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Review Article
A Review of *Pterocarpus angolensis* DC. (Mukwa) an Important and Threatened Timber Species of the Miombo Woodlands

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Abstract

Background: This study reviews *Pterocarpus angolensis* one of the most important hardwood tree species found in the dry woodland savanna of East and Southern Africa. The tree produces one of the best timbers in the region and is also valued for its medicinal purposes. The populations of this species have declined in the wild due over-exploitation for timber, forest fires, drought and disease. The rate at which the tree is harvested is of great concern considering the number of trees in the small diameter classes. Regeneration of *Pterocarpus angolensis* in the wild is poor and sparsely because of poor survival of seedlings during establishment which has been attributed to damage by forest fires, harsh climatic conditions, browsing by animals, recurrent yearly dieback of seedlings, competition from other plants for resources and delayed seed production. In addition, the tree is vulnerable to mukwa disease which has killed many adult trees in Southern Africa in the past decades. *Pterocarpus angolensis* was recently introduced in the IUCN Red list as near threatened. **Conclusion:** Attempts to introduce the tree in commercial plantations failed and therefore more research and conservation efforts are required to find ways of regenerating and protecting this valuable resource from extinction.

Key words: Pterocarpus angolensis, timