et al.* 1979).

The inconspicuous flowers, which are wind pollinated rather than by insects (unusual in this family according to Ross, 1977), appear irregularly from December to March after the leaves. The ripe pods appear from March to June, mostly falling in May. Dispersal is believed to be principally by wind (Jarman & Thomas 1969), although adherence to the hooves of passing animals may also be important (Pardy 1953; Palgrave 1956).
[Refs. 20, 31, 37, 43, 54, 61, 75, 83, 84, 85, 86, 92, 111, 118, 122, 129, 130, 133, 134]

5. Physiology

Stress adaptations

Mopane appears to be physiologically adapted to xeric and low soil nitrogen and potassium conditions (Eyles 1971; Smith 1972; Henning & White 1974; Choinski & Tuohy 1991; Prior 1991), although growth is obviously more rapid when these factors are not limiting. Levels of stress adaptations differ between areas and appear to be genetically heritable (Prior 1991). The species is able to grow at a matric water potential below -15.2 bar (Henning & White 1974). Mopane is also capable of internal osmotic adjustment, perhaps involving osmotically-active N compounds in the cell sap. Increased soil sodium and potassium levels give a decline in yield, again probably due to increased soil osmotic suction, while increasing magnesium seems to improve soil moisture uptake (Henning 1976).

The performance of mopane (as measured by the product of mean diameter x density over all height classes) on a range of soils from Botswana, Zimbabwe and South Africa, was found to be correlated with soil nitrogen and phosphorous, exchangeable magnesium and per cent subsoil moisture (Henning 1976).

Mopane seeds will germinate under a wide range of conditions, but germination was found to be best at a water stress of -0.14 MPa [-1.4 bars] (Choinski & Tuohy 1991). Seedlings can withstand moisture stress to 32 bars without wilting (Henning 1976). The techniques used in these two studies, however, are not comparable (J. Prior, personal communication). Growth of seedlings increases with increased soil nitrogen and phosphorus when soil moisture content is above 20% at 0.33 bars matric suction (Henning & White 1974; Prior 1991), but appears to decline with increasing soil nitrogen on soils with less than 7% moisture (Henning & White 1974) owing to increased soil osmotic suction. Seedling growth has been found to lead to a reduction in soil pH due to selective uptake of cations (Smith 1972).

Decreasing rainfall has been found to result in increased calcium oxalate in the wood (Prior 1991).

Salinity

Despite stress adaptations irrigation experiments in India have shown that the species is not particularly tolerant of salinity. Jain & Muthana (1982) found that although mopane had 100% survival after 3 months when irrigated with water under 9 mmhos salinity, there was marked mortality over the next few months when irrigation was continued. Irrigation with water of 2.7 mmhos also led to a reduced survival and growth (Muthana 1984).

Photosynthetic rate

As part of the adaptation to moisture stress, the photosynthetic rate of mopane leaves was found to be lower in the heat of the day (Prior 1991). There is also a reduced number of stomata on exposed leaf surfaces compared to some pioneer species and an increased amount of the stress metabolite pinitol (Prior 1991). The mean CO_2 assimilation rate at Chiredzi (southern Zimbabwe) was 9.6 μmol $/m^2/sec$ (Tuohy *et al.* 1991).

Nutrient uptake

The nitrogen content of shoots and roots varies with soil type (Henning 1976) and soil nitrogen content, but was found to be quite low compared to other legumes (Balusandrum 1987). Tuohy *et al.* (1991), for a dry part of southern Zimbabwe, give figures of 260 and 17.5 mmol$/m^2$ for leaf nitrogen and phosphorus, respectively. Nutrient content of the leaves is given in Table 6.

Symbioses

Mopane is a member of the sub-family Caesalpiniodeae, very few of which are known to nodulate. Under nursery or greenhouse conditions various authors (Eyles 1971; Grobbelaar & Clarke 1972; Corby 1974; Balusandrum 1987) all report lack of nodulation, even on various soil types and with soil inoculation with *Rhizobia* strains. The species is reported to be endomycorrhizal (Högberg & Piearce 1986), similar to many trees from the Kalahari sands but in contrast to many miombo species. It is possible that mopane obtains at least some of its nutrient requirements with the aid of these symbiotic fungi, although it is not generally found in dystrophic environments.

Growth rings

No reference to the presence or absence of growth rings in mopane has been noted, except that in Prior (1991), who remarks that growth ring diameter does not appear to be related to rainfall. This is an area which would repay further investigation.

[Refs. 3, 14, 19, 26, 27, 29, 30, 38, 45, 46, 47, 50, 53, 58, 76, 79, 89, 100, 101, 102, 116, 124]

6. Propagation

Reproduction in mopane appears to be principally by seed (Jarman & Thomas 1969; NAS 1980), although root suckers have been recorded (NAS 1980) and coppicing is characteristic (Ross 1977; NAS 1980; Tietema 1989). What is not clear is whether the even-size structure of many natural stands is a result of episodic recruitment and an even-aged structure, or whether trees assume even-size although they are of unequal age.

Seed production is reported to be variable (Sharma *et al.* 1989). Seeds germinate easily (De Winter *et al.* 1966) but are also prone to damping off disease (Palmer & Pitman 1972). They require freedom from competition, especially that from grasses (Thompson 1960; IBPGR 1984; Sharma *et al.* 1989). Germination under natural conditions appears to be very good, and many seedlings can be found in the first few months after the rains. However, few seem to survive the first dry season to become saplings (personal observation). Jarman & Thomas (1969) suggest that larger mammals cause high mortality to mopane seedlings, and that seeds are wind dispersed and trapped by small topographic features. The seedlings are reported to be more stress tolerant than those of *Acacia* (Prior 1991) and the drought and temperature tolerance of seedlings differ genetically between populations.

No pre-treatment of seed prior to sowing is required, and nursery germination is good,

ranging from 45-90% within two weeks (Tietema *et al.* 1992), with most viable seed germinating within 5 days (J. Timberlake, unpublished data). Removal of seed from the fruit makes germination more even and rapid (Tietema *et al.* 1992).
[Refs. 14, 30, 45, 46, 50, 52, 53, 54, 59, 67, 74, 76, 78, 85, 89, 92, 97, 100, 105, 107, 111]

7. Pests and diseases

Few pests or diseases have been reported for mopane, although seedlings are prone to damping off (Palmer & Pitman 1972; Piearce 1986). Three leaf-spot fungi have been recorded on mopane in the Southern Province of Zambia and one further species has been reported from Zimbabwe (Piearce 1986).

One of the better-known products of mopane is the "mopane worm", an edible larva of the moth *Gonimbrasia belina* (Velcich 1963; Palmer & Pitman 1972; Turk 1990), which can cause severe defoliation of individual trees in some years (Voorthuizen 1976; NAS 1980). The trees, however, appear to be able to recover. The wild silk moth (*Gonometa rufobrunnea*) feeds on mopane leaves in Botswana (Hartland-Rowe 1993).

The mopane psyllid, *Arytaina mopane*, feeds on the leaves of mopane and produces an excretory product, lerp (Ernst & Sekhwela 1987), which is said to make the leaves more palatable to browsing animals (Wyk 1972). Perhaps the earliest published account of this secretion is given by David Livingstone in his "Missionary Travels and Researches in South Africa" (1857). He also refers to the edible mopane worm, lopané.

Mopane trunks are often characterised by their hollowness due to fungal heart-rot by *Phellinus rimosus* (Piearce 1986). This causes a localised hollowing of the stem following external stem injury. Henning (1976) suggested that this phenomenon may, in part, be due to termite attack through a decaying tap root, but this is unlikely as the rot does not extend downwards as far as the root collar or root (G.D. Piearce, personal communication). Trees in many areas of mopane woodland show forking of the trunk at heights of 1 to 3 m, possibly due to damage by elephant or other large mammals when the tree was still young (Caughley 1976; Lewis 1991). This is discussed further in section 12.
[Refs. 13, 29, 44, 45, 54, 63, 65, 70, 78, 85, 87, 92, 117, 118, 122]

ECOLOGY

8. Distribution

Mopane is a xeric species of the savanna woodland zone of south tropical Africa, being found mostly on heavier-textured soils in the wide, flat valley bottoms of lower altitude river valleys such as the Limpopo, Zambezi, Okavango, Cunene, Shire and Luangwa (Cole 1986; Mapaure 1994). It is indigenous to southern Angola, northern Namibia, northern Botswana, Zimbabwe, southern Zambia, southern Malawi, northern South Africa and Mozambique, and has also been planted in semi-arid regions of India where it has shown some success (NAS 1980; IBPGR 1984; Sharma *et al.* 1989).

There does not appear to be a comprehensive map of the distribution of *C. mopane* as a species, but maps of *C. mopane*-dominant vegetation types are available for Angola (Barbosa 1970), Botswana (Weare & Yalala 1971), Namibia (Giess 1971), South Africa (Acocks 1988), Zambia (Republic of Zambia 1976), Zimbabwe (Rattray 1962) and the Flora Zambesiaca area (Wild & Barbosa 1967). These have been reviewed and compiled by Mapaure (1994) (Figure 1), who also gives areas under mopane vegetation for each country (Table 2). Outside of these mapped areas, mopane can be found on more clay-rich soils such as sites where subsoil has been exposed, termitaria or drainage lines (including clay pans).

The altitude at which mopane is found ranges from 200 m (Mozambique) to 1200 m (Zimbabwe), although most of the mopane-dominated vegetation lies within the range 300-1000 m. Mean annual rainfall ranges from 100-

800 mm, but most mopane woodland is found in the 400-700 mm annual rainfall zone. The species is reported to be intolerant of severe frosts, being restricted by the 5°C mean daily isotherm for July (Henning 1976; Erkkila & Siiskonen 1992), but stands can be found in some severely frost-prone areas south of Bulawayo.

Table 2. Area under vegetation dominated by *C. mopane*.

Country	area (km^2)	% of total mopane area
Angola	112,500	20.5
Botswana	85,000	15.5
Malawi	10,000	1.8
Mozambique	98,000	17.8
Namibia	77,000	14.0
South Africa	23,000	4.2
Zambia	43,000	7.8
Zimbabwe	101,500	18.5
Total	**550,000**	

The distribution of mopane is obviously determined by different ecological factors in different areas. To the south and west, frost incidence and/or minimum temperatures may play an important role along with minimum rainfall. Mopane is generally not dominant in vegetation where mean annual rainfall is below 350-400 mm, although deeper, moisture-retentive soils may allow the species to occur in otherwise drier areas. To the north and east, and where the land rises from the low-lying broad valleys to the central plateau, the increased rainfall (or, more accurately perhaps, the increased soil moisture availability) allows other tree species and vegetation types such as miombo woodland to assume dominance. This is illustrated in the transitional nature of the miombo-mopane mosaics of north west Zimbabwe (Timberlake *et al.* 1993). In these northern, more tropical areas, mopane trees, especially those found on deep alluvium, can be very tall, up to 18-20 m, and are sometimes termed "cathedral mopane". [Refs. 1, 4, 9, 18, 20, 28, 31, 32, 35, 37, 45, 51, 52, 67, 68, 69, 71, 72, 77, 78, 79, 82, 83, 84, 85, 86, 88, 90, 91, 92, 97, 106, 113, 114, 121, 122, 125, 126, 129, 130, 131]

9. Vegetation types and associated species

Colophospermum mopane occurs in a range of vegetation types, the structure and associated species depending primarily on soil type and climate. A full list of the vegetation types in which it is found is not available.

Within the Flora Zambesiaca area (Botswana, Malawi, Mozambique, Zambia, Zimbabwe) mopane-dominant vegetation is of three types: dry early-deciduous savanna woodland (north and west Zimbabwe, southern Zambia and Luangwa valley; Tete Province in Mozambique; Shire valley in Malawi), dry deciduous tree savanna (Okavango, Makgadikgadi pans and north east Botswana; Save valley and southern Zimbabwe; upper Limpopo and Save basins within Mozambique), and dry early-deciduous shrub savanna (Nata river in Botswana/Zimbabwe; basalt in southern Zimbabwe). The mopane woodland/shrubland in the northern Transvaal (Acocks 1975) is equivalent to the dry deciduous tree savanna of Wild & Barbosa (1968). In Namibia mopane-dominant vegetation, found in the north west interior, is mapped under one type as mopane savanna (Giess 1971), but from the description it would appear that in the drier west it is equivalent to the dry early-deciduous shrub savanna of the Flora Zambesiaca map, and in the moister east to dry early-deciduous savanna woodland, with perhaps an intermediate area of lower and sparser dry deciduous tree savanna. In Angola, dry deciduous mopane woodland or mosaic of savanna and steppe is found in the south west at the base of the Chela escarpment south to the Cunene River and is equivalent to the dry early-deciduous savanna woodland of Flora Zambesiaca map over much of its range, but with patches of dry deciduous tree savanna. A small area of low shrubby dry woodland of *Acacia* and mopane on heavy clay soils, equivalent to dry early-deciduous shrub savanna, is found in the far south east of Angola, while along parts of the south east littoral patches of shrub mopane are found.

The Flora Zambesiaca map does not separate out the tall dense mopane sometimes termed "cathedral mopane", which is found in homogenous and almost exclusive stands on old deep alluvium, but this type is restricted in its distribution to the more tropical regions north of 17° S.

Mopane woodland, savanna and shrubland is often noted for its low number of associated species (low alpha diversity), the vegetation in such areas being predominantly composed of *C. mopane*. Typical associated species are similar across much of the range of mopane, indicating relatively low gamma diversity compared to various miombo woodland types. Typical tree species include: *Acacia nigrescens*, *A. nilotica*, *Adansonia digitata*, *Albizia harveyii*, *Balanites* spp., *Combretum apiculatum*, *C. hereroense*, *Commiphora* spp., *Dalbergia melanoxylon*, *Diospyros quiloensis*, *Erythroxylum zambesiacum*, *Kirkia acuminata*, *Sclerocarya birrea*, *Terminalia prunioides*, *T. stuhlmannii* and *Ziziphus mucronata*. Shrubs include: *Combretum elaeagnoides*, *Dichrostachys cinerea*, *Gardenia resiniflua*, *Grewia* species, *Ximenia americana* and species of the family Capparidaceae, while the herb layer contains species of Acanthaceae. Grass cover is generally poor, and often dominated by annuals such as *Aristida*, *Enneapogon* and *Eragrostis* species.

Over much of its range, mopane woodland is found adjacent to miombo woodland or low woodland dominated by *Combretum* or *Terminalia* species. There is little overlap in species composition between the two types, the mopane vegetation generally having fewer species and a poorly-developed grass layer. In these circumstances mopane vegetation is restricted to depositional clay-rich soils in the lower parts of the catena, and the miombo or Combretaceae woodland to the upper parts on lighter-textured soils or rocky outcrops (Timberlake *et al.* 1993).

In northern Zimbabwe, Timberlake *et al.* (1993) describe a group of vegetation types where this catena is best termed a mosaic miombo-mopane woodland. Here the two vegetation types intermingle so much that it is often not possible to map them separately, although each type, with its distinctive suite of associated species, can be distinguished. It is particularly prevalent in areas of active natural erosion between level plateaux and the wide valleys below.

The Australian analogue of mopane is *Acacia harpophylla* (brigalow, Cole 1986). Surprisingly, there does not appear to be an analogue in the Sudanian phytogeographic region, which occupies a similar position to the Zambezian region north of the equator.
[Refs. 1, 4, 6, 9, 10, 18, 25, 26, 28, 32, 33, 35, 41, 42, 51, 55, 56, 67, 69, 70, 72, 82, 88, 90, 91, 94, 113, 114, 119, 121, 125, 126, 130, 131]

10. Soils

Mopane generally occurs on clay-rich soils, or on soils with a clay layer some centimetres below the surface. Most reported cases of it occurring on sand probably refer to a thin sand layer overlying a clay-rich layer, such as are found on the Kalahari sands at the edges of pans or drainage lines, including fossil drainage lines.

Duplex soils, in particular those on sodium-rich granite in areas under 700 mm mean annual rainfall, have an impervious clay layer at 20-60 cm depth. Where this is exposed by natural or accelerated soil erosion mopane is generally found, usually as a small tree or shrub. The presence of mopane, its shallow root system and the prevalence of surface capping on such soils (resulting from a relatively high silt content), often lead to further soil erosion and the expansion of the extent of exposed subsoil, in turn leading to expansion of the mopane zone and a reduction in the surrounding zone of miombo species or *Terminalia sericea* and *Combretum*.

Although sometimes said to be an indicator of sodic or infertile soils, mopane is by no means confined to them (Ellis 1950; Thompson 1960; Vincent & Thomas 1961; Nyamapfene 1988; Timberlake *et al.* 1993), and indeed grows much better on deeper, less compact soils (Dye & Walker 1980; Cole 1986; Mapaure 1994). The association with sodic soils (Dye 1977; Dye & Walker 1980), especially at the limits of its range on the central watershed of Zimbabwe at altitudes over 900 m, is said to be due to its shallow rooting system and ability to survive there, whereas many other woody species have difficulties (Thompson 1960). The root system coincides with the zone of maximum moisture retention on many soils (Ellis 1950; Thompson 1960), and mopane is excluded from better soils by deeper-rooted *Acacia* species (Cole 1986). Thompson (1960) also refers to the shallow-rooted nature of the species which only enables it to compete with deeper-rooted trees under conditions where moisture is principally retained near the surface. He also mentions that factors reducing grass growth will favour the establishment of mopane on suitable sites, factors such as (a) low and erratic rainfall in combination with sandy surface soils of low water-retaining capacity, (b) competition for available moisture by massed mopane surface roots, and (c) the occurrence of shallow sandy soils over relatively impervious sodic subsoils. On cracking clay soils root pruning may reduce moisture-obtaining capabilities (Nyamapfene 1988). Dye & Walker (1980), studying the sodic soils of the gneissic-granite of the central watershed of Zimbabwe, found tall non-coppice mopane on soils with a deep A-horizon and only a weakly sodic subsoil, which could be expected to allow a moderate amount of moisture to penetrate into the B-horizon. Coppice or stunted mopane occurred on soils with an A-horizon of intermediate depth and relatively permeable B-horizon. Soils with a shallow A-horizon underlain by a highly sodic and impermeable B-horizon did not support tree or shrub growth.

Low tree and shrub forms of mopane are found on the floors of old dismembered drainage systems in Botswana and the northern Transvaal, and on alkaline black clays from Karoo basalts and shales (Cole 1986). The tree form is found on more permeable soils, especially those derived from Karoo sediments (Thompson 1965), fine-textured alluvium (Timberlake *et al.* 1993), termitaria (Timberlake *et al.* 1993), Quaternary lacustrine calcareous sediments and Cretaceous deposits (Wild & Barbosa 1968). As rainfall increases edaphic factors become more important in its distribution and mopane is confined to physiologically drier sites (Thompson 1965), effected primarily in the root zone.

One feature of some of the stands of mopane shrubland is the bareness of the soil and the prevalence of sheet erosion (Hudson 1963). Other woody plants in such areas tend to be clumped or associated with termitaria, and much of the remaining area has a poor cover of annual grasses and herbs. A major causative factor is probably the sodicity of these soils or the high silt content, leading to extensive surface capping, which in turn can lead to gully formation. Attempts have been made to vegetate such soils using the grass *Cynodon* (Hudson 1963), but with little success. Indeed, these areas often expand slowly, especially under heavy grazing, as the topsoil erodes and more subsoil exposed.
[Refs. 6, 9, 18, 25, 26, 27, 30, 31, 32, 33, 45, 46, 48, 50, 55, 56, 57, 65, 67, 69, 72, 78, 79, 90, 94, 100, 105, 106, 113, 114, 121, 126, 130, 131, 133]

11. Tree-shrub mopane

The phenomenon of mopane occurring in both tree and shrub forms is well-known. In some areas of the Zambezi valley and to the north, tall-boled mopane woodland is found reaching heights of 16-20 m, colloquially termed "cathedral mopane" (Fanshawe 1969; Timberlake *et al.* 1993), with reasonable grass growth underneath. This type is generally found on old (Quaternary) and deep, clay-rich alluvium. Mopane woodland on many Karoo sediments is generally lower (8-12 m) and with a less well-developed herbaceous layer, while woodland or shrubland on sodium-rich soils, or on cracking clays, is only 2-6 m high with a very poorly-developed herbaceous layer.

Although little experimental work has been done on this phenomenon, most authors are agreed that it results from differences in effective rooting depth on different soils and differences in soil moisture availability (Thompson 1965; Schijff 1969; Mitchell 1976; Dye & Walker 1980; Cole 1986; Fraser *et al.* 1987; Nyamapfene 1988; Madams 1990; Timberlake *et al.* 1993). J. Bryant (personal

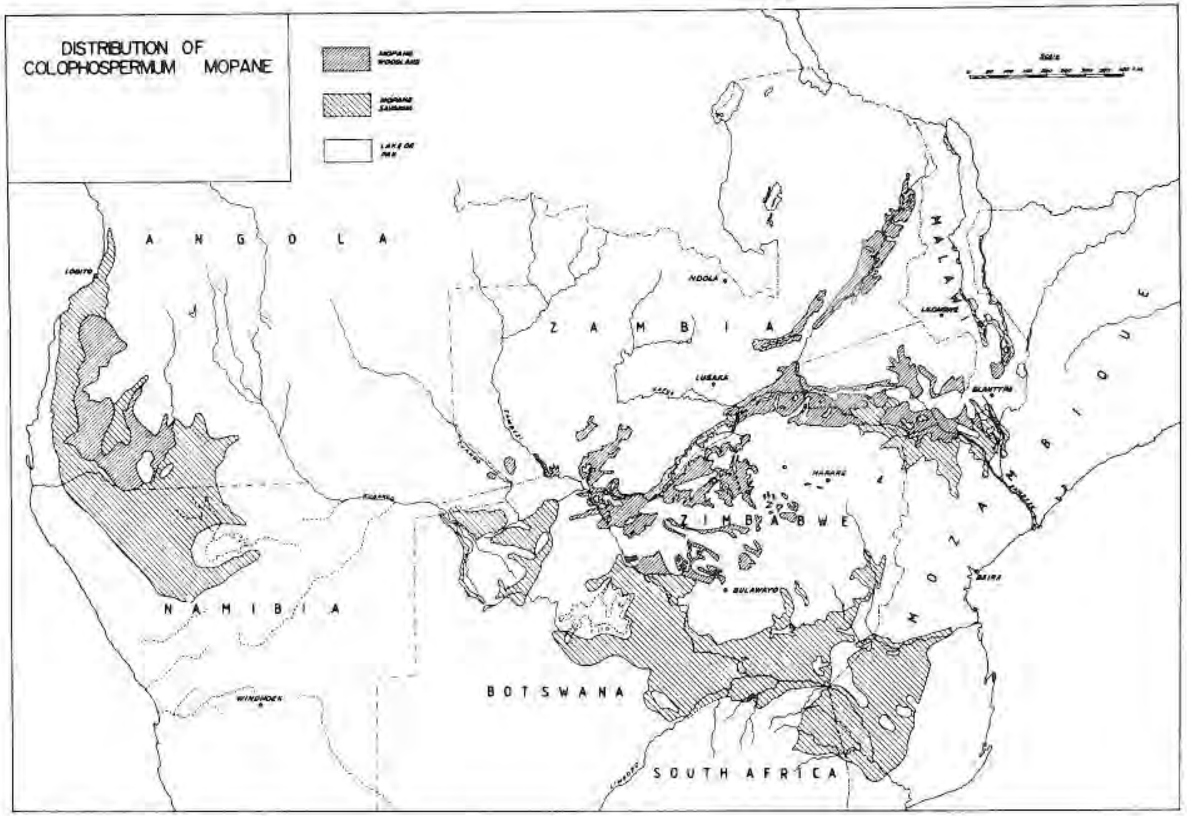

FIGURE 1. Distribution of Colophospermum mopane *in Southern Africa (from Mapaure 1994).*

Dead C. mopane *trees on the shores of Lake Kariba, killed when the rising waters flooded their roots (Binga, northern Zimbabwe).*

Mopane woodland flanking the Lutope floodplain (Sengwa, north western Zimbabwe).

Well developed mopane woodland on Karoo sandstone soils (Sinamatella, western Zimbabwe).

Clumped mopane woodland with Sansevieria pearsonii *on surface-sealing soils (Nkayi, western Zimbabwe).*

Low mopane woodland fringing a small pan. Area heavily utilised by cattle (Kezi, southern Zimbabwe).

[photo P. Shaw]

Leafless C. mopane *in the late dry season (Gwayi Forest, western Zimbabwe).*

communication, 1991) has raised seeds from both types together and found no physiological differences. There are no reports of any genetic differences. Fraser *et al.* (1987) report that shrub mopane, at least in the Kruger National Park, is only found on soils with a high clay, magnesium and calcium content. Other possible causative factors have been given as frost (Schijff 1969; Joubert 1971), fire (Boughey 1961, 1963), old cultivation (I. Zimmermann, personal communication, 1989), and, more frequently, elephant damage (Boughey 1963; Fanshawe 1969; Lewis 1991). However, the occasional tall tree in a low stand, the inconsistency in occurrence when compared to adjacent areas which should have similar frost conditions and large mammal impact, and the consistency with which shrub mopane occurs under similar physiographic and soil conditions, strongly suggests that soil factors are the determining ones.

In areas of relatively uniform short mopane woodland or shrubland in the central part of its range, occasional tall mopane trees (8-10 m high) are sometimes seen. This phenomenon does not seem to have been investigated. It is postulated that the tall trees are found on sites with a more pervious subsoil, such as old termitaria (now eroded down to ground level) or sites with underlying rocks.

The phenomenon of the often clear separation of the two growth forms of mopane needs to be investigated further as it would appear to be of major importance in management of existing stands and selection of new areas for management.
[Refs. 9, 10, 18, 25, 26, 32, 33, 45, 55, 63, 65, 67, 69, 70, 79, 84, 90, 94, 106, 114, 126, 130, 131, 133]

12. Elephant damage to mopane

Elephants, more than any other large mammal, can cause marked destruction of mopane trees, sometimes reducing woodland to shrubland (Anderson & Walker 1974; Martin 1974; Caughley 1976; Guy 1976; Lewis 1986, 1991; Frost *et al.* 1987). Damage is often localised and is related to areas of high elephant concentration. It tends to occur more in the early dry season when other browse and grass is less available. Male elephants seem to be mostly responsible (Guy 1976; I. Coulson, personal communication, 1989). Elephant damage to mopane has been particularly reported from Gonarezhou in south eastern Zimbabwe, the mid-Zambezi valley below Kariba, the Chizarira-Sengwa area of north-central Zimbabwe and the Luangwa valley in Zambia. Most of the work that has been done on the subject has been from the latter two areas.

Mopane is an important browse species for elephant (Martin 1974; Guy 1976; Villiers & Kok 1988; Viljoen 1989; Lewis 1991). Concentrated attention from elephant, particularly when their range is compressed, may result in many small and medium-sized trees being knocked down, effectively forming a shrubland 1.5-2 m high. Caughley (1976) reports tree felling by elephant in the Luangwa valley at a rate of 138 trees/km^2/yr or 4% of standing crop. Most of this damage was in the 16-29 cm diameter classes. A double-tiered woodland structure results, with a preponderance of larger trees and coppice shrubs. It was concluded that elephant do not prevent regeneration of mopane as such, but prevent recruitment into taller size classes. A preponderance of forking of the lower bole, ascribed to old elephant damage, was also found in the 3-22 cm and 60-73 cm diameter classes and was thought by Caughley (1976) to indicate higher elephant populations at those times, consistent with a quasi-200 year stable limit population cycle. A study at Kariba, northern Zimbabwe, comparing islands regularly or irregularly frequented by elephant (Frost *et al.* 1987) showed more coppicing and forked stems on the regularly frequented island with differences most apparent in trees less than 6 m high or with a stem diameter less than 13 cm, but there was no obvious missing diameter class.

The reduction of mopane woodland to shrubland has important effects on its ecology and that of the associated fauna. Martin (1974) points out that in Sengwa only 6.3% of potential browse in mopane woodland is found below 2.5 m, thus effectively precluding it from most browsing mammals. By bringing the canopy down from 10-14 m to 1.5-2 m this biomass can play a major role in nutrient and energy cycling instead of being comparatively "locked up". Elephant can thus be considered a keystone species in the ecology of mopane woodlands.

As elephant range is influenced by dry season availability of grass cover, Lewis (1987) has suggested that early burning of grass in mopane areas with high elephant concentrations would reduce browse pressure on the mopane allowing better regeneration to occur. Poaching pressure in and around areas within the Luangwa valley caused loss of mopane woodland cover in safer areas where elephant concentrated, particularly along the rivers (Lewis 1986). Little regeneration of coppice mopane was found there.

It is not clear if the coppice mopane shrubland repeatedly browsed and broken by elephant could develop into a taller woodland, or whether soil conditions would limit its growth to a small tree. The boundary between tall woodland and shrubland is sometimes remarkably abrupt and appears to follow a soil boundary. It has been suggested that elephants intentionally browse woody vegetation in order to increase its food value as regrowth has a higher food value or is more palatable (J. Bryant, personal communication 1991). Lewis (1991) found that mopane survival in response to elephant browsing in the Luangwa valley was influenced by soil characteristics and past levels of browsing. Most important were the physical characteristics of the soil B-horizon and the soil nutrient content of the A-horizon. Woodlands most likely to coppice were those with an impervious B-horizon and nutrient-rich A-horizon. Recruitment from seed and recruitment of saplings into the tree layer is much reduced in this type because of high browsing pressure. He found an annual mortality of coppice mopane of 0.5%/yr.

[Refs. 2, 10, 13, 34, 40, 41, 63, 64, 65, 70, 113, 114, 119, 120]

13. Growth rates

Little information is available on growth rates of natural stands of mopane compared to information on standing biomass. Comparisons are difficult owing to a wide ecological range over which the little data has been collected (including both woodland and shrubland) and differences in methodology (including lack of separation of tree, shrub and herbaceous components). Some studies use fresh weight (FW), others use air or oven dry weights (DW). Available data are shown in Table 3.

Growth rates are generally reported to be low (Eyles 1971; Wyk 1972), but this may in part be due to adverse soil conditions. Sharma *et al.* (1989), however, report fast growth in India of up to 4 m in height and 15 cm diameter over 8 years in one locality, with an average of 50 cm height/yr over 6 years, but only 8 cm/year in drought years. Tewari *et al.* (1989), in Jodhpur, an arid part of India, recorded a mean annual diameter increment of 0.49 cm dbh (diameter at breast height, 1.3 m), equivalent to a basal area increase of 4.29 cm^2/tree for trees averaging 11.2 cm dbh. Within its native range, Tietema (1989) reports growth

TABLE 3. Annual production of mopane woodland.

t/ha	area	source
1.18 (mean, FW)	Sengwa, N. Zimbabwe	Guy 1981
1.58 (t+s FW, no util.)	S.E. Zimbabwe	Kelly & Walker 1976
1.49 (t+s FW, light util.)	S.E. Zimbabwe	Kelly & Walker 1976
1.66 (t+s FW, moderate util.)	S.E. Zimbabwe	Kelly & Walker 1976
1.22 (t+s FW, high util.)	S.E. Zimbabwe	Kelly & Walker 1976

of mopane woodland in northern Botswana of around 10 t/ha/year. Diameter growth was linear up to 7 years for coppice shoots. However, weight increase of coppice shoots was said to slow after 5 years to a rate of 1 kg FW/shoot/year at a population density of 10,000 shoots/ha (equivalent to 1 t/ha/year). Guy (1981a) gives mopane woodland production figures of 1.18 t FW/ha/year in Sengwa, northern Zimbabwe, but this figure covers all species present (*C. mopane*, however, probably accounts for 90% of this). Scholes (1990) reports a basal area increment of 0.4 m^2/ha/year for coppice growth in the northern Transvaal, which would be greater in above-average rainfall years. Shoot elongation from coppice has been found to be faster from large and tall stumps compared to narrow stumps cut low down (Mushove & Makoni 1993).

Seedling growth rates are given by Mushove (1993) as 2.3-3.2 mm/day for shoots and 8.7-10 mm/day for roots. The shoot:root weight ratios were inversely proportional to seedling age.
[Refs. 13, 16, 17, 30, 41, 45, 46, 50, 56, 57, 65, 73, 74, 75, 76, 89, 95, 97, 104, 107, 110, 133]

14. Biomass production and stand density

As mopane occurs under a wide range of climatic conditions and soil types, and at varying densities and sizes, standing biomass figures for mature woodland stands obviously vary greatly. Available data for biomass are given in Table 4, and basal area figures in Table 5. Reported figures for biomass of *C. mopane* in mature woodland, based on a few trees, range from 61 (Martin 1974, dry weight) to 80 t/ha (Tietema 1989, fresh weight). However, as the species often occurs in even-sized stands, projections of species biomass from a few sample trees is probably more accurate than in many other woodland types. Mopane generally comprises 90% of total biomass of mopane woodland (Martin 1974; Guy 1981a), which is probably a higher proportion than most other individual species contribute to the woodland types in which they are found. Only 3.7% of total mopane biomass was found to be browse (leaf + growing twig), the rest principally being wood (Martin 1974). Figures for biomass of *C. mopane* in drier woodland/shrubland range from 11 to 18 t/ha (Kelly & Walker 1976).

Various equations have been developed for predicting biomass of mopane from individual stem diameter or crown measurements (Martin 1974; Barnes *et al.* 1976; Kelly & Walker 1976; Guy 1981b; Tietema 1989, 1993; Scholes 1990), and these are shown in Table 6. Most of the equations have good correlation coefficients, but as they are all from drier regions they may not accurately describe trees from the moister or more tropical part of its range.

Very few studies have been done on root biomass. Smit *et al.* (1994) report a biomass of 17.35 t DW/ha (range 9.76-29.79) in shrub mopane woodland in the northern Transvaal, probably equivalent to the above-ground biomass, while Roux *et al.* (1994) in the same area report a total root biomass to 1 m depth of 29.79 t DW/ha.

Stocking density of trees or stems mostly depends on whether the area is a mature woodland or coppice shrubland (Table 7). Within mopane shrubland self-thinning also occurs (Scholes 1990), so age and stocking density affect survival and stem size. Reported densities for mature woodland range from 7 trees/ha in northwest Namibia (Viljoen 1989) to 481 trees/ha in southeast Zimbabwe (Kelly & Walker 1976), but a normal figure for mature, non-stunted mopane woodland would appear to be around 200-400 trees/ha. Densities in shrubland are, of course, much higher.
[Refs. 2, 3, 5, 12, 13, 16, 17, 34, 39, 40, 41, 42, 45, 46, 54, 56, 57, 63, 65, 67, 70, 93, 95, 96, 98, 99, 107, 108, 110, 112, 119]

TABLE 4. **Standing above-ground biomass estimates for *C. mopane*.**

Biomass (t/ha)		Area	Source
Mopane woodland			
15.0	(mean FW, no util.)	S.E. Zimbabwe	Kelly & Walker 1976
15.7	(mean FW, light util.)	S.E. Zimbabwe	Kelly & Walker 1976
28.0	(mean FW, medium util.)	S.E. Zimbabwe	Kelly & Walker 1976
15.9	(mean FW, high util.)	S.E. Zimbabwe	Kelly & Walker 1976
63.2	(mean, 3 yrs)	Sengwa, N. Zimbabwe	Guy 1981a
67.8	(DW, all woody species)	Sengwa, N. Zimbabwe	Martin 1974
64.3	(DW)	Mutanda, E. Zimbabwe	Grundy *et al.* 1993
***C. mopane* (species)**			
9.8	(tree mean FW, no util.)	S.E. Zimbabwe	Kelly & Walker 1976
0.9	(shrub mean FW ")	S.E. Zimbabwe	Kelly & Walker 1976
10.9	(tree mean FW, light util.)	S.E. Zimbabwe	Kelly & Walker 1976
1.1	(shrub mean FW, ")	S.E. Zimbabwe	Kelly & Walker 1976
16.6	(tree mean FW, medium util.)	S.E. Zimbabwe	Kelly & Walker 1976
1.8	(shrub mean FW, ")	S.E. Zimbabwe	Kelly & Walker 1976
6.6	(tree mean FW, high util.)	S.E. Zimbabwe	Kelly & Walker 1976
0.5	(shrub mean FW, ")	S.E. Zimbabwe	Kelly & Walker 1976
61.1	(tree + shrub DW)	Sengwa, N. Zimbabwe	Martin 1974
79.0	(tree FW, undisturbed)	Dukwe, N. Botswana	Tietema 1989
0.8	(shrub FW, undisturbed)	Dukwe, N. Botswana	Tietema 1989
61.0	(tree FW, harvested)	Dukwe, N. Botswana	Tietema 1989
2.4	(shrub FW, harvested)	Dukwe, N. Botswana	Tietema 1989
53.4	(DW, disturbed)	Mutanda, E. Zimbabwe	Grundy *et al.* 1993

TABLE 5. **Basal area of mopane in natural vegetation.**

Basal area (m^2/ha)		Area	Source
Mopane woodland			
26.8	(trees, mean)	Sengwa, N. Zimbabwe	Guy 1981a
***C. mopane* (species)**			
21.7	(at base)	Sengwa, N. Zimbabwe	Anderson *et al.* 1974
5.91	(at base, mean)	Boteti, C. Botswana	Coe 1991
16.80	(trees, undisturbed)	Dukwe, N. Botswana	Tietema 1989
10.66	(shrubs, harvested)	Dukwe, N. Botswana	Tietema 1989
0.53	(shrubs, undisturbed)	Dukwe, N. Botswana	Tietema 1989
1.26	(shrubs, harvested)	Dukwe, N. Botswana	Tietema 1989
6.40	(thicket, at base)	E. Transvaal, RSA	Scholes 1990
5.00	(mature 12 year thicket, at base)	E. Transvaal, RSA	Scholes 1990

Table 6. **Predictive equations for biomass of mopane.**

equation	area	reference
Trees - standing biomass		
mass (t DW) = (diameter @ base, cm)$^{2.4575}$ x 0.0544	Sengwa, N. Zimbabwe	Guy 1981b
mass (t DW) = (diameter @ base, cm)^{2} x (height, m)$^{0.9335}$ x 0.0408	Sengwa, N. Zimbabwe	Guy 1981b
mass (kg DW) = (circ., cm) x (height, m)^{3} x 0.0027	Sengwa, N. Zimbabwe	Martin 1974
$\log_e$(mass, kg DW) = -5.41 + 2.84 x $\log_e$ (height, m) + 0.95 x $\log_e$(circ., cm)	Sengwa, N. Zimbabwe	Martin 1974
mass (kg FW/ha) = -2934.8 + 219.1 x (canopy area, m^{2} x dbh, cm)	S.E. Zimbabwe	Kelly & Walker 1976
mass (kg FW) = 0.0644 x (basal area @ 10 cm, cm^{2})$^{1.3341}$ [for stems >5 cm]	Dukwe, N. Botswana	Tietema 1989
mass (kg FW) = 0.15 x (basal area, cm^{2})$^{1.09}$ [for stems<5 cm]	Dukwe, N. Botswana	Tietema 1989
mass (kg DW) = -3.04 + 1.278 x (stem diameter, cm)^{2} [individual plants]	E. Transvaal, RSA	Scholes 1990
leaf mass (kg DW) = -0.029 + 0.0067 x (stem diameter, cm)^{2}	E. Transvaal, RSA	Scholes 1990
Shrubs - standing biomass		
$\log_e$(mass, g DW) = -3.26 + 1.73 x $\log_e$(height, cm) [individual plants]	Sengwa, N. Zimbabwe	Martin 1974
mass (kg FW/ha) = -481.4 + 425.6 x (canopy volume, m^{3})	S.E. Zimbabwe	Kelly & Walker 1976
mass (kg DW/ha) = 882.3 x (canopy volume, m^{3}) [shrubs <1.5 m]	S.E. Zimbabwe	Kelly & Walker 1976
leaf mass (kg DW) = 0.159 + 0.23 (product leaf canopy axes, m^{2})	Nuanetsi, S. Zimbabwe	Barnes *et al.* 1976
leaf mass (kg DW) = 0.177 = 0.0064 x Σ(stem diameter, cm)^{2}	Nuanetsi, S. Zimbabwe	Barnes *et al.* 1976
leaf mass (kg DW) = 0.005 + 0.0398 x (stem diameter, cm)^{2} [coppice stems]	E. Transvaal, RSA	Scholes 1990
Annual production		
production (kg FW/ha/year) = -2505.4 + 993.1 (height, m) [trees: leaves + twigs]	S.E. Zimbabwe	Kelly & Walker 1976
production (kg FW/ha/year) = 175.1 + 71.4 (canopy volume, m^{3}) [shrubs: leaves + twigs]	S.E. Zimbabwe	Kelly & Walker 1976

TABLE 7. **Reported densities of mopane in natural vegetation.**

stems/ha		area	source
mopane woodland			
563.3	(trees, mean)	Sengwa, N. Zimbabwe	Guy 1981a
3635.3	(shrubs, mean)	Sengwa, N. Zimbabwe	Guy 1981a
935	(unharvested)	Dukwe, N. Botswana	Tietema 1989
343	(disturbed)	Dukwe, N. Botswana	Tietema 1989
427	(trees)	Sengwa, N. Zimbabwe	Martin 1974
440		Binga, N. Zimbabwe	Jarman & Thomas 1969
421.8	(mean tree + shrub - minimal damage)	Luangwa, N. Zambia	Lewis 1991
826.5	(tree + shrub - elephant damage)	Luangwa, N. Zambia	Lewis 1991
955.5	(mean, no utilization)	S.E. Zimbabwe	Kelly & Walker 1976
983.5	(mean, light utilization)	S.E. Zimbabwe	Kelly & Walker 1976
1717	(mean, medium utilization)	S.E. Zimbabwe	Kelly & Walker 1976
850	(mean, high utilization)	S.E. Zimbabwe	Kelly & Walker 1976
1936	(shrub)	Sengwa, N. Zimbabwe	Martin 1974
11,700	(unharvested)	Dukwe, N. Botswana	Tietema 1989
12,000	(disturbed)	Dukwe, N. Botswana	Tietema 1989
***C. mopane* (species)**			
214	(live trees)	Sengwa, N. Zimbabwe	Anderson & Walker 1974
483	(mean, no utilization)	S.E. Zimbabwe	Kelly 1975
742	(mean, light utilization)	S.E. Zimbabwe	Kelly 1975
961.3	(mean, moderate utilization)	S.E. Zimbabwe	Kelly 1975
491.5	(mean, high utilization)	S.E. Zimbabwe	Kelly 1975
690	(trees)	Kariba, N. Zimbabwe	Frost *et al.* 1987
2940	(shrubs)	Kariba, N. Zimbabwe	Frost *et al.* 1987
8200	(mean, coppice)	Boteti, C. Botswana	Coe 1991
69.5	(mean trees, minimal elephant damage)	Luangwa, N. Zambia	Lewis 1991
119.7	(mean shrubs, minimal elephant damage)	Luangwa, N. Zambia	Lewis 1991
15.4	(trees, elephant damage)	Luangwa, N. Zambia	Lewis 1991
686.5	(shrubs, elephant damage)	Luangwa, N. Zambia	Lewis 1991
6.9	(trees)	N.W. Namibia	Viljoen 1989
13,500	(regenerating thicket, 13yrs)	E. Transvaal	Scholes 1990
2002	(mature thicket)	E. Transvaal	Scholes 1990
2436	(4.4-13 yrs old)	N. Transvaal	Roux *et al.* 1994
2374	(shrubs)	Sengwa, N. Zimbabwe	Martin 1974
339.4	(trees)	Sengwa, N. Zimbabwe	Martin 1974

MANAGEMENT AND USES

15. Management

Two types of management of mopane have been reported - thinning and coppicing. Both have shown potential for use by rural populations, and in Dukwe (northern Botswana) coppicing of natural woodland has been suggested as a way of providing much of the construction and firewood requirements for a refugee camp (Tietema *et al.* 1988). There have been no reported trials on planting of mopane, probably as the species is still locally abundant in many areas and is not considered to be of particularly high value.

Thinning of dense mopane stands from c. 8000 stems/ha to 1500-3400 stems/ha is reported to increase basal area growth by 11 to 21% after one year in eastern Botswana (Coe 1991, 1992), but will only marginally increase the height of the remaining shoots. Extensive cutting in Malawi (Nyasaland Government 1943) was found to result in poor regeneration by coppicing due to competition with grasses, and better regeneration was achieved with 50% thinning. Thinning frequently has little effect on tree height, the main effect being in the redistribution of basal area increment among fewer stems. Although it will result in some loss of production per hectare, it will produce the desired pole size quicker.

Mopane coppices easily, and production of poles from seedlings takes twice as long as production from coppice (Tietema *et al.* 1988). As mentioned previously, diameter growth of coppice shoots is linear up to 7 years, and weight gain at 5 years is around 1 t/ha/year at a density of 10,000 shoots/ha (Tietema 1989). Tietema (1989) on the basis of regressions, predicted 12 kg/tree for mopane of 7.5 cm basal diameter at a population density of 10,000 trees/ha after 15 years, 22 kg/tree and 9.5 cm diameter at 5,000 trees/ha, and 92 kg/tree and 17.0 cm diameter at 1,000 trees/ha. The desired diameter classes (5-25 cm basal diameter) can be achieved in 5-10 years (Tietema *et al.* 1988). In the northern Transvaal, Scholes (1990) found that cleared mopane thicket or shrubland (c. 10,000-13,000 stems/ha) could revert back to its original basal area (c. 5.5 m^2/ha) after 14 years, a mean annual increment of 0.4 m^2/ha/year (or faster in years of above-average rainfall). The initial increase in stem density was later followed by self-thinning as larger stems became dominant. In Namibia the best growth was obtained by keeping coppice growth at 1 to 2 stems per rootstock (Erkkila & Siiskonen 1992). Trials with coppicing in southern Zimbabwe have shown that 20-80% of stumps have coppice shoots 3 months after cutting, and that trees coppiced at 1 m height produced more and taller coppice shoots than those cut at 10 cm height (Mushove 1992; Mushove & Makoni 1993). Larger diameter stumps were also slower in sprouting.
[Refs. 12, 16, 17, 28, 39, 73, 75, 80, 95, 97, 98, 103, 107, 110, 112]

16. Chemical control

Mopane is known to coppice prolifically from the base following mechanical clearing or the application of arboricide sprays (Scholes 1990). The resulting shrub mopane, often only 1 to 2 m high, virtually precludes grass growth and can sometimes form almost impenetrable thickets. These areas have little value for grazing animals and their browse value is essentially limited to a few months in the dry season.

Various trials have been carried out in Zimbabwe (particularly Tuli and Matopos in the south west) on the chemical control of mopane (Cleghorn, McKay & Cronin 1958; West 1958; West 1964; Wilson 1967; Teague 1973), and goats have been reported as being effective in the control of regrowth (West 1964; Teague 1973). A threefold increase in grass production has been reported from cleared mopane woodland in Zimbabwe (Teague 1973). The most effective form of control appears to be application of 2,4,5-T in diesel to cut mopane stumps, which results in a kill of around 60-80% after 3 years. (The use of this chemical is now banned in many countries.) Ringbarking was recorded as giving 50% mortality after 3 years, and some success has

been achieved by soil application of Bromacil (Teague 1973).
[Refs. 15, 103, 127, 128, 132]

17. Timber

The heartwood of mopane is dark red to blackish, very hard and heavy. It is considered a strong, durable and insect-resistant wood (De Winter *et al.* 1966; Palmer & Pitman 1972; Wyk 1972; Goldsmith & Carter 1981). The wood is moderately coarse-grained and even-textured (Division of Forest Products Research 1979). Density is reported to be 1120 kg/m^3 air dry or 1280 kg/m^3 green in Zambia (Division of Forest Products Research 1979), and 1200 kg/m^3 in Zimbabwe (Goldsmith & Carter 1981), but up to 1344 kg/m^3 in South Africa (Wyk 1972). The sapwood is yellowish or straw-coloured, sharply defined from the heartwood (Palgrave 1956), and less dense.

The heartwood is too hard to work for furniture, although craftwork and small household items are carved from it, and it is generally used for fence posts, hut poles, mine-props, railway sleepers, and sometimes parquet flooring. Where it is common, mopane is widely used for hut, kraal and fence construction, leading sometimes to local depletion and a coppice shrubland. Most larger trees have poor form, contain large knots and are very often hollow due to heart rot (Fanshawe 1962; Palgrave 1956; Palmer & Pitman 1972; Wyk 1972; Piearce 1986).

An inventory of mopane in the mid-Zambezi valley of Zimbabwe (Carter & Thompson 1952), showed that there were few trees suitable for railway sleepers as most trees with a butt diameter over 30 cm had a timber height less than 3 m.

The wood has been analyzed for some of its chemical constituents (Drewes & Roux 1966, 1967; Steynberg *et al.* 1990a,b) and similar flavenol compounds to those found in the tropical hardwood "purpleheart" (*Peltogyne* spp.).
[Refs. 12, 20, 21, 23, 24, 31, 36, 37, 78, 83, 84, 85, 86, 89, 101, 102, 129, 133]

18. Fuelwood

Mopane provides a good firewood and is a preferred species for this purpose in many areas where it occurs (Palmer & Pitman 1972; IBPGR 1984; Tietema *et al.* 1991a). It burns slowly and produces much heat, but also much smoke (De Winter *et al.* 1966), and makes a good charcoal.

It is reported to be slow in heating up water compared to other readily-available woods in Botswana, but the remaining coals give high radiant heat and so are good for extended cooking periods, although the burning efficiency is not considered high (Tietema *et al.* 1991a). The wood has a high specific weight (1190 kg/m^3 air dry) and a moderate ash content (3.78% of dry weight), with an energy content of 21,570 kJ/kg (Tietema *et al.* 1991a).
[Refs. 20, 21, 39, 78, 80, 84, 85, 86, 109]

19. Browse

Mopane leaves and young twigs are a well-known and valuable source of browse for livestock or wildlife in the dry season, particularly in the drier parts of its range. Access to mopane browse has greatly reduced stock losses in drought years (Bonsma 1942), and maintained condition of cattle in other years. Although cattle are reported to browse mopane year-round in the northern Transvaal (Bonsma 1942), in most cases browsing is seasonal. Leaves alone are not enough for survival, and they should be hammer-milled and supplemented with grass hay and molasses (Ludemann 1966). In Zimbabwe, mopane leaves are sometimes mixed with maize, molasses, urea and bonemeal to provide a nutritious dry season "bushmeal" (Grassland Society of Zimbabwe Newsletter, October 1992).

Crude protein values of the leaves range from 8.4% in September to 16.6% with leaf flush in November in the northern Transvaal (Bonsma 1942), and most other reported analyses fall within this range (Table 8). In the dry season, dry grass and most browse species have

TABLE 8. Browse nutritive value of *C. mopane*.

part	month	CP(%)	P(%)	Ca(%)	place	source
leaves	Jan	13.7	0.19	1.51	Transvaal	Bonsma 1942
leaves	Feb	13.7	0.18	1.80	Transvaal	Bonsma 1942
leaves	March	12.0	0.14	2.04	Transvaal	Bonsma 1942
leaves	April	12.4	0.13	1.41	Transvaal	Bonsma 1942
leaves	May	11.2	0.20	2.28	Transvaal	Bonsma 1942
leaves	June	11.5	0.12	1.33	Transvaal	Bonsma 1942
leaves	Aug	13.8	0.19	1.35	Transvaal	Bonsma 1942
leaves	Sept	8.4	0.12	3.23	Transvaal	Bonsma 1942
leaves	Oct	11.6	0.12	2.98	Transvaal	Bonsma 1942
leaves	Nov	16.6	0.23	1.15	Transvaal	Bonsma 1942
leaves	Dec	12.0	0.19	1.37	Transvaal	Bonsma 1942
leaves	summer	14.7	0.22	1.19	Transvaal	DHV 1979[1]
leaves	autumn	12.6	0.21	1.82	Transvaal	DHV 1979
leaves	winter	12.3	0.16	1.95	Transvaal	DHV 1979
leaves	spring	10.3	0.15	2.13	Transvaal	DHV 1979
leaves	Apr/May	8.1	0.09	1.50	E. Botswana	DHV 1979
twigs	Apr/May	4.2	0.07	1.40	E. Botswana	DHV 1979
pods	Apr/May	8.6	0.16	0.82	E. Botswana	DHV 1979
seeds	Apr/May	19.5	0.43	0.35	E. Botswana	DHV 1979
leaves/twigs	Mar/Apr	20.0	-	-	Zimbabwe	DHV 1979
green leaf	Apr/May	12.6	-	-	Zimbabwe	DHV 1979
greenish leaf	Apr/May	6.8			Zimbabwe	DHV 1979
leaves	-	12.3	-	-	S.E. Zimbabwe	Walker 1980
twigs	-	5.0	-	-	S.E. Zimbabwe	Walker 1980
green leaves	(mean)	13.8	-	-	Zimbabwe	Hunt 1954
-	(mean)	15.4 (9-20)	-	-	Zimbabwe	Lawton 1980
young leaves	(mean)	13.1	0.27	0.52	Zambia	Lawton 1968
green leaf	?June	12.3	-	-	S. Mozambique	Myre 1962
dry leaf	?June	11.3	-	-	S. Mozambique	Myre 1962
green pods	?June	10.2	-	-	S. Mozambique	Myre 1962
dry pods	?June	15.9	-	-	S. Mozambique	Myre 1962

[1] DHV (1979). Countrywide Animal and Range Assessment Project, Vol. 5. Govt. of Botswana, Gaborone.

protein levels below 6%. Calcium and phosphorous levels are also comparatively high, ranging from 0.12 to 0.23% and 1.15-3.23% respectively in the northern Transvaal (Bonsma 1942), although there does not appear to be any clear pattern of variation through the year. [In that particular study the Ca figures for September and October seem rather high.] Surprisingly, only one set of values through a year seems to have been published (Bonsma 1942), most other authors quoting him. This would appear to be an important area for future investigation.

There are no reports of anti-nutritional factors (e.g. condensed tannins) in the leaves, but this probably reflects a lack of documented studies.

Mopane leaves are reported to contain a high essential fatty acid content (Lawton 1968), which helps to keep cattle in good condition. In early summer leaves have a mildly laxative effect (Bonsma 1942). The leaves of mopane smell strongly of turpentine, but the breath of cattle feeding on them smells of onions (Bonsma 1942). However, this does not impart a taint to the milk or meat.

The most desirable livestock option in mopane shrubland areas in northern South Africa is reported to be grazing cattle and goats in a ratio of 1:2 (Donaldson 1979), as the goats keep the shrubs under control and allow an increase in grass growth for the cattle.

Branches and small trees of mopane are locally heavily browsed by elephant (Lawton 1968, 1980; Lewis 1986, 1991) and often much damaged in the process. Damage caused to mopane is discussed in section 12. In some areas of Namibia it is the major forage source for elephant (Villiers 1988; Viljoen 1989). Elephant are reported to eat both old leaves in July and the new flush in November/ December (Lawton 1980), but giraffe in the north eastern Transvaal generally avoid mopane except in late winter when nothing else is available (Oates 1972). Research is in progress in northern Zimbabwe on mopane plant selection by elephant as related to plant and soil nutrient content (J. Dudley, personal communication, 1994).
[Refs. 2, 8, 22, 29, 31, 34, 40, 49, 52, 56, 57, 60, 61, 63, 64, 65, 66, 70, 77, 78, 81, 92, 95, 98, 99, 116, 119, 120, 122, 123, 124, 133]

20. Uses

Mopane worms

One of the best-known products of mopane is the mopane worm, the edible larva of the Saturnid moth *Gonimbrasia belina* (Velcich 1963; Voorthuizen 1976), sometimes termed the Anomalous Emperor. This larva is much sought after in Botswana and the Transvaal as a delicacy. There are normally two broods of the moth per year, one with the larva feeding from December to February, and the other feeding from April to May (Velcich 1963). Individual trees, or sizeable patches of trees, can be almost totally denuded by these larvae, but only one brood per year is found on any one individual tree (Voorthuizen 1976). The larvae are collected by rural people as a source of food or to be sold or exchanged. They are prepared by killing in boiling water or in a fire after squeezing out the intestines, then dried for storage or cooked by frying or roasting (Velcich 1963; Voorthuizen 1976). They are very nutritious with a high protein content of 47.5% (at 11.4% moisture content, Voorthuizen 1976) and a fat content of 51.5% (Velcich 1963).

Medicine

Mopane is not widely used for medicine, but a bark extract is reported to be used against syphilis in the Eastern Transvaal and to treat inflamed eyes (Watt & Breyer-Brandwijk 1962), and also as a remedy for diarrhoea and dysentery in northern Zimbabwe (Forest Research Centre, archive files, 1914[1]). An infusion of the roots has been used in Zambia to cure temporary madness (Palgrave 1956) and in Mozambique to kill intestinal worms (Gomes e Sousa 1966). In some parts of Namibia, gum extracted from heated wood is used to heal stubborn wounds (Palmer & Pitman 1972).

Tannin

In the early years of this century interest was expressed by various colonial authorities in the tannin content of mopane bark. On investigation the bark was found to contain tannin levels from 5.9% (Bennett & Pearman 1953) to 8.7% (Watt & Breyer-Brandwijk 1962), the lower figure is equivalent to 32% tannin in solid extract (compared to 60% in wattle, *Acacia mearnsii*), and was too low to be commercially viable.

Resin

The resin-covered seeds of mopane yield a hard resin on extraction, sometimes termed gum copal, Angola copal or balsam (hence some of the common names of the tree). Palgrave (1956) reports resin yields of up to 20% of the seed weight, while archive files held at the Forest Research Centre in Harare mention resin yields of 11.6% of the fruit weight (or 26% of seeds alone) on alcohol extraction (analyses carried out by Imperial Institute, London in 1914).

It was originally hoped (Forest Research Centre archive files, enquiry to Native Commissioners, 1914) that mopane resin would prove an economic alternative to gum copal, but the yields were too low. The resin or gum was reported at that time to be used in various

[1]See Timberlake, J. & Crockford, K.J. (1994) *Archived species files held at the Forest Research Centre.* Forest Research Paper No. 4, Forestry Commission, Harare.

parts of Zimbabwe for mending broken pots and gourds, and for fixing spear heads, but yields per tree were low.

Details on the insect-excreted lerp which reportedly increases leaf palatability to cattle are given in section 7.

Soil stabilization

Mopane has been used experimentally in India to stabilize sand dunes (Shankarnarayan & Kumar 1986; Kumar & Shankarnarayan 1988), but showed poor establishment and survival.

Other uses

The bark is reported to be used in making twine or string in various countries (Miller 1952; Palmer & Pitman 1972; Wyk 1972).

The wood ash left after burning contains from 15.5% (Watt & Breyer-Brandwijk 1962; Palmer & Pitman 1972) to 50-55% (Palgrave 1956; Fanshawe 1962) lime, which is sometimes used as a fertilizer.

Compound oils found in the mature leaves, bark and seed of mopane have been investigated by Brophy *et al.* (1992). Fifty different essential oils were detected along with various other compounds.

The Leopard Orchid, *Ansellia africana*, is occasionally found in the forks of mopane trees - apparently its major habitat.

The Red-billed Hornbill is reported to nest in hollows in the mopane tree.
[Refs. 7, 11, 20, 21, 23, 24, 28, 31, 36, 37, 39, 44, 48, 52, 59, 71, 78, 83, 84, 85, 86, 96, 97, 101, 102, 104, 117, 118, 122, 124, 129, 133, 134]

21. Conservation

Although mopane-dominated vegetation covers 550,000 km^2 of Southern Africa (Mapaure 1994), much of it not presently cultivated, thought needs to be given to the longer term conservation of the species and the vegetation types within which it occurs.

It is where mopane woodland occurs on good arable soils, such as old alluvium and colluvium, that it is likely to be cleared as land pressures intensify and agricultural machinery to deal with the heavier soils on which it is generally found becomes more available. For example, large areas of well developed, tall, "cathedral" mopane woodland are being cleared for settlement and cotton production in the mid-Zambezi valley of northern Zimbabwe (Timberlake & Mapaure 1992) - the soils here are deep and fertile and relatively well-drained. Mopane woodlands on such substrata are local in occurrence, and those on old clay-rich alluvium are of great conservation interest due to unique assemblages of species (Timberlake *et al.* 1994). Mopane-dominated vegetation on what are essentially non-arable soils (due to shallowness, stoniness or poor drainage) are unlikely to be threatened by widespread land clearance, but the vegetation structure and some of the associated species may disappear in the face of heavy livestock pressure or from wood cutting. It is not only domestic livestock that cause loss of biodiversity in such situations. High concentrations of elephant can cause radical changes in vegetation structure, as seen in National Parks such as Gonarezhou, Hwange and the Luangwa valley. Large areas of many of the mopane vegetation types are found in National Parks in Botswana, Malawi, Namibia, Zambia and Zimbabwe, and their conservation there is assured if elephant destruction can be controlled.

In general, mopane vegetation is species-poor and appears to hold no endemics and few spectacular species. This may be the reason it has attracted relatively little attention from conservationists in the past. But as a key species in a wide range of landscapes mopane will hopefully attract attention in the future, including as an important wildlife habitat.

With such a wide-ranging species, occurring on a diversity of substrata under a wide range of climatic conditions, there is presumably a fairly wide genetic base or ecological tolerance. There would appear to be potential for genetic selection for more productive or tolerant phenotypes, particularly of those provenances from stressed habitats such as sodic

soils or lithosols. Balanced against this, however, should be the realisation that mopane is not a primary colonizer which reproduces rapidly from seed, and that establishment is slow and difficult. Perhaps concentrating attention on primary colonizers, such as *Acacia* species with their prolific and rapid reproduction from seed and short generation times, may yield more useful results for programmes such as the rehabilitation of degraded lands. Given the large remaining areas of mopane woodland and shrubland there is likely to be less incentive for planting of mopane than management of existing stands.
[Refs. 69, 113, 114, 126]

DISCUSSION

Mopane is an adaptable and obviously successful tree species of south-central Africa, occurring over a wide range of ecological conditions, but being found principally in areas of lower agricultural potential and extensive land use. Although essentially a species of heavier and eutrophic soils, it can occur on lighter-textured soils under low rainfall conditions. Due to its dominance it is also very often a key species in the ecology of the places where it is found, but as a secondary colonizer its weakness appears to be in establishment, particularly when in competition with grasses.

One of mopane's remarkable features is the formation of extensive mono-specific stands with an even size structure, a feature which, along with its readiness to coppice, lends it well to woodland management. In those areas where it occurs it is of significant economic value for construction wood, firewood and livestock browse, and the species shows potential for management for such products. Given the relatively low value of these products, however, it is unlikely that large investments in selection and planting will provide a good return. The major economic potential of mopane in the future is likely to be for low-cost subsistence products, wildlife habitat and for rehabilitation of degraded areas under certain edaphic conditions.

Comparatively little work has been done on mopane considering its ubiquitousness and economic importance in the region, and many questions relevant to its management need answers. Those that are of major importance to successful and sustained management of the species are given below:

1. Elucidate exactly what factors determine the phenomenon of stunted or shrub mopane.
2. Determine whether it is possible to age mopane from growth rings or other method.
3. Determine whether even-sized stands of mopane are even-aged, and whether recruitment is episodic. If so, what the factors are that cause this.
4. Determination of growth rates of mopane stands under different climatic and edaphic conditions.
5. Investigations into the sustainability of coppice management of mopane, and suitable harvesting intervals.
6. Determine whether mopane heart-rot can be controlled in order to increase its timber value.
7. Determination of the nutritive value of mopane browse through the year on different soil types.
8. Determine why elephant damage to mopane is localised, and under what conditions it occurs.

Open mopane bushland on rocky soils. Trees are stunted as the roots cannot penetrate deep (Omay, northern Zimbabwe).

Low mopane bushes in edaphic grassland on vertisols. Note coppice growth resulting from burning (Gokwe, northern Zimbabwe).

Cotton fields cleared from mopane woodland. Soils in such areas are fertile and large areas of mopane woodland are being cleared in Gokwe and the mid-Zambezi valley (Mushumbi Pools, northern Zimbabwe).

Coppice C. mopane *heavily damaged by elephant. Note browse height at c. 1.5m (Gonarezhou National Park, southern Zimbabwe).*

Goats browsing C. mopane *bushes in the dry season on black clay soils. Note leaves of* C. mopane *on ground (Matibi communal land, southern Zimbabwe).*

Mopane shrubland on black clay soils in the dry season with scattered mopane trees (Matibi communal land, southern Zimbabwe).

Leaves of C. mopane *on a coppice shoot in the late wet season (Sinamatella, northern Zimbabwe).*

Fockea, *a woody climber on a young* C. mopane *tree (Gokwe, northern Zimbabwe).*

Roadside regeneration from seed of C. mopane *(Sinamatella, northern Zimbabwe).*

Bibliography

1. ACOCKS, J.P.H. **Veld Types of South Africa.** *Memoirs of the Botanical Survey of South Africa* No. 40 (1975) South Africa, Pretoria; Botanical Research Institute. 128 pp. [En, 20 ref.]

Survey of vegetation of South Africa. Vegetation dominated by *Colophospermum mopane* (Mopani Veld, type 15) is found in N. and N.E. South Africa between the Soutspansberg mountains and the Limpopo river, and in Kruger National Park north of the Olifants river. Both areas are hot and dry (under 450 m altitude and c. 450 mm annual rainfall). *C. mopane* is relatively shrubby and usually mixed with other tree species (especially *Acacia* and baobab) and sparse tufted grasses.

2. ANDERSON, G.D.; WALKER, B.H. **Vegetation composition and elephant damage in the Sengwa Wildlife Research Area, Rhodesia [Zimbabwe].** *Journal of South African Wildlife Management Association* (1974) 4 1-14 [En, 37 ref.]

Study of elephant damage to the woody component of the vegetation of an area of central Zimbabwe, 33% of which is dominated by *Colophospermum mopane*. Damage was assessed and related to the chemical composition of bark, leaves and soil. 34% of *C. mopane* trees were found to be damaged, mostly in the form of broken stems and branches, and 4.4% showed recent elephant damage. *C. mopane* appears to be resistant to heavy utilization, responding by coppicing. Large areas have been reduced to shrubs 1-2 m high. The damage rate per elephant per km^2 is similar in both miombo and mopane woodland, but because of elephant concentration damage is higher in riverine areas. No link between damage and chemical constituents of the bark or leaves was found, only a slight correlation with soil Na content.

3. BALASUNDARUM, V.R. **Studies on the native nodulation and biomass production of some tree legumes.** *Indian Journal of Forestry* (1987) 10 (2) 94-96 [En, 7 ref.]

Study of native nodulation over 6 months in 21 tree legume species in New Delhi, India. *Colophospermum mopane* did not nodulate, and produced the lowest %N per plant value of all species.

4. BARBOSA, L.A. GRANDVAUX. **Carta fitogeográfica de Angola.** Luanda, Angola; Instituto de Investigaçâo Científica de Angola (1970) 323 pp. [Port, 146 ref. + map]

Description of the vegetation of Angola. 32 main types are described, including three types dominated by *Colophospermum mopane* (20, Dry deciduous woodland and mosaic of savanna and shrubland; 21, Dry valley woodland and riverine vegetation; 27, Sublittoral shrubland). These types are found along part of the southern coastal strip south of Lobito and in the south west corner of the country, at altiudes from sea level to 1100 m and rainfall from 100-650 mm yr^{-1}.

5. BARNES, D.L.; LLOYD, B.V.; McNEILL, L. **The use of shoot dimensions to estimate the leaf mass or leaf area of certain indigenous trees in Rhodesia [Zimbabwe].** *Proceedings of Grassland Society of Southern Africa* (1976) 11 47-50 [En, 7 ref.]

Account of an attempt to relate shoot dimensions to leaf mass for *Colophospermum mopane* and *Brachystegia* spp. Large and small trees of *C. mopane* from the S. Zimbabwe lowveld were measured for height, stem diameter and canopy spread, and then leaves and young twigs from above and below 2 m were weighed. Young twig mass (DM) comprised 8.5% of total matter weighed. The best practical regression equations determined were $y = 159 + 230$ C, where C is the product of leaf canopy axes (m^2), and $y = 177 + 6.41 \sum D^2$, where D is stem diameter (cm^2). The ratio of leaf mass below 2 m to total leaf mass in trees greater than 2 m in height was expressed by $\log_{10}$ (mass ratio + 1) = 0.3514 - 0.0422 H,

where H is tree height.

6. BARRETT, J.C.; BRINN, P.J.; TIMBERLAKE, J.R. **Tsetse control, agropastoralism and environmental degradation in the Zambezi valley; an interdisciplinary case study in Chiswiti Communal Land.** Unpublished report. Harare, Zimbabwe; Tsetse and Trypanosomiasis Control Branch, Department of Veterinary Services (1991) 225 pp. [En, 174 ref.]

A rapid rural appraisal of degradation associated with an area of settlement in the eastern part of the Zambezi valley in Zimbabwe, some of it in *Colophospermum mopane-Terminalia stuhlmannii-Combretum apiculatum* woodland. Natural accelerated soil erosion is relatively common in undisturbed mopane woodland due to soil capping, but there is evidence for some reduction in its intensity under present levels of cultivation. Mopane soils appear suitable for cotton cultivation, but their heaviness may have precluded cultivation in the past. The oft-quoted blanket statements on the unsuitability for cultivation and sodic nature of soils under mopane are challenged. A proposal for a research project into the land use potentials of soils under *C. mopane* in the mid-Zambezi valley is appended, which highlights their potential value.

7. BENNETT, H.; PEARMAN, R.W. **Mopani bark from the Bechuanaland Protectorate [Botswana].** *Colon. Plant Anim. Prod.* (1953) 3 (3) 232-234 [En]

Examination of tanning properties of bark of *Colophospermum mopane* from Botswana. The bark is poor in tannin (5.9%) compared to that from wattle and gives a highly coloured infusion. The ratio of tannins to non-tannins is also low. Tanning properties, however, are good.

8. BONSMA, J.C. **Useful bushveld trees and shrubs their value to the stock farmer.** *Farming in South Africa* (1942) **17** 226-239, 259 [En]

Account and descriptions of useful trees and shrubs for ranchers in South Africa, including *Colophospermum mopane*. Cattle are recorded as browsing the leaves and thin stalks year-round in N. South Africa. In summer the young leaves have a mildly laxative effect, but no tainting of milk or meat has been recorded. The average monthly crude protein content was 12.6% DM, ranging from 8.4% in September to 16.6% in November. Phosphorous (P_2O_5) averaged 0.172% and calcium (CaO) 1.86%.

9. BOUGHEY, A.S. **The vegetation types of Southern Rhodesia [Zimbabwe]: A reassessment.** *Proc. & Trans. of Rhodesia Scientific Assoc.* (1961) **49** 54-98 [En, 21 ref.]

Account of the vegetation of Zimbabwe, described under 7 catena types. The *Colophospermum mopane* catena type is found below 900 m over much of the country, particularly the flatter portions of the Limpopo, Save and Zambezi valleys. Tree height depends on mean annual rainfall, and shrub mopane results from old cultivation and fire. Typical associated species are given for the different areas of mopane woodland or shrubland.

10. BOUGHEY, A.S. **Interaction between animals, vegetation, and fire in Southern Rhodesia [Zimbabwe].** *Ohio Journal of Science* (1963) **63** (5) 193-209 [En, 9 ref.]

Account of vegetation catenas and ecology of Hwange National Park, W. Zimbabwe. Savanna woodland dominated by *Colophospermum mopane* is found in the northern parts, mostly in clay depressions, and typically supports herds of impala which browse *C. mopane* leaves in the dry season. Sable antelope and elephant are also found. Around waterholes *C. mopane* occurs as shrub savanna as a result of elephant damage. Repeated fire, which is common, is said to weaken *C. mopane* coppice leading to grass savanna.

11. BROPHY, J.J.; BOLAND, D.J.; LINGEN, S. VAN DER **Essential oils in the leaf, bark and seed of mopane (*Colophospermum mopane*).** *South African Forestry Journal* (1992) **161** 23-25 [En, 9 ref.]

Account of the essential oils obtained from leaves and bark of *Colophospermum mopane* plants from Kwekwe, central Zimbabwe, and from seeds from the S.E. lowveld. 65 compounds were identified from the leaves, 49 compounds from the bark and 72 compounds from the seed, including over 50 different essential oils. The major compound from all three sources was á-pinene, accounting for more than 50% of the total oil in both leaves and seeds.

12. CARTER, D.T.; THOMPSON, B. **Report on the survey of mopani in the Chirundu area of the Zambezi valley**. Unpublished report. Harare, Zimbabwe; Forest Department, Ministry of Agriculture (1952) 20 pp. [En]

Investigation using transects into the quantity of marketable *Colophospermum mopane* trees in the Chirundu-Nyakasanga river area of the Zambezi valley, Zimbabwe. No stands of good and large mopane were found, only scattered individuals many of which were of poor form. The greatest density was 93 stems ha^{-1} with an average butt diameter of 10 cm. The lowest density was 28 stems ha^{-1} with a butt diameter of 20-43 cm. Even trees with butt diameter over 30 cm had a timber height rarely exceeding 3 m. Of the classes enumerated 90% were badly warped, bent or had heartrot. The available timber was not thought suitable for railway sleepers.

13. CAUGHLEY, G.C. **The elephant problem an alternative hypothesis.** *East African Wildlife Journal* (1976) 14 265-283 [En, 44 ref.]

Discussion on the effects of elephant on the age structure of vegetation, using data from mopane woodland in the Luangwa Valley, Zambia as an illustration. Under high elephant density there was a reduced number of trees in the 50-90 cm dbh classes, reflecting the main tree classes pushed over. The rate at which *Colophospermum mopane* trees are uprooted and broken averaged 138 $km^{-2}\ yr^{-1}$, or 4% of standing crop; the number felled being primarily dependent on elephant density, not tree density. Frequency of trees forked at 0.5-2 m is also a function of past elephant numbers, and findings suggest that elephant densities were as high about 200 years ago as now. Regeneration is not inhibited by elephant browsing or damage, but this restricts recruitment into taller size classes.

14. CHOINSKI, J.S.; TUOHY, J.M. **Effect of water potential and temperature on the germination of four species of African savanna trees.** *Annals of Botany* (1991) 68 227-233 [En, 26 ref.]

Study of germination responses of seeds from four Zimbabwe tree species, including *Colophospermum mopane*, under varying regimes of temperature and water stress. *C. mopane* germinated under a wide range of temperature and water potential, but best at a water stress of -0.14 MPa [-1.4 bars]. Hypocotyl elongation was similar or greater under water stress than under germination in water. The species seems physiologically well adapted to stress conditions.

15. CLEGHORN, W.B.; McKAY, A.D.; CRONIN, C.H. **Results of preliminary arboricide and herbicide trials on a number of species limiting livestock carrying capacity of veld in Southern Rhodesia [Zimbabwe].** Paper 1st African Weed Control Conference, Victoria Falls July 1958, 22-49 [En, 10 ref.]

Results of herbicide trials on woody species at various research stations in Zimbabwe. Complete clearing of bush at Tuli Pasture Research Station, where the main shrub species is *Colophospermum mopane*, increased grass yields by 100%. 2,4,5-T gave an 80% kill of *C. mopane* after 2 years when stumps were treated. Kills in a similar experiment ranged from 60% with 0.5% wt./vol. spray in water to 100% with 1% wt./vol. in diesel. Coppice *C. mopane* treated with 2,4,5-T ester in water (1% wt./vol.) at 10 gm ha^{-1} gave a high defoliation percentage but low kill by the following season.

16. COE, K.H. **Effects of thinning on *Colophospermum mopane* in an indigenous woodland setting.** *Journal of Forestry Association of Botswana* (1991) 47-57 [En, 8 ref.]

Report on a trial in mopane woodland in Boteti district, north central Botswana. Measurements were made of a number of *Colophospermum mopane* trees, diameter, basal area and heights within 4 plots, 3 of which were then thinned from 7900-8600 stems ha^{-1} to 1500-3400 stems ha^{-1}. Results showed an inverse relationship between stocking rate and diameter and basal area growth within one year, showing the necessity for thinning. Basal area increased 11-21% in thinned plots compared to 3.5% for the control. Height showed a 1.2-3.9% increase in thinned plots, compared to 1.1% in the control.

17. COE, K.H. **Managing natural woodlands in dryland Botswana.** *Agroforestry Today* (1992) 4(2) 6-8 [En, 7 ref.]

Account of the potentials of managing natural stands of vegetation in Botswana with particular reference to a thinning experiment on *Colophospermum mopane* at Boteti, north central Botswana (see Coe 1991). *C. mopane* comprises 93.3% of biomass at the site. Treatments were thinned from 7900-8600 stems ha^{-1} to 1500, 2800 and 3400 stems ha^{-1}. After 11 months the 3400 stems ha^{-1} treatment showed the highest growth rates for stem diameter, height and basal area, while the control showed the lowest. Height growth increased less in thinned plots than stem diameter growth, showing the potential for coppicing to increase biomass production.

18. COLE, M.M. **The savannas: biogeography and geobotany.** London, U.K.; Academic Press (1986) 438 pp. ISBN 0-12-179520-9 [En, 395 ref.]

Textbook on the biogeography and geobotany of savannas worldwide. *Colophospermum mopane* occurs in the savanna woodland zone of south-central Africa in wide, flat, valley bottoms of larger rivers (Zambezi, Luangwa, Shire, Limpopo, Okavango, Cunene). Low tree and shrub forms are found on old floors of dismembered drainage systems in Botswana, Transvaal lowveld and Bushveld. The characteristic soils on which it occurs are alkaline black clays derived from Karoo (Triassic) basalts and shales. Distribution of *C. mopane* is mostly controlled by edaphic factors, particularly on base-rich soils with impeded drainage. The extensive shallow root system coincides with the zone of maximum moisture retention. It is usually excluded from better soils by deeper-rooted *Acacia* spp. Mopane is ecologically aggressive and is extending its range into other savanna types. Its ecological analogue in Australia is *Acacia harpophylla* (brigalow).

19. CORBY, H.D.L. **Systematic implications of nodulation among Rhodesian [Zimbabwe] legumes.** *Kirkia* (1974) 9(2) 301-329 [En, 42 ref.]

Listing of occurrence of nodulation on the roots of 539 species of legumes found in Zimbabwe. *Colophospermum mopane* is reported not to nodulate even in nursery trials.

20. DE WINTER, B.; DE WINTER, M.; KILLICK, D.J.B. ***Colophospermum mopane* (Kirk ex Benth.) Kirk ex J. Léonard.** In *Sixty-six Transvaal Trees*. Pretoria, South Africa; Botanical Research Institute (1966) 64-65 [En]

Guide to some of the commoner trees of the Transvaal (N. South Africa). *Colophospermum mopane* is a small to medium, narrow crowned, irregularly deciduous tree, sometimes shrubby, found in hot dry areas. It is not used as a garden tree and the seeds, although germinating readily, are inclined to damp off. The generic name is derived from the Greek meaning "seed inhabiting the light".

21. DIVISION OF FOREST PRODUCTS RESEARCH **Timbers of Zambia *Canarium schweinfurthii, Colophospermum mopane.*** *Technical Note 21/79*. Kitwe, Zambia; Division of Forest Products Research, Forest Department (1979) 5 pp. [En, 5 ref.]

Brief account of timber properties of two tree species. *Colophospermum mopane* timber has a density of 1120 kg m^{-3} air dry, 1280 kg m^{-3} green. Sapwood is straw coloured and distinct from the red to dark red-brown heartwood. Grain is generally interlocked, and texture fine and even. The heartwood is very durable and impermeable and seasons well, although liable to surface checks. It is hard to work when dry but cuts cleanly and is moderately strong and heavy. Its main uses are as untreated fence posts and building poles, but it could make good flooring and sleepers. It is a good firewood and makes good charcoal.

22. DONALDSON, C.H. **Goats and/or cattle on Mopani veld.** *Proceedings Grassland Society of Southern Africa* (1979) 14 119-123 [En, 7 ref.]

The effects on animal performance and vegetation change from running steers and goats, separate or combined, on mopane bushveld in the northern Transvaal was studied over 6 years. Most livemass per ha was produced by steers alone, and the goat treatments resulted in a marked reduction in browse and an increased growth of grass. Goats alone utilized 74.5% of available browse, most of this being *Colophospermum mopane*, but *Terminalia prunioides*, *Combretum apiculatum* and *Grewia* spp. were also browsed. The use of both cattle and goats was the most desirable option in order to utilize and control woody plants, with an optimum cattle:goat ratio of less than 1:2.

23. DREWES, S.E.; ROUX, D.G. **Stereochemistry and biogenesis of mopanols and peltogynols and associated flavonoids from *Colophospermum mopane*.** *Journal Chemical Society* (1966) **19c** 1644-1653 [En, 32 ref.]

Account of analysis of heartwood of *Colophospermum mopane* from Kruger National Park, N.E. South Africa. An association of flavonoid compounds of interest in the biogenesis of tannins was noted, and the mopanol compounds in *C. mopane* were found to be similar to peltogynol compounds in *Peltogyne porphyrocardia*.

24. DREWES, S.E.; ROUX, D.G. **Isolation of mopanin from *Colophospermum mopane* and interrelation of flavonoid components of *Peltogyne* spp.** *Journal Chemical Society* (1967) **15c** 1407-1410 [En, 13 ref.]

Account of the first isolation of the compounds mopanin and fisetin from the heartwood of *Colophospermum mopane* in the Kruger National Park, N.E. South Africa. Mopanin is a flavonol analogue of mopanol. The anthocyanidins peltogynidin and mopanidin were also found. Similar compounds are found in the commercial timber "purple heart" (*Peltogyne pubescens*).

25. DYE, P.J. **Vegetation-environment relationships on Rhodesian [Zimbabwe] sodic soils.** Unpublished MSc thesis. Johannesburg, South Africa; University of the Witwatersrand (1977) 148 pp. [En, 112 ref.]

Stands of vegetation on sodic soils in the gneissic-granite areas of the central watershed of Zimbabwe were examined for variations in species composition and soil structure. Plant growth was found to be limited by a relatively shallow rooting depth resulting from a sodic and largely impermeable B horizon. Three vegetation types with *Colophospermum mopane* were found: tall *C. mopane* trees and associated species (*Commiphora* spp., *Combretum apiculatum*, *Cissus cornifolia*) on soils with a relatively deep A horizon; tall *C. mopane* trees without companion species on soils with a shallow A horizon and relatively permeable subsoil; and stunted coppicing *C. mopane* on soils with a shallow A horizon and impermeable subsoil.

26. DYE, P.J.; WALKER, B.H. **Vegetation-environment relations on sodic soils of Zimbabwe Rhodesia.** *Journal of Ecology* (1980) **68** 589-606 [En, 21 ref.]

Study of the vegetation of granitic-gneissic sodic soils in Zimbabwe. *Colophospermum mopane* was the most common tree on these soils; it is a drought-resistant, shallow-rooted species, widely distributed and dominant in the dry, hot low-altitude regions of the country. In the mopane soils examined a relatively impermeable B horizon with a dispersed clay fraction restricted moisture penetration to a shallow depth, providing *C. mopane* with a competitive advantage over deep-rooted species. The distribution and physiognomy of mopane on sodic soils results from the interaction of factors affecting the absorption and retention of moisture in the B horizon, i.e. depth of A horizon, soil texture, and electrolyte:exchangeable Na ratio in the B horizon. Tall non-coppice *C. mopane* is characteristic of soils with a deep A horizon and weakly sodic subsoil, while coppice mopane was found on soils with an intermediate A horizon and a relatively permeable B horizon. No trees or shrubs were found on soils with a shallow A horizon underlain by a highly sodic impermeable B horizon.

27. ELLIS, B.S. **A guide to some Rhodesian [Zimbabwe] soils: II a note on mopani soils.** *Rhodesian Agricultural Journal* (1950) **47** 49-61 [En, 2 ref.]

Account of the distribution and properties of soils associated with *Colophospermum mopane*, with particular reference to the Save valley, S. Zimbabwe. Mopane soils are often considered comparatively infertile. In the

Bulawayo and Harare areas it was found that *C. mopane* was particularly associated with an accumulation of clay and salts (especially sodium) beneath the soil surface, leading to a paucity of grass and increased incidence of soil erosion. *C. mopane* is thought to be resistant to high pH, presence of soluble salts, and to the physiological dryness in the lower horizons of the soil found under these circumstances. In the Save valley a different situation prevails, and *C. mopane* was found on various soils including deep alluvium. The rooting system was found to be very shallow with no tap root but descending radial roots. The area of root development coincided with the zone of greatest soil moisture content; in these mopane soils moisture is held at a relatively shallow depth. It is concluded that *C. mopane* is not confined to sodic or infertile soils, but its distribution is a result of certain soil features affecting moisture availability and rooting patterns. Data are presented on some of the soils examined.

28. ERKKILÄ, A.; SIISKONEN, H. **Forestry in Namibia 1850-1990.** *Silva Carelica* No.20. Finland; University of Joensuu (1992) 244 pp. ISBN 951-708-010-7 [En, 383 ref.]

Account of the distribution, practices and history of forestry and the Forest Department in Namibia. *Colophospermum mopane* is only found in Owamboland and the E. Caprivi in the north west of the country. It is dominant over much of W. Owambo but does not occur in E. Owambo or Kavango. At the southern boundary, which follows the 5°C isotherm of mean daily temperature for July, frost damage is frequent. *C. mopane* is generally found as a 7-10 m tall deciduous tree with a stunted shape, and forms a spaced woodland with a shrubby understorey in many areas. At its western limits it occurs as scattered shrubs, sometimes with *Welwitschia* in dry river beds. The height of *C. mopane* decreases from north to south and west, where the climate is cooler and drier. Its growth is also reduced by alkaline soils. Grass cover is usually sparse due to the dense and shallow lateral root system of the trees. The resultant absence of fire helps in regeneration, including from woody suckers. Crown fires can be fierce due to the resinous leaves. In central Owambo much of the mopane woodland has been cleared for fields or for grazing land, and most mopane woodlands have been converted to low shrublands. The wood is termite resistant and the most popular construction and firewood. Due to its strong coppicing ability woodlot management is thought to have potential. Similar management was practised in the 1960s, and a mopane management project started then. The number of shoots should be kept at 1 or 2 per stool.

29. ERNST, W.H.O.; SEKHWELA, M.B.M. **The chemical composition of lerps from the mopane psyllid *Arytaina mopane* (Homoptera, Psyllidae).** *Insect Biochemistry* (1987) 17 (6) 905-909 [En, 18 ref.]

Colophospermum mopane is the host for nymphal stages of a psyllid insect (*Arytaina mopane*) which feeds on the phloem sap and produces an excretion product (lerp). In large numbers the psyllid can reduce levels of photosynthesis and increase the palatability of leaves to cattle, perhaps due to the high concentration of monosaccharides. Lerp was chemically analyzed and found to be quite different to that from Australian psyllids feeding on *Eucalyptus* spp. The selective accumulation of potassium and phosphorous in the lerp from *C. mopane* may strongly influence the mineral and carbohydrate metabolism of the leaves, although it is not yet certain if it has an impact on tree growth.

30. EYLES, P.A. **The effect of soil conditions and Rhizobium treatment on the growth and nitrogen content of *Colophospermum mopane*.** Unpublished BSc dissertation. Johannesburg, South Africa; University of the Witwatersrand (1971) 49 pp. [En, 53 ref.]

The effects of different soil conditions on nodulation of *Colophospermum mopane* were studied. Seeds from Orapa (N. Botswana) were raised in pots containing soils from mopane areas in Tzaneen (N.E. Transvaal, South Africa), Hwange National Park (W. Zimbabwe) and Bubi River (S. Zimbabwe) and inoculated with a broad-spectrum *Rhizobium* strain. Two levels of calcium carbonate were used to raise pH. No nodulation was observed on any roots of *C. mopane* and, as conditions were considered optimal, it was concluded that this species does not nodulate. Nitrogen content of the shoots and roots differed with different soils and was related to nitrogen present in the soil. It is suggested that *C. mopane* is adapted to low nitrogen soils, eliminating the need for nodulation. However, it is also suggested that *C. mopane* is slow-growing in its natural environment due to low soil nitrogen concentrations.

31. FANSHAWE, D.B. ***Colophospermum mopane.*** In *Fifty Common Trees of Northern Rhodesia [Zambia].* Lusaka, Northern Rhodesia [Zambia]; Natural Resources Board and Forest Department (1962) 42-43 [En]

Brief illustrated account of 50 Zambian trees, including vernacular names. *Colophospermum mopane* (Mopane, muPane, mWane, muSania) is a deciduous tree of alluvial clay areas in the lower Zambezi, Kafue and Luangwa valleys where it forms extensive pure woodlands. On basalt around Victoria Falls it forms scrub vegetation, and extends into mixed woodlands on sandy soils in the Gwembe valley. *C. mopane* grows up to 50 feet [15 m] high and 4 feet [1.22 m] in diameter, with a rounded crown. The bark, which has a low tannin content and exudes gum copal, is silver-brown with shallow furrows, while the slash is pink to red, laminated and fibrous. Flowers appear with the new leaves in January to March; pods ripen from June to September. The wood is red to dark brown or grey-black, heavy, oily and hard. It is good for fence posts, hut poles, handles, carving and as firewood, although timber-sized trees are normally hollow. Wood ash has a 50% lime content. The seeds yield 20% of a heavy balsam. Leaves are browsed by cattle and game, and mopane worms often strip the leaves. All parts are used in traditional medicine.

32. FANSHAWE, D.B. **The vegetation of Zambia.** *Forest Research Bulletin* No.7. Division of Forest Research, Kitwe, Zambia (1969) 67 pp. [En, 65 ref.]

Account and classification of the vegetation of Zambia, with detailed descriptions of each type. Two vegetation types are dominated by *Colophospermum mopane*: mopane woodland and mopane termitaria. Mopane woodland is single-storeyed with an open deciduous canopy 6-18 m high, usually with pure mopane but sometimes with munga elements. This is found in the Luangwa, Luano, Kafue, Zambezi and Mashi valleys. A species list is given. Mopane termitaria, found in mopane woodland and other vegetation types, contain species typical of mopane woodland.

33. FRASER, S.W.; ROOYEN, T.H.VAN; VERSTER, E. **Soil-plant relationships in the Central Kruger National Park.** *Koedoe* (1987) 30 19-34 [En, 11 ref.]

Investigation into the soils of part of the Kruger National Park (N.E. South Africa) and the associated vegetation. *Colophospermum mopane* vegetation types were found to be closely related to different soil types. Shrub mopane (1-2 m high) occurs on fine-textured soils derived from basic rocks (basalts, diabase, olivine gabbro), mixed savanna woodland dominated by *C. mopane* trees up to 5 m high is found on deeper coarse-textured soils derived from granitic gneiss, and dense stands of stunted tree *C. mopane* or single-stemmed shrubs are found on most duplex soils. It is concluded that shrub mopane is associated with soils having a high clay, Mg and Ca content, and the tree form associated with sandy soils low in clay. On deep riverbank soils *C. mopane* trees up to 20 m high can be found.

34. FROST, P.G.H. (compiler) **Damage to mopane, *Colophospermum mopane*, in relation to elephant density at Kariba [Zimbabwe].** Unpublished report. Harare, Zimbabwe; Department of Biological Sciences, University of Zimbabwe (1987) 17 pp. [En, 15 ref.]

Study of the damage by elephant to *Colophospermum mopane* trees on two islands in Lake Kariba (N. Zimbabwe), one regularly visited by elephant and the other very rarely. *C. mopane* trees on the rarely-visited island show less coppicing, fewer forked stems and less scarring, the differences are most apparent in trees <6 m high and with stems <40 cm girth. On the regularly visited island 65% of saplings and 68% of trees were damaged and coppicing. The girth-height relationship of undamaged *C. mopane* was curvilinear, although with considerable variation. It appears elephant preferentially break branches and stems of smaller plants, but resort more to pushing over larger trees.

35. GIESS, W. **A preliminary vegetation map of South West Africa [Namibia].** *Dinteria* (1971) **4** 5-64 [En/Afr/Ger, 26 ref.]

Descriptions of 15 vegetation types with a map of the whole country at scale 1:3 million. Mopane savanna is the only vegetation type containing *Colophospermum mopane* as an important constituent. It is found over a large area of N.W. Namibia from the Cunene river to south of Etosha pan. The species occurs as a shrub or tree, in dense woodland or scattered with other species. Rainfall varies from 50-100 mm yr^{-1} in the west to 600 mm yr^{-1} in the east. Species of *Commiphora* are also common. *C. mopane* is also found as a constituent of riverine woodland in the north west.

36. GOLDSMITH, B.; CARTER, D.T. ***Colophospermum mopane.*** In *The Indigenous Timbers of Zimbabwe*. Zimbabwe Bulletin of Forestry Research No.9 (1981) 96. ISBN 0-86923-294-0 [En]

Descriptions of timber properties of some trees indigenous to Zimbabwe. *Colophospermum mopane* (iphane, mopane, musaru, mwani, shanatsi) is an abundant tree up to 20 m high with a stem diameter of up to 70 cm. The sapwood is narrow, straw-coloured, and sharply defined from the dark red-brown heartwood, which is generally black-streaked. It is very heavy (1200 kg m^{-3}) and hard, difficult to work, but turns well if done with care. Details are given on texture, grain, mechanical strength, shrinkage, sawing and planing, durability, nail holding, ability to take paint, varnish and glue, preservation, seasoning defects, and susceptibility to insect and fungal attack.

37. GOMES E SOUSA, A. ***Colophospermum mopane.*** In *Dendrologia de Moçambique - estudo geral* Vol 1. Série Memórias No.1. Lourenço Marques [Maputo], Mozambique; Centro de Documentação Agrária, Instituto de Investigaçäo Agrónomica de Moçambique (1966) 250-251 [Port]

Descriptive account of the trees of Mozambique. *Colophospermum mopane* (messanha) is a small or medium tree to 15 m high. Flowers are produced in March just after leaf flush, and fruits in May to June. It is found in hot dry areas at lower altitudes such as the Zambezi and Limpopo valleys and Alto Changane (S. Mozambique), generally on clay soils. Trunks of large trees are used for telegraph posts, huts and fences, leaves are browsed by elephants, and an infusion of roots is used against intestinal worms. The wood is hard and difficult to work, but weather-resistant.

38. GROBBELAAR, N.; CLARKE, B. **A qualitative study of the nodulating ability of legume species: list 2.** *Journal of South African Botany* (1972) 38(4) 241-247 [En, 5 ref.]

A list of the occurrence of nodulation among 215 species of southern African legumes. *Colophospermum mopane* did not nodulate.

39. GRUNDY, I.M.; CAMPBELL, B.M.; BALEBEREHO, S.; CUNLIFFE, R.; TAFANGENYASHA, C.; FERGUSSON, R.; PARRY, D. **Availability and use of trees in Mutanda Resettlement Area, Zimbabwe.** *Forest Ecology and Management* (1993) **56** 243-266 [En, 40 ref.]

Account of wood supply and consumption in an area of E. Zimbabwe. Mopane woodland had the highest woody biomass per unit area at 64.3 t (oven dry) ha^{-1}, with *Colophospermum mopane* itself contributing 83% of this. Consumption of *C. mopane* wood was around 3.4 t ha^{-1} yr^{-1}; the major uses were for walls and roofs of huts as well as for cattle kraals, fences and firewood. Wood density of *C. mopane* is given as 1200 kg m^{-2}.

40. GUY, P.R. **The feeding behaviour of elephant (*Loxodonta africana*) in the Sengwa area, Rhodesia [Zimbabwe].** *South African Journal Wildlife Research* (1976) **6** 55-63 [En, 29 ref.]

Account of the feeding behaviour, plant preferences and tree destruction by elephant in Sengwa, central Zimbabwe. Plant species appear to be chosen in rough proportion to their abundance, and *Colophospermum mopane* was one of the commonest browse species. Most leaves chosen were less than 2 m from ground level. *C. mopane* trees accounted for 50% of the number pushed over by elephant, partly, it is suggested, because of its shallow rooting system and the frequency of hollow stems.

41. GUY, P.R. **Changes in the biomass and productivity of woodlands in the Sengwa Wildlife Research Area, Zimbabwe.** *Journal Applied Ecology* (1981) **18** 507-519 [En, 16 ref.]

Study of woody biomass in miombo, mopane and riverine woodlands in an area of central Zimbabwe, and its relation to damage by elephant and fire. Biomass of mopane woodland, the major vegetation type in the study area, decreased by over 6% in 4 years, 6% for trees and 33% for shrubs. Although many were damaged by elephant, trees were not destroyed giving a relatively low decrease compared to the other woodland types. Total biomass was 65.8 t ha^{-1} in 1972, with over 90% of total stem area and density contributed by *Colophospermum mopane*. Annual production of trees and shrubs in the mopane woodland decreased between 1972 and 1974, but increased between 1974 and 1976, with an overall decrease of 10%. There was little change in the age structure. Fire seemed to have little effect on biomass in mopane woodland because of poor grass cover.

42. GUY, P.R. **The estimation of the above-ground biomass of the trees and shrubs in the Sengwa Wildlife Research Area, Zimbabwe.** *South African Journal Wildlife Research* (1981) **11** 135-142 [En, 33 ref.]

Measurements of above-ground woody biomass in woodland subject to elephant damage in an area of central Zimbabwe, and determination of regression equations. The regression for mass against diameter for *Colophospermum mopane* was $M = D^{2.4575} \times 0.0544$, with a correlation coefficient of 0.9794 (19 trees). The regression for diameter^2 height against mass was $M = D^2H^{0.9335} \times 0.0408$, with a correlation coefficient of 0.9854.

43. GUY, P.; MAHLANGU, Z.; CHARIDZA, H. **Phenology of some trees and shrubs in Sengwa Wildlife Research Area, Zimbabwe-Rhodesia [Zimbabwe].** *South African Journal of Wildlife Research* (1979) **9** 47-54 [En, 20 ref.]

Descriptive account of the phenology of trees and shrubs in four woodland types in central Zimbabwe, including one type dominated by *Colophospermum mopane*. *C. mopane* leaf buds were principally found in October/November, while mature leaves were found year-round except from October to December when leaf flush occurred. Flowering was for a short period in January, with unripe fruits on the trees from February to March, but ripe fruits generally fell soon after. Regrowth of leaves is possible if young leaves are removed soon after the start of the growing season. In mopane woodland many leaves of woody plants are available through the year except in October to December, a period of shortage for browsing animals in all vegetation types.

44. HARTLAND-ROWE, R. **The biology of the wild silkmoth *Gonometa rufobrunnea* Aurivillius (Lasiocampidae) in northeastern Botswana, with some comments on its potential as a source of wild silk.** *Botswana Notes and Records* (1992) **24** 123-133 [En, 2 ref.]

Account of work carried out on the biology and rearing of the wild silk moth (*Gonometa rufobrunnea*) in N.E. Botswana. The larvae of this insect feed solely on leaves of *Colophospermum mopane*, unlike those of the closely related *G. postica*, and within Botswana have only been found north of latitude 23°S. Larvae initially aggregate in groups of up to 10 near tips of slender branches, but later instars are more solitary and often rest on the bark. Larger larvae wander widely over the plant. Cocoons are not always constructed on mopane bushes. Emergence and oviposition coincide with the flush of new mopane leaves in early October, and delay in flushing can result in high larval mortality.

45. HENNING, A.C. **A study of edaphic factors influencing the growth of *Colophospermum mopane* (Kirk ex Benth.) Kirk ex J. Léonard.** Unpublished PhD thesis. Johannesburg, South Africa; University of the Witwatersrand (1976) 141 pp. [En, 198 ref.]

Review of literature and a study of plant performance of *Colophospermum mopane* in the field (Zimbabwe, Botswana, South Africa) and laboratory on different soil types and under different environmental conditions. The phytogeographical limits appear to be the 1000 mm annual rainfall isohyet and 5° C mean daily isotherm for July, but with a disjunction associated with deep Kalahari sand. *C. mopane* is generally confined to the 200-800 mm annual rainfall zone and is intolerant of severe frosts.

There was a correlation between plant performance (DBH x plant density) and total surface-soil N and P, % subsoil moisture, and with exchangeable soil Mg. *C. mopane* is shallow-rooting, growing mostly on shallow Ca-accumulating sands over loamy sands.

Laboratory experiments showed that *C. mopane* is capable of internal osmotic adjustment, perhaps involving osmotically active N compounds in the cell sap. Seedlings in pots can withstand moisture stress up to 32 bars without wilting. Increased Na and K caused a decline in yield on all soil types, which was primarily due to increased soil osmotic suction. The species is dependent on exchangeable Mg and the ratio of Mg to other nutrients, especially Ca and Na, but high levels of the latter two are detrimental. Mg induces improved moisture uptake.

C. mopane thus acts as an important buffering element in the maintenance of ecosystem stability in the dry tropics, and is a "key" species. It has a wide ecological amplitude and is not an indicator of soil infertility.

46. HENNING, A.C.; WHITE, R.E. **A study of the growth and distribution of *Colophospermum mopane* (Kirk ex Benth.) Kirk ex J. Léon.: the interaction of nitrogen, phosphorous and soil moisture stress.** *Proceedings of the Grassland Society of Southern Africa* (1974) **9** 53-60 [En, 35 ref.]

Study of the interaction of edaphic and climatic factors in the distribution of *Colophospermum mopane*. The performance of *C. mopane* (DBH x density) at 8 sites in N.W. Zimbabwe (Chete, Hwange) and S. Zimbabwe (Bubi River), N.E. South Africa (Tzaneen) and N. Botswana (Orapa) was found to be highly correlated with total N and extractable P in the surface soil. In a pot trial using three soil types *C. mopane* seedlings responded to increased N and P supply on soils with over 20% water at 0.33 bars matric suction. Soil with only 7% water at 0.33 bars suction showed a significant decrease in yield with increased N and decreasing available moisture. These effects are primarily due to increased soil osmotic suction. Growth of *C. mopane* was unaffected by osmotic suctions less than 3 bars on soils of higher available moisture, but was reduced at suctions above 3 bars on low moisture soil. At higher suctions (6-8 bars) internal osmotic adjustment enables the plant to continue to grow at a reduced rate. These responses to water stress may be an important adaptive mechanism to xeric conditions and a long dry season.

47. HÖGBERG, P.; PIEARCE, G.D. **Mycorrhizas in Zambian trees in relation to host taxonomy, vegetation type and successional patterns.** *Journal of Ecology* (1986) **74** 775-785 [En, 44 ref.]

An account of endo- and ecto-mycorrhizal associations in 13 Zambian trees, determined from fine roots at a soil depth of 10-20 cm. Most species of dystrophic miombo woodland were ecto-mycorrhizal, while *Colophospermum mopane* and species of the Kalahari sand woodlands were endo-mycorrhizal.

48. HUDSON, N.W. **Gully control in mopani soils.** *Rhodesian Agricultural Journal* (1963) **60** (1): 22-31 [also Bulletin 2180 (1970)] [En]

Illustrated account of methods of gully control in mopane soils. Sheet and gully erosion is widespread on these soils and productivity is low. Attempts to establish plant cover to reduce run-off were not very successful; only star grass (*Cynodon dactylon*) showed promise.

49. HUNT, T.E. DE LA **The value of browse shrubs and bushes in the lowveld of the Gwanda area, S. Rhodesia [Zimbabwe].** *Rhodesia Agricultural Journal* (1954) **51** 251-262 [En, 5 ref.]

Account of useful browse species in an arid part of S.W. Zimbabwe. *Colophospermum mopane* is the most common and valuable browse species of the lowveld. It occurs as a tree up to 12 m high on deeper, well-drained soils, and as a thicket-forming shrub on poorly drained soils or after mismanagement. Cattle normally feed on new leaves of *C. mopane* in early spring before grass is widely available, and from June onward during the dry season. Leaves are eaten both off the tree and off the ground. Leaf crude protein levels are quoted at 13.8%; nutritive analyses from South Africa are tabulated.

50. HUSSEIN, I; MATHUR, A.N.; ALI, A. **Effect of gypsum on survival and growth of tree species in saline sodic soil.** *Nitrogen Fixing Tree Reports* (1990) 8 32-33 [En, 3 ref.]

Report on a trial carried out in India on saline sodic soils. Gypsum was added at a rate of 1.25 t ha^{-1}. *Colophospermum mopane* had a slightly lower survival (50%) and a lower height (40 cm) on gypsum-treated soils, but a higher basal diameter (2.52 cm) after one year compared to the control. However, differences were not significant.

51. HUTCHINSON, J. **General Smuts' botanical expedition to Northern Rhodesia [Zambia].** *Kew Bulletin* (1931) 5: 225-254 [En]

Anecdotal account of a botanical expedition from Pretoria through Zimbabwe to Zambia, including many notes on species found. *Colophospermum mopane* was first recorded some km north of Potgietersrust in the N. Transvaal, but was also noted at the base of the Soutpansberg hills. It was found at many localities through Zimbabwe from the Limpopo to Zambezi rivers, and into Zambia.

52. IBPGR ***Colophospermum mopane.*** In *Forage and browse plants for arid and semi-arid Africa.* Kew, London; International Board for Plant Genetic Resources and Royal Botanic Gardens (1984) 43-46 [En, 7 ref.]

Colophospermum mopane is a tree to 25 m high of river basins of southern Africa (Luangwa, Zambezi, Save, Limpopo and Cunene), and has been introduced in India. It occurs in the 200-800 mm yr^{-1} rainfall zone; in areas of lower rainfall it is found on most soil types and in areas of higher rainfall only on shallow soils. It is absent from saline areas. *C. mopane* is a valuable browse species and although scented does not taint milk or meat. Nutritive values of the leaves are from 12.3-16.6% crude protein. The species regenerates well from seed but seedlings are susceptible to competition. Growth is best on deep rich alluvial soils. It has potential for improvement, for either timber/firewood or forage.

53. JAIN, B.L.; MUTHANA, K.D. **Performance of different tree species under saline irrigation at nursery stage.** *Myforest* (1982) **18** (4) 175-180 [En, 9 ref.]

Account of an experiment to determine susceptibility to saline irrigation water of various semi-arid tree species. *Colophospermum mopane* showed 100% survival after 3 months irrigation with water under 9.0 mmhos salinity. Beyond 3 months mortality occurred using water between 6.0 and 9.0 mmhos, indicating relatively poor salinity tolerance.

54. JARMAN, P.J.; THOMAS, P.I. **Observations on the distribution and survival of mopane (*Colophospermum mopane* (Kirk ex Benth.) Kirk ex J. Leonard) seeds.** *Kirkia* (1969) 7 (1) 103-107 [En, 1 ref.]

Investigation into marked differences in the frequency of *Colophospermum mopane* seedlings near the Mwenda estuary (Lake Kariba, Zimbabwe). Sites chosen were a fenced area of mopane woodland (0.75 trees 100 m^{-2}), unprotected mopane woodland (4.4 trees 100 m^{-2}) and *Combretum* thicket woodland (0.75 mopane trees 100 m^{-2}). Seeds and seedlings were counted in quadrats. More non-germinated seeds were found in unprotected mopane woodland than seedlings, roughly equal numbers in the *Combretum* woodland, but twice as many germinated than ungerminated seeds in protected mopane woodland. These differences were put down to large mammals eating seeds and seedlings in the unprotected areas. Evidence of wind dispersal and trapping of seeds by small topographic features was given by the distribution of seeds across a small island.

55. JOUBERT, E. **The physiographic, edaphic and végetative characteristics found in the western Etosha National Park [Namibia].** *Madoqua Series 1* (1971) 4 5-32 [En, 15 ref.]

Account of the vegetation types and soils of part of Etosha National Park (N. Namibia). *Colophospermum mopane* occurs in 5 of the 9 vegetation types: *C. mopane* tree savanna on granitic sand, *C. mopane-Acacia reficiens-*

Terminalia prunioides tree and shrub savanna on sand, *C. mopane-T. prunioides-Combretum apiculatum* tree and shrub savanna on sand, *C. apiculatum-C. mopane* tree and shrub savanna on sand, and *C. mopane-Catophractes alexandri* shrub savanna on calcrete. A description of each type is given, and some of the associated species listed. These 5 types cover most of the study area.

56. KELLY, R.D. **A comparative study of primary productivity under different kinds of land use in south eastern Rhodesia [Zimbabwe].** Unpublished PhD thesis. Harare, Zimbabwe; University of London (1975) 250 pp. [En, 267 ref.]

Study of the effects of 4 different utilization regimes, from no utilization and light utilization by wildlife to heavy utilization by cattle and goats, on mopane woodland on shallow basalt soils in the lowveld of S.E. Zimbabwe. The dominant tree is *Colophospermum mopane*, and *C. mopane* shrubs are also common. The standing crop of *C. mopane* (trees and shrubs combined) ranged from 3725 to 22,707 kg ha^{-1}, with 8459-13,002 kg ha^{-1} under nil utilization and 3701-10,390 kg ha^{-1} under intense utilization. The densities of *C. mopane* plants were 100-450 trees ha^{-1} and 33-1068 shrubs ha^{-1}. Regression equations were: y = -2934.8 + 219.1 (area x dbh) for standing crop of *C. mopane* trees, and y = -2505.4 + 993.1 (height) for production (leaves + twigs). For shrubs under 1.5 m equations were: y = -481.4 + 425.6 (volume) for standing crop, and y = 175.1 + 71.4 (volume) for production.

57. KELLY, R.D.; WALKER, B.H. **The effects of different forms of land use on the ecology of a semi-arid region in south-eastern Rhodesia [Zimbabwe].** *Journal of Ecology* (1976) 64 553-576 [En, 37 ref.]

Study of the effects of 4 different herbivore utilization regimes on mopane woodland on shallow basalt soils in S.E. Zimbabwe [see ref. 56]. Maximum woody canopy cover (75%) occurred at a density of 2000 individuals ha^{-1}; at higher densities canopy size was limited by competition. Data presented are as in ref. 56.

58. KNAPP, R. **[Influence of litter of some African grasses and xerophytic trees upon germination].** *Ber. Deutsch Bot. Ges.* (1966) **79** (7) 329-335 [Ger, 10 ref.]

Laboratory experiments on the effect of litter on germination of various tropical grasses and herbs. Litter of *Colophospermum mopane*, particularly when still green, decreased germination of two grass species at 16^0C. Germination was reduced further at 32^0C.

59. KUMAR, S.; SHANKARNARAYAN, K.A. **Aerial seeding on sand dunes: seedling survival and growth.** *Journal of Tropical Forestry* (1988) 4 (2) 124-134 [En, 8 ref.]

Account of trials with aerial seeding of 2 herbaceous and 4 woody (including *Colophospermum mopane*) species on shifting sand dunes at two sites in an arid part of N.W. India. *C. mopane* had poor establishment and disappeared after 2 years.

60. LAWTON, R.M. **The value of browse in the dry tropics.** *East African Agricultural and Forestry Journal* (1968) 33 227-230 [En, 6 ref.]

Brief account of use of browse. In dry woodland areas of Zambia *Colophospermum mopane* is a valuable source of browse for cattle and game, especially elephant. It has a high essential fatty acid content which, with the high crude protein, may be responsible for the excellent condition of cattle browsing it. Nutritive values reported are 13.1% crude protein, 0.52% Ca and 0.27% P.

61. LAWTON, R.M. **Browse in miombo woodland.** In *Browse in Africa, the current state of knowledge [edited by Le Houérou, H.N.]*. Ethiopia, ILCA (1980) 25-31 [En, 34 ref.]

Review of browse availability and values in miombo woodland. *Colophospermum mopane* is a good browse species, often pollarded by elephants at a height of 1-2 m. Elephant eat old leaves in July and the new flush in November-December. Nutritive analyses show a crude protein content of 13.1-15.4%).

62. LÉONARD, J. ***Colophospermum.*** In Notulae Systematicae IV (Caesalpiniaceae-Amherstieae africanae americanaeque). *Bulletin du Jardin Botanique de L'état (Bruxelles)* (1949) 19 388-391 [Fr]

First account of the genus *Colophospermum*, of which *C. mopane* is the only species, separating it from the genera *Copaifera* and *Guibourtia*. *Colophospermum* differs in having a vestigial third leaflet, no bracteoles, 20-25 equal-length stamens, and a single ovule.

63. LEWIS, D.M. **Disturbance effects on elephant feeding: evidence for compression in Luangwa Valley, Zambia.** *African Journal of Ecology* (1986) **24** (4) 227-241 [En, 22 ref.]

Account of a series of experiments to determine the effects of disturbance on elephant feeding patterns in mopane woodland around the S. Luangwa National Park (E. Zambia). Stem production of *Colophospermum mopane* trees was reduced by up to 100% by elephant browsing in some places due to disturbance effects. Coppiced trees typically showed more damage. *C. mopane* had a relatively low selectivity rating compared to other species.

64. LEWIS, D.M. **Elephant response to early burning in mopane woodland, Zambia.** *South African Journal of Wildlife Research* (1987) **17** (2) 33-40 [En, 21 ref.]

Report on an experiment in the Luangwa valley (E. Zambia) to determine if elephant range is influenced by dry season availability of grass. Early dry season burning of grass in mopane woodland reduced elephant utilization and tree damage, suggesting that elephant were principally interested in grass roots, not browse, during the dry season. Burning may be a useful tool in controlling elephant distribution.

65. LEWIS, D.M. **Observations on tree growth, woodland structure and elephant damage on *Colophospermum mopane* in Luangwa Valley, Zambia.** *African Journal of Ecology* (1991) **29** 207-221 [En, 20 ref.]

Monitoring tagged coppice shrubs of *Colophospermum mopane* browsed by elephants over 5 years in 6 areas of the Luangwa Valley showed that physiognomic variation among the locations was related to soil differences, and was also correlated with different elephant browsing habits. The impact of elephant further influenced both the physiognomy and demography of *C. mopane*. Soils that promote coppicing in *C. mopane*, those with high soil nutrients in the A-horizon and a relatively impenetrable B-horizon, yield less stable woodlands when associated with elephants than soils promoting woodlands with large non-coppicing trees. The dynamics of the latter are determined more by tree recruitment and survivorship of younger age classes. The influence of soils and elephant appears to alter successional transitions from grassland to woodland.

66. LUDEMAN, F. **Drought feed from veld trees and inferior roughage.** *Farming in South Africa* (1966) **42** (6) 59-61 [En]

Account of drought feeds in drier parts of South Africa. Dry twigs and leaves of *Colophospermum mopane* were fed after hammer-milling to a small group of cattle, but a 25% supplement of hay or molasses was found to be necessary for survival, mostly in order to increase feed intake.

67. MADAMS, R.W. **The biogeography of *Colophospermum mopane* (Kirk ex Benth.) Kirk ex J. Léonard at its distribution limit in eastern Botswana.** Unpublished PhD thesis. London, UK; University of London (1990) 252 pp. [En, 91 ref.]

Study of the distribution limits of *Colophospermum mopane* in E. Botswana from the perspectives of suprapopulation, population and the individual, with particular reference to the Palapye area. Different physiognomic forms appear to be related to soil type and parent material, with the taller forms in areas of deeper soils and higher rainfall. At a suprapopulation level much of the distribution of *C. mopane* at its limits in E. Botswana can be correlated with edaphic or topographic factors, but these do not fully explain the situation. There was no correlation between its distribution and edaphic factors at the population level. Distribution becomes clumped towards the distributional limits, but this is still relatively abrupt. At the limit there is a well-balanced population structure, performance of individuals seems undiminished and there is adequate regeneration. Interspecific competition was not considered to be a factor in boundary determination and it was concluded that the species is still extending its range.

68. MALAWI GOVERNMENT **The National Atlas of Malawi.** Lilongwe, Malawi; Department of Surveys (1983) 79 pp. [En]

Compendium atlas covering the geography, human and natural, of Malawi. Of the 19 vegetation types shown for the country, only one is dominated by *Colophospermum mopane* and one other has scattered *C. mopane*. Mopane woodland is found at the south end of Lake Malawi and in patches along the Shire valley.

69. MAPAURE, I. **The distribution of mopane.** *Kirkia* (1994) **15** (1) 1-5 [En, 13 ref. + 1 map]

Account of the distribution of *Colophospermum mopane* in southern Africa, compiled from existing national-level vegetation maps. Total area under *C. mopane* vegetation types is calculated as 550,000 km^2. A brief account on environmental factors thought to influence its distribution is given for each country. The species principally occurs at low altitudes (400-700 m) in low rainfall areas (200-800 mm yr^{-1}), often on heavy calcareous, sometimes sodic, soils.

70. MARTIN, R.B. **Structure, biomass and utilization of vegetation in the mopane and miombo woodlands of the Sengwa Wildlife Research Area [Zimbabwe].** Unpublished thesis for Certificate in Field Ecology. Harare, Zimbabwe; University of Rhodesia [Zimbabwe] (1974) 154 pp. [En, 27 ref.]

Study and comparison of vegetation biomass in mopane and miombo woodlands at Sengwa, central Zimbabwe, with particular reference to wildlife utilization. The structure of the biomass was assessed in terms of vertical and horizontal weight distribution, species composition and numbers of discrete individuals. The standing crop in mopane woodland was 68,100 kg ha^{-1}, three times the biomass of miombo woodland, of which 95.8% was wood, 3.7% browse and 0.5% graze. 90% of mopane woodland biomass comprised *Colophospermum mopane* trees and shrubs, which were dominant at all levels. Species diversity in mopane woodland was also much lower than in the miombo. Only 1% of total browse was available as most was above 2.5 m height, and the pushing over of *C. mopane* trees by elephant was shown to increase the utilization efficiency by herbivores by making more browse available and increasing the proportion of leaf to wood. The mopane woodland was "top heavy" with mature trees, which could be due to high elephant damage, synchronised germination or suppressed sapling growth.

71. MILLER, O.B. ***Colophospermum mopane* (Kirk) J. Leonard.** In *The woody plants of the Bechuanaland Protectorate [Botswana]*. Journal of South African Botany (1952) **18** 30 [En, 26 ref.]

List of woody plants from Botswana. *Colophospermum mopane* (mophane), previously *Copaifera mopane* Kirk, is a tree to 9 m. The wood is hard, heavy and durable, and makes good mining props and charcoal. The southern limit in Botswana is 26 km north of Mahalapye. Large areas have been reduced to coppice by fire and frosts.

72. MITCHELL, A.J.B. **The irrigation potential of soils along the main rivers of Eastern Botswana: A reconnaissance assessment.** *Land Resource Study No.7*. London, UK; Land Resources Division, Ministry of Overseas Development (1976) 220 pp. [En, 97 ref. + maps]

Report on the potential for irrigated farming along most of the larger rivers of eastern Botswana from Gaborone to Francistown. About half of the studied area contains mopane vegetation. There is some correlation between climate and distribution of *Colophospermum mopane*; where rainfall exceeds 500 mm it occurs mainly on lower slopes with sodic soils and sandy soils over impermeable clay, but south of this it occurs as woodland with species such as *Kirkia*, *Commiphora* spp., *Acacia nigrescens*, *Sclerocarya birrea* on upland and colluvial soils with impeded drainage. It is usually dominant on poorly drained sites while other species dominate on well drained sites. On valley sides *C. mopane* tree savanna mixed with *Acacia* spp., *Terminalia prunioides*, *Combretum* spp. and *Boscia* spp. can be found. Low *C. mopane* coppice, the clumps having a number of stems of similar height, always indicates adverse soil conditions (sodic soils, vertisols), but tall coppice (over 4.5 m high) indicates impeded drainage. The species does not occur south of the Mokoro hills, but is dominant to the north.

73. MUSHOVE, P.T. **Productivity from mopane stumps and seed.** *ForMat* (1992) 4 (1) 4 [En]

Preliminary account of research on germination and coppicing of *Colophospermum mopane* in Zimbabwe. Survival of germinants (40 days) using standard nursery practices ranged from 79% (Zambezi valley provenance) to 85% (Chiredzi provenance). Three months after cutting, between 20% and 80% of stumps (depending on treatment) were coppicing in a stand of *C. mopane* in Chivi (south central Zimbabwe).

74. MUSHOVE, P.T. **Shoot/root growth relations as determinants of nursery rotation in *Colophospermum mopane* seedlings raised in containers.** In *The Ecology and Management of Indigenous Forests in Southern Africa*, Harare, Zimbabwe; Forestry Commission (1993) 221-225 [En, 6 ref.]

Trial on early growth of *Colophospermum mopane* seedlings under greenhouse conditions. Lengths and weights of shoots and roots from 2 provenances were measured over 60 days. Mean rate of root elongation was 8.7-10.0 mm day^{-1} and shoot elongation 2.3-3.2 mm day^{-1}. Shoot/root weight ratios were inversely proportional to seedling age. As root growth is rapid there is a danger of seedlings becoming root-bound in pots, and planting out is recommended at 2 months.

75. MUSHOVE, P.T.; MAKONI, J.T. **Coppicing ability of *Colophospermum mopane*.** In *The Ecology and Management of Indigenous Forests in Southern Africa*, Harare, Zimbabwe; Forestry Commission (1993) 226-230 [En, 19 ref.]

Study of coppicing of *Colophospermum mopane* in Chivi, S. Zimbabwe. Coppicing started 4 months after felling in July (dry season), but almost immediately when felling was in January (wet season). In both cases tall stumps (1 m) produced more coppices than short stumps (10 cm), and had taller coppice heights. Stump diameter only had a significant effect on coppice growth 3 months after first coppices appeared. The interaction of stump height and size had no effect on number of coppices produced or coppice height growth. Sprouting appeared to occur at a slower rate in larger diameter stumps.

76. MUTHANA, K.D. **Use of saline water for raising tree seedlings.** *Indian Farming* (1984) 34 (2) 37-38, 40 [En]

Research note on the effects of saline water on germination and early growth of 7 tree species, including *Colophospermum mopane*, in arid India. Water for germination was of 0.6 mmhos salinity, and water used for irrigation after 2 months ranged in salinity from 0.6-9.0 mmhos. There was no effect on survival of *C. mopane* up to 5 months, but prolonged irrigation at 6.0 mmhos beyond 6 months gave higher mortality. Increase in height and increase in collar diameter was slightly reduced by increasing salinity. *C. mopane* showed higher rates of survival, growth and collar diameter at salinity levels up to 2.7 mmhos, indicating moderate tolerance of salinity.

77. MYRE, M.; COUTINHO, L.P. **Pastos arbóreos e arbustivos, o "chanate" [Tree and shrub forages, "mopane"].** Separate from *Anais dos Serviços de Veterinária* (1962) 10 1-11 [Port, 19 ref.]

Account of the taxonomy, botany, distribution, ecology and browse value of *Colophospermum mopane* (chanate) within Mozambique. It is an important species in the Tete (upper Zambezi valley) and upper Limpopo valley areas, principally in areas of below 400 mm yr^{-1} rainfall. The fallen leaves, which smell of turpentine, are an important feed resource for cattle. Nutritive analyses of pods and leaves are given, showing crude protein values of 10.2-15.9%.

78. NATIONAL ACADEMY OF SCIENCES ***Colophospermum mopane.*** In *Firewood Crops - shrub and tree species for energy production*. Washington, USA; National Academy of Sciences (1980) 122-123 [En]

Descriptive account of various lesser-known woody species from humid, highland and semi-arid tropical zones suitable for firewood production. *Colophospermum mopane*, which grows in areas of poor soil quality in south central Africa, is sometimes acclaimed as the best firewood in Africa. It grows best below 900 m altitude under rainfall from 200-800 mm yr^{-1}. Although the species is generally found on shallow, compacted alkaline clays, it grows best on rich, deep, alluvial soils. In 1965 *C. mopane* was introduced to the Rajasthan area of India where it has regenerated from self-sown seed. Growth rate there was slow, reaching c. 5 m in 10 years. The heavy and hard wood (specific gravity > 1.0) burns slowly, quietly and with great heat. The tree also has uses as construction wood, ornaments and as fodder, the leaves retaining a high food value even after falling. Trees coppice vigorously after fire, frost or felling and also reproduce well from seed. The mopane worm often defoliates individual trees, but is a protein-rich delicacy for local people. *C. mopane* is difficult to fell because of the hardness of the wood, and becomes even harder to cut after drying. There is little information on propagation, protection and yield.

79. NYAMAPFENE, K.W. **A note on some Zimbabwean soil-vegetation relationships of important indicator value in soil survey.** *Kirkia* (1988) **13**(1) 239-242 [En, 10 ref.]

Description of soil relationships of 8 woody species in Zimbabwe. *Colophospermum mopane* is common on moderately deep to deep soils of good agricultural potential in lower rainfall areas, but occurs on sodic soils in higher rainfall areas. It is confined to sites of low moisture availability. Stunting of trees on vertisols is due to root pruning.

80. NYASALAND [MALAWI] GOVERNMENT **Annual Report of the Forestry Department for the year 1942.** Government Printer, Zomba (1943) 15 pp. [En]

Report on forestry activities in Malawi including an account of fuelwood cutting in *Colophospermum mopane* woodland in Utale, south central Malawi. Regeneration since 1938/39 was found to be poor due to an invasion of tall grass and subsequent fires. In areas with only 50% felling coppice regeneration was much better owing to less grass. *C. mopane* is reported to produce good charcoal, generating great heat with little air required for combustion.

81. OATES, L.G. **Food preferences of giraffe in Transvaal lowveld mopane woodland.** *Journal of the South African Wildlife Management Association* (1972) **2** 21-23 [En, 14 ref.]

The trees and shrubs browsed by giraffe in a nature reserve in N.E. Transvaal (South Africa) were recorded by direct observation, and a preference rating determined based on frequency of occurrence. *Colophospermum mopane*, the most abundant tree in the area (frequency 37.6%), was generally avoided (7.5% of browsing records), except in the late winter when browse from other species is not so available.

82. OBERMEIJER, A.A. **Notes on the distribution of *Copaifera mopane* Kirk [*Colophospermum mopane*].** *South African Journal Science* (1933) **30** 266-269 [En, 7 ref.]

Copaifera mopane [*Colophospermum mopane*] is a gregarious, resiniferous, deciduous tree extending from 80-160 km from the E. African coast to the western coast, between 15 and 24ºS latitude. It is found in low, warm and dry country in Mozambique, northern Transvaal, Zimbabwe, southern Malawi, southern Zambia, northern Botswana, northern Namibia and southern Angola, ranging in altitude from sea-level to 1500 m. Generally, the lower the rainfall the higher the elevation to which *C. mopane* extends, and frost appears to limit its southern distribution. If soils are waterlogged in the rainy season or if frost is present, the shrub form predominates. On alluvium *C. mopane* forms more of a forest with little herbaceous ground cover. In the Transvaal it is only in the northern part of the Kruger Park that *C. mopane* forms a woodland, compared to shrubland, with some trees attaining 20 m.

83. PALGRAVE, O.C. ***Colophospermum mopane* (Kirk ex Benth.) Kirk ex J. Léonard.** in *Trees of Central Africa*. Harare, Zimbabwe; National Publications Trust, Rhodesia and Nyasaland (1956) 101-106 [En]

Descriptive illustrated accounts of 110 trees of Malawi, Zambia and Zimbabwe. *Colophospermum mopane* (mopane, balsam tree, turpentine tree, Rhodesian ironwood, musharo, shanatse, musara, ipane, ilipani, mupane, mwane, chanya, lupanye, tsanya) is a tree usually 14 m high (up to 21 m in Malawi) with a diameter of up to 90 cm. Flowers irregularly appear from December to March, and fruits from March to June. It is a tree of lower areas and tolerates poorly drained soils. Mopane woodland in Zimbabwe is sometimes associated with a low, dense "jesse" bush. The wood is used for construction, mine props, railway sleepers, disselbooms, fence posts, cabinet making, parquet floors and handicrafts. Wood ash contains up to 55% lime. Medicinal uses include for sore eyes and as a cure for madness. 20% heavy balsam can be obtained from the seed.

84. PALGRAVE, K.C. ***Colophospermum mopane***. In *Trees of Southern Africa*. Cape Town, South Africa; Struik (1983, Third Edition) 268-269 ISBN 0-86977-081-0 [En]

Descriptive illustrated account of the woody plants of Africa south of the Zambezi. *Colophospermum mopane* is a medium to large tree 4-18 m high, dominant over hot low-lying areas of tropical Africa, often on alluvial soils, although it tolerates alkaline and poorly drained soils. Flowers appear from October to March and the flattened indehiscent pod from March to June. The species reaches its southernmost limit just south of the Oliphants river in the Kruger National Park. Under unfavourable conditions the trees remain stunted as mopane scrub. The leaves are an important source of fodder for livestock and wildlife. Seeds germinate easily provided they are planted while in the pod, but seedlings are slow growing and susceptible to damping off. Mopane wood is durable and heavy, and has been used for mine props and railway sleepers; it makes a good firewood, burning with an intense heat and a sweet smell.

85. PALMER, E.; PITMAN, N. ***Colophospermum mopane***. In *Trees of Southern Africa*, Vol. 2. Cape Town, South Africa; A.A. Balkema (1972) 842-845 ISBN 0-86961-033-3 [En]

Descriptive illustrated account of the trees of southern Africa. *Colophospermum mopane* (mopane, butterfly tree, turpentine tree, Rhodesian ironwood, Rhodesian mahogany, nxanatsi, mophane, mupani, mutanari, omutati, omufiadi) is a dominant tree of large parts of N. South Africa and N. Namibia from 300-600 m altitude, often in pure stands. In South Africa it occurs north of the Soutspansberg and in E. Transvaal north of the Letaba river. Leaves and fruits are important browse for elephants. The wood is heavy (1218 kg m^{-3} air dry) but generally of poor form, containing large knots and often spoilt by heart rot. It burns even when green.

86. PARDY, A.A. ***Colophospermum mopane* Kirk ex J. Leonard (Caesalpiniaceae).** Notes on indigenous trees and shrubs of Southern Rhodesia [Zimbabwe]. *Rhodesia Agricultural Journal* (1953) **50** (2) 152-154 [En]

Colophospermum mopane (mopani, mupane, musaru, musharo, lipane) is a tree commonly only 9 m high, but up to 15 m, dominant over extensive areas of lowveld in Zimbabwe. Pods are adapted to wind or water dispersal, or on the hooves of mammals. The wood is too hard and heavy for general use, but is suitable for railway sleepers and parquet flooring, and also makes a good firewood.

87. PIEARCE, G.D. **Tree diseases and disorders in the Zambezi teak forests.** In *The Zambezi Teak Forests* [edited by Piearce, G.D.]. Ndola, Zambia; Zambia Forest Department (1986) 239-256 [En, 18 ref.]

Account of tree diseases of six major species in the Zambezi teak forests. Seedlings of *Colophospermum mopane* are prone to damping-off and three leaf-spot fungi have been recorded. Heart-rot due to *Phellinus rimosus* is common and often makes logs unexploitable. Two polypores have been noted, *Ganoderma lucidum* and *Hexagonia speciosa*, but are not common. Elephant damage is noted to be one of the most serious problems.

88. PORTER, R.N. **The distribution and ecology of *Colophospermum mopane*.** Unpublished BSc dissertation. Pretoria, South Africa; University of Pretoria (1968) [En]

[Not seen]

89. PRIOR, J.A.B. **The improved productivity of African fuelwoods by the use of trees with stress-induced adaptations.** Final Report of Southern Africa Wood Studies Project (EEC TS20211). London, U.K.; Imperial College (1991) 81 pp. [En, 15 ref.]

Report on a multi-disciplinary project on the eco-physiology of four Zimbabwe tree species, including *Colophospermum mopane*. Measurements were made in four different parts of Zimbabwe on photosynthetic and transpiration rates at different times of day and under different light intensities, total chlorophyll, sap content, growth increments in wood, and seed germination. Additional experiments were done on germination in response to drought, heat and moisture stress.

Naturally occurring populations of *C. mopane*, a secondary coloniser, show a wide range of adaptations enabling the trees to withstand moisture stress and stress from high temperatures. Both *C. mopane* and *Combretum apiculatum* were found to be more drought tolerant than *Acacia* spp. Photosynthetic rates were lower in *C. mopane* during the heat of the day, and it is capable of greater levels of water use efficiency than the other species, particularly in the more arid areas. Other stress adaptations include a reduction in the number of stomata on exposed leaf surfaces and increased amounts of stress compounds (especially pinitol) in the leaves. The diameter of growth rings did not appear to be related to rainfall, and was less than in adjacent *C. apiculatum*. Wood production in *C. mopane* was greatest (c. 3700 kg ha^{-1}) at Matopos, and growth increment (c. 1 mm yr^{-1}) greatest at Chiredzi. The low biomass at Kadoma is thought to be due to lower temperatures. There also appears to be a positive relationship between available soil ammonium N and biomass production. Heartwood was attacked by termites and wood rotting fungi. Decreasing rainfall resulted in increased calcium oxalate in the wood, retarding the speed of combustion. Results of experimental work indicate that some of these ecotypic adaptations are genetically inheritable.

90. RATTRAY, J.M. **Vegetation types of Southern Rhodesia [Zimbabwe].** *Kirkia* (1962) 2 68-93 [En, 7 ref.]

Physiognomic and floristic classification of the vegetation of Zimbabwe. 14 physiognomic types are described, which can be subdivided into 52 floristic types, 4 with *Colophospermum mopane* dominant (mopane woodland, mopane tree savanna, mopane tree/bush savanna, and mopane scrub savanna) and 8 with *C. mopane* as a constituent. Mopane tree savanna is found especially below 500 mm yr^{-1} rainfall in the south of the country on a range of soil types. Where soils are poorly drained, and on shallow basalt soils, trees are stunted. At higher altitudes shrub mopane is found on sodic soils. Grass cover is often good where open canopy *C. mopane* is well developed. Associated tree species are similar across the range of *C. mopane*.

91. REPUBLIC OF ZAMBIA (compiled A.C.R. Edmonds) **Vegetation map 1:500,000.** Lusaka, Zambia; Survey Department (1976) [En, 9 maps]

Vegetation maps of Zambia with descriptions of 17 types. *Colophospermum mopane* is dominant in one woodland type, and also present on a sub-type of termitaria thicket. Mopane woodland is principally found in the Luangwa valley, but also along parts of the Zambezi valley and its lower tributaries. *C. mopane* is also found scattered through miombo woodland to the north.

92. ROSS, J.H. ***Colophospermum.*** *Flora of Southern Africa* (1977) **16** (2) 16-19 [En]

Taxonomic account of the species of *Leguminosae*, subfamily *Caesalpinioideae* in South Africa, Lesotho, Swaziland and Namibia. *Colophospermum* is a monotypic genus occurring in Angola, Namibia, Botswana, Zambia, Malawi, Zimbabwe, South Africa (N. Transvaal) and Mozambique. The name is derived from the Greek meaning "resinous seed". A small to medium-sized tree 5-12 m high with an erect narrow crown, occasionally up to 22 m under favourable conditions; often a shrub. Gregarious and often dominant, forming almost pure stands in hot dry low rainfall areas on various soil types. Plants have the ability to coppice vigorously and sometimes form thickets. The turpentine-smelling leaves fold together during the heat of the day to reduce water loss. The wood is resinous and burns well, with much smoke, and the tree is said to be susceptible to fire, burning even when green. The sticky seeds are dispersed by adhering to hooves of animals. Mopane worms (*Gonimbrasia belina*) feed on the leaves and are a nourishing local delicacy. The palatability of the leaves is said to be increased by secretions of an insect larva (*Arytaina mopane*) which adhere to the leaves. Flowers are said to be anemophilous.

93. ROUX, A.LE; SMIT, G.N.; SWART, J.S. **Root biomass of a dense stand of *Colophospermum mopane*.** *Bulletin Grassland Society of Southern Africa* (1994) 5 (1) 50 [abstract] [En]

Study of distribution of root biomass in a dense stand of *Colophospermum mopane* near the Soutspansberg, N. Transvaal (South Africa) using 1 m^3 soil monoliths to 1 m depth. Stand density was 2436 plants ha^{-1} with a mean height of 2.7 m. Leaf dry mass was estimated using a regression equation at 1445 kg ha^{-1}, and total root biomass was 29,790 kg ha^{-1}. Fine roots (0-1 mm) were concentrated in the top 20 cm of soil (2980 kg ha^{-1}) with a linear decline with increasing depth. Coarse roots (>10 cm) showed increased concentration with soil depth up to 40-60 cm, after which they declined.

94. SCHIJFF, H.P.VAN DER **The affinities of the flora of the Kruger National Park [South Africa].** *Kirkia* (1969) 7 (1) 109-120 [En, 16 ref.]

Account of new plant records, floral affinities and some ecological notes for the Kruger National Park (N.E. South Africa). The vegetation is shown to have affinities to tropical Africa. The southern limit of *Colophospermum mopane* is said to be the Orpen-Satara road 64 km south of the Oliphants river, and frost probably limits its southern distribution. Throughout the park *C. mopane* occurs mainly on soils from basic igneous rock and on heavier soils from granite, and is absent from deep loose sands. It is not found on waterlogged soils. On deep alluvial-colluvial soils and alluvium along frost-free rivers mopane is a tall tree. Mopane soils have a high montmorillonite clay content, thought to be an important requirement, and also have higher Mg and Ca contents.

95. SCHOLES, R.J. **The regrowth of *Colophospermum mopane* following clearing.** *Journal Grassland Society of Southern Africa* (1990) 7 (3) 147-151 [En, 14 ref.]

The recovery of cleared *Colophospermum mopane* thicket in the E. Transvaal (South Africa) was measured and a model developed to help determine how long the beneficial effect on herbaceous production might last. The monitored plots recovered to pre-clearing basal area in 14 years (mean increment 0.4 m^2 ha^{-1} yr^{-1}). Annual stem increment was found to be directly related to rainfall during the growing season, and the increase in plant density for the first few years represented a delay-period as the below-ground organs recover. Leaf mass in *C. mopane* is linearly related to stem basal area, and leaf area is a linear function of leaf mass (specific leaf area 8.1 m^2 kg^{-1}).

96. SHANKARNARAYAN, K.A.; KUMAR, S. **Aerial seeding of sand dunes: 1 trends in seed germination and seedling distribution.** *Journal of Tropical Forestry* (1986) 2 (1) 3-20 [En, 10 ref.]

Report of a trial to establish trees (including *Colophospermum mopane*) and shrubs on two sites on shifting sand dunes in arid W. Rajasthan (N. India). Seedling density of *C. mopane* was relatively low compared to some other species. Establishment was better when seeds were sown during the monsoon, and also on windward slopes.

97. SHARMA, B.D.; TEWARI, J.C.; GUPTA, I.C.; HARSH, L.N. **Colophospermum mopane, an exotic tree for the arid zone.** *Indian Farming* (1989) 39 (6) 5-6 [En]

Brief account of results and potentials of *Colophospermum mopane* in the arid zones of India. It is said to grow fast, tolerate alkalinity and improves soil fertility. In the first 6 years it puts on 50 cm yr^{-1} in height, but only 8 cm yr^{-1} in drought years. Green fodder production at 8 years was 3.3 kg $tree^{-1}$ (50% of canopy) and 6.7 kg $tree^{-1}$ (75% of canopy), neither level had a negative effect on subsequent growth. *C. mopane* is also said to improve the stability and fertility of sand dunes, particularly by increasing organic carbon, available N and P_2O_5.

98. SMIT, G.N.; SWART, J.S. **Successional trends in the establishment of herbaceous plants following different intensities of bush clearing in mopane veld.** *Bulletin Grassland*

Society of Southern Africa (1993) 4 (1) 20 [abstract] [En]

Account of effects on grass cover due to various degrees of clearance of trees of *Colophospermum mopane* in the N. Transvaal, South Africa. Little grass cover was found in the original densely wooded area, possibly due to extensive soil surface capping. There were six treatment plots, ranging from 0 to 75% of original leaf biomass. Drastic colonisation of bare soil by grass (initially mostly *Tragus berteronianus*) resulted from clearing, and the frequency of bare patches was significantly correlated with the remaining leaf biomass of *C. mopane*, but decreased over a 3-year period. Perennial grasses increased in years 2 and 3.

99. SMIT, G.N.; SWART, J.S.; ROUX, A.LE **Root biomass, spatial distribution and relations with aboveground leaf biomass of *Colophospermum mopane*.** *Bulletin Grassland Society of Southern Africa* (1994) 5 (1) 32 [abstract] [En]

Differences in root size with depth were investigated for shrub *Colophospermum mopane* near the Soutspansberg, N. Transvaal (South Africa) using 1 m^3 cores to 1 m depth. Leaf dry mass for each tree was estimated from the canopy volume using a regression equation. Mean tree height was 1.91 m and mean canopy diameter 1.71 m. Mean total root biomass was 17,354 kg ha^{-1}. Of this 19% was in the 0-1 mm class, and 20%, 16% and 44% in the >1-5, >5-10 and >10 mm classes respectively. A mean of 66% of fine roots <5 mm) was found in the top 40 cm of soil; coarse roots (>5 mm) were sparse or absent in the top 20 cm, the concentration being highest between 20-60 cm. Mean total leaf biomass was 1082 kg ha^{-1}, significantly lower than root biomass. It was estimated that tree roots extended horizontally to a distance of 7.6 times their height and 12.5 times their canopy width.

100. SMITH, V.R. **A pot culture investigation into the effect of *Colophospermum mopane* growth on the chemical properties of four selected soils.** Unpublished BSc dissertation. Johannesburg, South Africa; University of the Witwatersrand (1972) 45 pp. [En, 43 ref.]

Colophospermum mopane seeds from Orapa, N. Botswana, were raised in pots of mopane soils collected from Bubi River (S. Zimbabwe), Hwange National Park (W. Zimbabwe) and Tzaneen (N.E. Transvaal, South Africa). The effects of presence or absence of seedling growth, watering, and additional nitrogen (NH_4NO_3) on cation exchange capacity (CEC), total exchangeable bases (TEB), percent base saturation (%BS) and organic matter (OM) was measured over a 96 day period. The four soils differed markedly in their chemical responses to *C. mopane* seedling growth. The addition of NH_4NO_3 caused the soil pH to decrease markedly, but in the presence of seedling growth did not cause a reduction in CEC due to uptake of NH_4 ions. *C. mopane* is thus thought to be able to take up nitrogen in the form of ammonium or nitrate ions. Seedling growth also caused reduction in soil pH due to selective uptake of cations, and this was generally accompanied by a decrease in TEB. No changes in CEC due to changes in OM from seedling growth were noted, although a longer experimental period is necessary to confirm this. Seedling growth consistently caused large decreases in exchangeable soil K, depending on original levels of K in the soils, and this is thought to be an indication of tolerance of low exchangeable K. It is suggested that *C. mopane* has a wide edaphic tolerance, which is one reason for its large ecological amplitude.

101. STEYNBERG, J.P.; BURGER, J.F.W.; MALAN, J.C.S.; CRONJE, A.; YOUNG, D.A.; FERREIRA, D. **Natural (-) fisetinidol (4,8) (-) epicatechin profisetinidins.** *Phytochemistry* (1990) 29 (1) 275-277 [En, 16 ref.]

Account of the occurrence of profisetinidins (condensed tannin prototypes) in the heartwood of 3 Caesalpinoid timbers. Only the (4α,8)-isomer 1 of fisetinidol-( )-epicatechins 1 and 3 was found in *Colophospermum mopane*.

102. STEYNBERG, J.P.; BURGER, J.F.W.; CRONJÉ, A.; BONNET, S.L.; MALAN, J.C.S.; YOUNG, D.A.; FERREIRA, D. **Structure and synthesis of phlobatannins related to fisetinidol epicatechin profisetinidins.** *Phytochemistry* (1990) 29 (9) 2979-2989 [En, 23

ref.]

Study of some natural 'phlobaphene' condensed tannins from the heartwood of various Caesalpiniodeae, including *Colophospermum mopane*. These compounds, and others present, are described.

103. TEAGUE, W.R. **Bush control - a review.** Unpublished report. Bulawayo, Zimbabwe; Matopos Research Station, Department of Research and Specialist Services (1973) 125 pp. [En, 82 ref.]

Review of results from bush control trials in Zimbabwe. On Nyamandhlovu sandveld (W. Zimbabwe) grass production from *Colophospermum mopane* woodland after clearing increased on average 3.3 times to 987 kg DM ha^{-1}. At Tuli (S. Zimbabwe), where *C. mopane* is preferentially browsed by goats, 50% mortality occurred 3 years after ringbarking. Kills of 60-80% were found at Matopos (S. Zimbabwe) with basal bark treatment of various combinations of 2,4-D and 2,4,5-T in diesel, but zero kill with Tordon in water. Aqueous 2,4,5-T at Tuli gave 60-80% kill on application to cut stumps, but 100% kill when in diesel. Basal spray of *C. mopane* scrub with 2,4,5-T in diesel at Matopos gave 100% kill, as did foliar application of Tordon 101 in water. Soil application of Bromacil gave higher kills (50-92%) when applied in March compared to earlier in the season, but Atrazine powder gave practically zero mortality.

104. TEWARI, J.C.; HARSH, L.N.; PATWAL, D.S. **Wind stability status of certain promising tree species introduced in arid region.** *Journal of Tree Science* (1989) 8 (1) 18-21 [En, 9 ref.]

Assessment of 14 indigenous and exotic tree species for their wind stability in Rajasthan, an arid region of India. *Colophospermum mopane* had a relatively low wind stability compared to *Prosopis juliflora*, but was higher than *Acacia senegal*. Mean annual increment for *C. mopane* over 23 years was 0.49 cm dbh, or 4.29 cm^2 $tree^{-1}$ basal area.

105. THOMPSON, J.G. **A description of the growth habits of mopani in relation to soil and climatic conditions.** In *Proceedings of the First Federal Science Congress, Salisbury, Southern Rhodesia [Zimbabwe]* (1960) 181-186 [En, 2 ref.]

Discussion of the conditions required by *Colophospermum mopane* for initial establishment, early survival and growth to maturity. *C. mopane* is shallow rooted and can compete most effectively with deeper-rooted trees under soil conditions where moisture is mostly retained nearer the soil surface. In a trial *C. mopane* could not establish on soil with a good grass cover. Factors such as low and erratic rainfall, sandy surface soils, massed shallow mopane roots and shallow sandy soils over impervious sodic sub-soils, which suppress grass growth, tend to favour its establishment. It does not particularly favour alkaline conditions, but can tolerate such these conditions better than other species. Mopane will grow well under climatically moister conditions where soil conditions create a drier regime than normal in the root zone. Above 500-600 m altitude it can be considered an indicator of adverse soil conditions.

106. THOMPSON, J.G. **The soils of Rhodesia [Zimbabwe] and their classification.** *Technical Bulletin No. 6, Rhodesia Agriculture Journal* (1965) 64 pp. [En]

Descriptive account of the soils of Zimbabwe. The type of soil on which *Colophospermum mopane* is found depends primarily on the prevailing climate. It is a xeric species widespread on almost all soils in hot areas with rainfall less than 450 mm yr^{-1}. On deeper permeable siallitic soils it can occur in a pure evenly-spaced and well-grown woodland with few young saplings. On sodic soils its character is different with trees smaller, gnarled and closer-spaced, sometimes forming thickets. As rainfall increases edaphic factors become more important and *C. mopane* is confined to physiologically drier sites (shallow sloping soils, or those with shallow dense impermeable horizons). Under rainfall of 510-610 mm yr^{-1}, such as on the central plateau, it only occurs on sodic soils where most rainfall runs off.

107. TIETEMA, T. **The possibility of management of the mopane woodland.** In *Report of Workshop on Management and Development of Indigenous Forests in the SADCC Region.* Lilongwe, Malawi; SADCC Forestry Sector

(1989) 263-282 [En]

A study of the actual and potential productivity from *Colophospermum mopane* woodland at Dukwe (N. Botswana), comparing harvested and non-harvested situations. Biomass of *C. mopane* in the understorey was much higher in the harvested area (2.4 compared to 0.8 t ha^{-1}), as was the number of seedlings, but basal area was slightly lower. In the tree layer the number of trees, total basal area and total biomass of *C. mopane* was lower (61 compared to 79 t ha^{-1}) in the harvested area. Harvesting was principally of stems in the 5-25 cm size classes. Regressions of basal area against weight for *C. mopane* are $W = 0.06 \times (BA)^{1.33}$ for stem diameters >5 cm, and $W = 0.15 \times (BA)^{1.09}$ for stem diameters <5 cm. Growth of coppice shoots was linear up to 7 years; after 5 years it slows down to 1 kg $shoot^{-1}$ yr^{-1} at a density of 10,000 shoots ha^{-1}. Natural production rate of *C. mopane* woodland at Dukwe is around 10 t ha^{-1} yr^{-1}. Thinning will result in some loss of production per ha, but will produce the desired pole size class.

108. TIETEMA, T. **Biomass determination of fuelwood trees and bushes of Botswana, Southern Africa.** *Forest Ecology and Management* (1993) **60** 257-269 [En, 21 ref.]

A study of the relationship between tree fresh biomass and tree dimensions for 14 tree species in Botswana. The best regression was obtained between fresh above-ground biomass and stem basal area plotted on a logarithmic scale. The regression equation for *Colophospermum mopane*, based on 36 individuals from *C. mopane* woodland in the Dukwe area (N.C. Botswana), was $B = 0.0644 \times BA^{1.3341}$ with an R^2 value of 0.95.

109. TIETEMA, T.; DITLHOGO, M.; TIBONE, C.; MATHALAZA, N. **Characteristics of eight firewood species of Botswana.** *Biomass and Bioenergy* (1991) **1** (1) 41-46 [En, 14 ref.]

Eight firewood species used in Botswana were evaluated for their burning abilities and *Colophospermum mopane* was a preferred species. It was slow to heat up water (75 C h^{1}), but because of high radiant heat from the remaining charcoal water was slow to cool down after boiling (1 C h^{1}). The wood has a high specific weight (1.19 g cm^{-3} air dry) and a moderate ash content (3.78% of dry weight). Carbon content of the heartwood was .9%, and the energy content determined from bomb calorimetry was 21, 70 kJ kg^{-1}. However, the burning efficiency of *C. mopane* was the lowest of the species tested (1.42%).

110. TIETEMA, T.; KGATHI, D.L.; MERKESDAL, E. **Wood production and consumption in Dukwe: A feasibility study for a woodland management and plantation scheme.** NORAD/National Institute for Development Research and Documentation, Gaborone, Botswana (1988) 86 pp. [En, 12 ref.]

Consultants report of wood consumption and woodland management at Dukwe refugee camp, N. Botswana. All households used *Colophospermum mopane* wood for fuel. A comparison was made of harvested and unharvested areas of mopane woodland, with particular reference to size classes. The harvested area had more *C. mopane* seedlings and more coppice than the unharvested area, but fewer trees in the -2 cm ankle-diameter classes. Regressions of basal area against fresh weight for *C. mopane* were: $0.06 \times BA^{1.33}$ for stems > cm and $0.1 \times BA^{1.09}$ for stems < cm. Seedlings grew at a rate of 0. 7 gm gm^{-1} yr^{-1} until 7-8 years when they weigh around 1 kg. Seedlings grow at half the rate of coppice shoots. Growth of coppice shoots is linear until 7 years, then slows down to 1 kg $shoot^{-1}$ yr^{-1} at a population density of around 10,000 shoots ha^{-1}. Normal production at Dukwe is estimated as 10 t ha^{-12} yr^{-1}. Thinning would increase growth rate and could improve number of stems in the desired size classes, but would result in a reduction in production ha^{-1}.

111. TIETEMA, T.; MERKESDAL, E.; SCHROTEN, J. **Seed Germination of Indigenous Trees in Botswana.** ACTS Press, Nairobi/Biomass Users Network, Harare/Forestry Association of Botswana, Gaborone (1992) 106 pp. ISBN 9966-41-038-4 [En, 17 ref.]

Descriptions of seed collection practices, germination and raising seedlings of 62 tree species. *Colophospermum mopane* pods ripen in April/May and no pre-treatment for germination is required, although removal of the seed from the fruit makes germination more rapid and even. 45% germination is reported after 2 weeks and 70% germination after 2-3 weeks.

112. TIETEMA, T; TOLSMA, D.J.; VEENENDAAL, E.M.; SCHROTEN, J. **Plant responses to human activities in the tropical savanna ecosystem of Botswana.** In *Ecological Responses to Environmental Stresses*, Netherlands; Kluwer (1991) 262-276 [En, 30 ref.]

Account of effects of overgrazing and wood cutting on vegetation in Botswana. Size structure of uncut and repeatedly harvested stands of *Colophospermum mopane* are shown to be different, particularly the 5-20 cm diam. class. Biomass of *C. mopane* in Dukwe (N. Botswana) is given as 80 t FW ha^{-1} when unharvested, and 63 t ha^{-1} when harvested.

113. TIMBERLAKE, J.R.; MAPAURE, I. **Vegetation and its conservation in the eastern mid-Zambezi valley, Zimbabwe.** *Transactions of Zimbabwe Scientific Association* (1992) **66** 1-14 [En, 23 ref. + 2 maps]

Descriptive account of the vegetation of part of the Zambezi valley (N.E. Zimbabwe). *Colophospermum mopane* is an important component or dominant in 6 out of 12 described vegetation types: dense woodland on old alluvium, mopane woodland on deeper soils, mopane-*Terminalia stuhlmannii* woodland, mopane-*Combretum apiculatum* woodland, mopane-*C. apiculatum-Julbernardia* woodland, and *Brachystegia allenii*-mopane woodland. Aspects of the ecology and associated species are given. Three areas of tall ("cathedral") mopane woodland are described as of particular interest for conservation as some are now being cleared for cotton cultivation.

114. TIMBERLAKE, J.R.; NOBANDA, N.; MAPAURE, I. **Vegetation survey of the communal lands - north and west Zimbabwe.** *Kirkia* (1993) 14 (2) 171-270 [En, 94 ref. + 2 maps]

Descriptions and maps of 37 vegetation types covering 79,150 km^2 of north and west Zimbabwe, based on a phytosociological survey and satellite imagery. Three vegetation types dominated by *Colophospermum mopane* which occur on Karoo sediments and shallow basalt soils are described. They are principally found below 900 m altitude, but up to 1100 m in the driest parts in the west. A further 5 types of miombo-mopane vegetation, a catena or mosaic with *C. mopane* on the heavier depositional soils, are also described. *C. mopane* is also found in some other vegetation types on granite or on termitaria. The species is confined to xeric sites on clay-rich soils, which together with the aggressive rooting habit is responsible for its dominance in such areas.

115. TIMBERLAKE, J.R.; CALVERT, G.M. **Preliminary root atlas for Zimbabwe and Zambia.** *Forest Research Bulletin* **10** (1993). Zimbabwe Forestry Commission, Harare [En, 10 ref.]

Illustrations of root profiles from a range of sites in Zambia and Zimbabwe, including 7 profiles of *Colophospermum mopane*. These profiles are varied; two show strong shallow lateral rooting while 5 have relatively deep taproots. Two of the latter are larger trees and have downward-sinking laterals.

116. TUOHY, J.M.; PRIOR, J.A.B.; STEWART, G.R. **Photosynthesis in relation to leaf nitrogen and phosphorous content in Zimbabwean trees.** *Oecologia* (1991) 88 378-382 [En, 19 ref.]

A study of CO_2 assimilation in relation to light intensity, and its relationship to leaf nitrogen and phosphorous concentrations, in 14 species of tree in Zimbabwe. Leaves on *Colophospermum mopane* trees in Chiredzi (S.E. Zimbabwe) showed a mean CO_2 assimilation rate of 9.6 μmol m^{-2} sec^{-1}. Leaf nitrogen was 260 mmol m^{-2} and phosphorous 17.5 mmol m^{-2}. The assimilation rate rose with increasing photosynthetic photon flux density to an asymptoe at around 800 μmol m^{-2} sec^{-1}.

117. TURK, D. **Leguminous trees as forage for edible caterpillars.** *Nitrogen Fixing Tree Reports* (1990) 8 75-77 [En, 21 ref.]

Brief account including mention of the use of *Colophospermum mopane* as host for *Gonimbrasia belina*, the most commercialised caterpillar in southern Africa.

118. VELCICH, G. **Mopani worms.** *Bantu* (1963) **10** (11) 604-605 [En]

Account of the harvesting and preparation of mopani worms by tribal people in the northern Transvaal (South Africa). The worms feed on the leaves of *Colophospermum mopane* trees and there are two worm seasons December to February and April to May. Those from April-May are said to be richer in fat and tastier. Dried mopani worm is reported to contain 51.1% fat (ether extract). Preparation is by de-skinning then roasting the carcass in a fire before being placed in the sun to dry. Worms are usually reconstituted in water or milk for eating, and are said to be a popular food.

119. VILJOEN, P.J. **Habitat selection and preferred food plants of a desert-dwelling elephant population in the northern Namib Desert, South West Africa/Namibia.** *African Journal of Ecology* (1989) **27** (3) 227-240 [En, 26 ref.]

Account of plant and habitat preferences of elephants in N. Namibia. *Colophospermum mopane*, along with *Tamarix usneoides* and *Combretum imberbe*, appear to be the most important food plants for this elephant population. Overall *C. mopane* had a mean plant density of 6.56 ha^{-1}, and 38% of plants were fully utilized by elephant.

120. VILLIERS, P.A.DE; KOK, O.B. **[Food ecology aspects of elephants in Etosha National Park] [Namibia].** *Madoqua* (1988) **15** (4) 319-338 [Afr, en, 32 ref.]

Study of the relative availability of forage for elephants in the Etosha National Park, Namibia. Although there was marked seasonal variation in forage availability, *Colophospermum mopane* was the most important component, especially in the warm, dry season. Elephant damage to trees is limited, but increasing.

121. VINCENT, V.; THOMAS, R.G. **An agroecological survey of Southern Rhodesia [Zimbabwe]: Part 1 Agro-ecological survey.** Harare, Zimbabwe; Government Printer (1961) 124 pp. [En, maps]

Comprehensive and detailed account of the agroecology of Zimbabwe, including details on soils and vegetation. *Colophospermum mopane* mostly occurs in the lower and drier parts. Soils where it occurs typically have a compacted, clayey, strongly alkaline subsoil and high content of exchangeable Na. External drainage is often poor, grass cover is sparse and soils badly eroded. *C. mopane* can also be found on shallow soils and, rarely, on deep sandy well-drained soils where high temperatures and low rainfall restrict downward movement of moisture. Where it invades in the central watershed it is associated with infertile, strongly alkaline sodium-clays, thus it is sometimes erroneously regarded as an indicator of infertile soil.

122. VOORTHUIZEN, E.G.VAN **The mopane tree.** *Botswana Notes and Records* (1976) **8** 223-230 [En, 12 ref.]

Account of the botany, distribution, vegetation types and uses of *Colophospermum mopane* in southern Africa, with emphasis on Botswana. Protein, fibre and mineral analyses of mopane leaves through the year are given, and show an average crude protein content of 12.6%. An account and analysis of the protein-rich mopane worm is also given.

123. WALKER, B.H. **A review of browse and its role in livestock production in southern Africa.** In *Browse in Africa, the current state of knowledge [edited by Le Houérou, H.N.]*. Ethiopia, ILCA (1980) 7-24 [En, 29 ref.]

Review of browse including analyses of nutritive values. *Colophospermum mopane* occurs in woodland and tree/shrub savannas. It is regarded as valuable browse but often low in production. The leaves of *C. mopane* have a high tannin content when fresh, but are more palatable when dry. Crude protein values range from 8.4 to 16.6%.

124. WATT, J.M.; BREYER-BRANDWIJK, M.G. ***Medicinal and poisonous plants of Southern and Eastern Africa***, second ed. London, U.K.; E. & S. Livingstone (1962) 1457 pp. [En, 7454 ref., 14 on mopane]

Colophospermum mopane is reported to have medicinal use (syphilis, inflamed eyes), and the seed contains a balsam. Leaves are an important browse source for elephant and cattle and are rich in tannin, which has given a positive haemolysis test. Although leaf and seed smell strongly of turpentine, and the young leaves are purgative to cattle in early summer, neither milk nor meat are tainted. Timber is used for various purposes and the ash has a high percentage of PO_4 and Ca, with 15.5% lime in dry timber. A strong fibre is obtained from the bark, which is low in tannin (5.9-8.7%).

125. WEARE, P.R.; YALALA, A. **Provisional vegetation map of Botswana.** *Botswana Notes & Records* (1971) **3** 131-147 [En, 10 ref. + map]

Description and map of the vegetation types of Botswana. *Colophospermum mopane* is dominant in 4 of the 29 described types (one of which is subdivided on the basis of *C. mopane* physiognomy into 4 sub-types), and is occasionally present in a further 5 types. The distribution of *C. mopane* in the country is shown separately. Mopane vegetation types are found in the north around the Okavango swamps and in the north east from Palapaye to the Makgadikgadi pans.

126. WERGER, M.J.A.; COETZEE, B.J. **The Sudano-Zambezian Region.** In *Biogeography and Ecology of Southern Africa [edited by Werger, M.J.A.]*. The Hague, Netherlands; W. Junk (1978) 301-462 ISBN 90-6193-083-9. [En, 262 ref.]

Comprehensive description of the vegetation of the Sudano-Zambezian floral region. *Colophospermum mopane* is indigenous to south central Africa, and is nearly always the sole dominant of a woodland community, comprising up to 90% of total phytomass. Mopane woodland mostly occurs in the flattish wide valley bottoms of large rivers (Zambezi, Luangwa, Shire, Save, Limpopo, Okavango and Cunene) between 100-1200 m altitude, with annual rainfall of 400-800 mm. This broad-sclerophyll arid woodland or bushveld separates the moist-tropical miombo woodlands from the warm-temperate and dry-tropical bushveld. Low winter temperatures seem important in determining its southern boundary. Mopane woodland is generally found on fine grained sandy to loamy and clayey, usually deep soils, although sometimes with a calcrete layer near the surface. Mopane soils tend to develop a high exchangeable Na content resulting in reduced permeability and increased susceptibility to erosion. Trees are from 5 to 17 m tall, up to 25 m in the north. A shrubby form is also found on heavy, impervious soils. Height generally increases from periodically cooler and drier parts in the south west to more constantly warm high rainfall areas in the north. Due to the position of the leaves a large quantity of light reaches the ground surface, but the understorey is poorly developed, possibly related to the shallow lateral roots of *C. mopane*. Most associated species in mopane woodland are only active in the rainy season. Trees stay green into the dry season and are an important browse source.

127. WEST, O. **Brief summary of trials with herbicides on trees and scrub at the Grasslands Research Station, Marondellas [Marondera, Zimbabwe].** *Pesticides Abstracts and News Summary* (1958) **7** (4) 551 [En]

Account of bush control trials at various research stations in Zimbabwe. At Tuli Research Station (S.W. Zimbabwe) application of 2,4,5-T (2.3, 4.5 and 9.1 kg acid equivalent per 455 litre of water) to cut stumps caused high mortality in *Colophospermum mopane*, but bark and stab treatments were ineffective. Application of 2,4,5-T in aqueous solution at 2.3 kg acid equivalent per 455 l to coppice *C. mopane* in a cleared paddock gave up to 50% kill, but new coppice was produced.

128. WEST, O. **Progress report of the standing sub-committee on bush control.** Paper at 9th meeting of Southern African Regional Conference on the Conservation and Utilization of Soil (SARCCUS), Salisbury [Harare] 1964. Extracted from *Weed Abstracts* (1964) **14** (3) 15 [En]

Account of bush control trials in Southern Africa. In Zimbabwe goats were found to be effective in controlling *Colophospermum mopane* at Tuli (S.W. Zimbabwe).

129. WHITE, F. **12. *Colophospermum mopane* Kirk ex J. Léon.** In *Forest Flora of Northern Rhodesia [Zambia]*. Oxford, UK; Oxford University Press (1962) 121 [En]

Taxonomic account of the woody plants of

Zambia. *Colophospermum mopane* (mupane, mwane) is a small to medium-sized tree to 15 m, widespread in hot, low places in the Zambezi and Luangwa valleys (S. and E. Zambia) and their tributaries. It is found on Karoo sediments or shallow overlying alluvium, where it is usually gregarious and dominant. It is also dominant on old, low termite mounds in flood-plain grassland in the south, and occurs locally on termite mounds on the southern plateau at 1250 m altitude. Flowers appear in March, and fruits are ripe from June to August. The timber is dark-hearted, durable, heavy and hard to work. Poles are used for pestles, hut making, mine props and fence posts. An infusion of roots is used to cure tape worm. Young leaves and branchlets are eaten by elephants.

130. WHITE, F. **The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa.** *Natural Resources Research No.20.* Paris, France; UNESCO (1983) 356 pp. ISBN 92-3-101955-4 [En, 50 pp. of ref.]

Account and maps of the vegetation types of Africa, with particular reference to phytogeography and regional endemism. *Colophospermum mopane* woodland and scrub woodland (type 28) is the only type in which *C. mopane* is dominant. It is a woodland vegetation type in drier parts of the Zambezian regional centre of endemism, and woodland and scrub mopane occur as a mosaic. It is very extensive in the Zambezi, Luangwa, Limpopo, Shashe and Sabi valleys, but absent from the Indian Ocean Coastal Belt. This type occurs locally in the Nanzhila and Machili basins in Zambia and in the Okavango area of Botswana, although it is generally absent from Kalahari sand. There are also extensive areas in N. Namibia and S.W. Angola. The woodlands are 10-20(25) m tall and there is a broad correlation between rainfall and tree height. The vegetation under *C. mopane* is physiognomically uniform under a wide range of climatic and edaphic conditions. The upper limits of altitude and rainfall tolerance are 1400 m and 800 mm yr^{-1}, respectively, and the species is killed back by frost. Below 500 mm rainfall mopane occurs on shallow soils or those with a heavy subsoil, mostly those associated with Karoo sediments and granite and often with high Na levels. It does not occur on true sodic soils (water soluble salts >0.2-0.3%). There is a shallow root system with a dense concentration of fine roots in the top 25 cm of soil. Grass is often absent, thus fire damage is minimal, although the tree is flammable once the bark is burnt. Fire can reduce mopane woodland to shrubby mopane grassland. Over much of its range *C. mopane* is deciduous for 5 months of the year, but only for 3 months in the Luangwa valley. Where moisture is available it is almost evergreen. There is a very different associated flora from miombo types.

131. WILD, H.; BARBOSA, L.A. GRANDVAUX. **Vegetation map of the Flora Zambesiaca region.** *Flora Zambesiaca* (1967) supplement. Harare, Zimbabwe; M.O. Collins. 70 pp. [En, 88 ref. + 2 maps]

Account and map of the vegetation types of the Flora Zambesiaca area (Botswana, Malawi, Mozambique, Zambia, Zimbabwe). Vegetation dominated by *Colophospermum mopane* is described under three types, which cover much of the Zambezi, Luangwa, Limpopo and Save valleys, and also the Makgadikgadi pans, Okavango and N.E. Botswana. In Dry Early-Deciduous Savanna Woodland (Lowland)-*Colophospermum mopane* (type 35) *C. mopane* occurs in pure stands, sometimes mixed, with canopies sufficiently close to form a true woodland. It is generally found on relatively deep soils, normally calcareous, but sometimes occurs on shallow rocky soils or on Kalahari sand. Dry Deciduous Tree Savanna-*Colophospermum mopane* (type 50) is found south of the main plateau in Zimbabwe and the Kalahari sand sheet. The woodland is more open and savanna-like than in type 50. *C. mopane* occurs in pure stands on level ground, but is mixed with other species on stony soils and low hills. Grass cover is reasonable, but is much less on heavy poorly-drained soils. In Mozambique extensive areas are found on Quaternary lacustrine calcareous formations, and also on Cretaceous deposits and alluvium. Dry Early-Deciduous Shrub Savanna-*Colophospermum mopane, Enneapogon, Aristida* (type 61) is found in low-lying drainage systems subject to severe frost, and on basalt soils in S. Zimbabwe. Associated grasses are predominantly annual.

132. WILSON, J.H. **The effects of basal injections of Tordon on some Central African indigenous trees.** *Rhodesia Zambia Malawi Journal Agricultural Research* (1967) 5 (3) 301-303 [En]

Account of trial on mortality of 13 tree species due to arboricide application. 44 trees of *Colophospermum mopane* were basal injected with doses of Tordon 22K at 0.25-0.75 ml $tree^{-1}$, plus a control. Although deaths were recorded at all doses, control (averaging 36%) was considered unsatisfactory in *C. mopane* compared to most other species.

133. WYK, P.VAN ***Colophospermum mopane.*** In *Trees of the Kruger National Park.* Cape Town, South Africa; Purnell & Sons (1972) 184-187 ISBN 360-00158-0 [En]

Descriptive account of 203 trees of this area of N.E. South Africa. Within the Park *Colophospermum mopane* is mainly found north of the Oliphants river on soils derived from basalt (shrub mopane), granite and rhyolite, but also sometimes on deep alluvium. The tree is 15-18 m high, with a diameter of up to 150 cm, and is locally dominant in almost homogeneous stands. Multi-stemmed shrubs are also found. The tendency to shrubby growth is ascribed to shallow poorly drained soils, where it also grows slowly. Trees have little resistance to fire. Germination is easy and plentiful, but the species grows slowly and cannot withstand cold. The attractive durable timber is heavy (1216 kg m^{-3}), hard and termite resistant. Most trunks are hollow. The bark is used medicinally and for tanning (5.9-8.7% tannin). The wood has a high phosphate and calcium content and the ash can be used as fertilizer. The leaves are an important browse for livestock and wildlife, especially elephant. Palatability is thought to be increased by secretions of an insect larva. Caterpillars of *Gonimbrasia belina* live exclusively on the leaves and are a protein-rich delicacy.

134. WYK, P.VAN ***Colophospermum mopane.*** In *Field Guide to the Trees of the Kruger National Park.* Cape Town, South Africa; Struik (1984) 83 ISBN 1-86825-107-1 [En]

Brief introduction, including a vegetation map, to the Kruger National Park in N.E. South Africa and illustrated descriptions of 203 tree species [content similar to ref. 133].

Front cover:

Colophospermum mopane tree in Hwange National Park, western Zimbabwe

Back cover:

C. *mopane* woodland in early dry season, Hwange National Park, western Zimbabwe (top left)

Leaves of C. *mopane* in early wet season, Nkayi, western Zimbabwe (top right)

Root profile of C. *mopane* along stream bank, Lupane, western Zimbabwe (middle left)

Mopane woodland on deep soils, Omay communal land, northern Zimbabwe (middle right)

Elephant damage to C. *mopane* woodland, now reduced to shrubland, Gonarezhou National Park, southern Zimbabwe (bottom)

Photos by J. Timberlake

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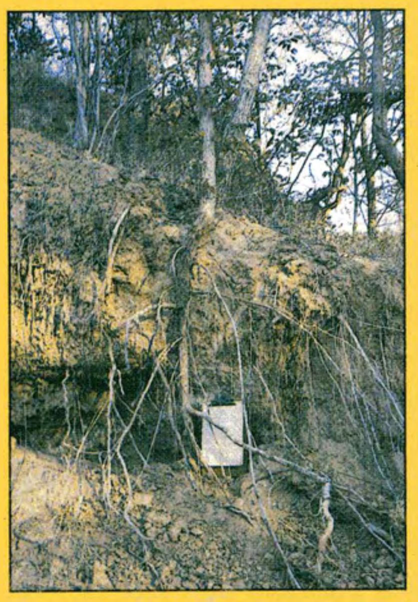

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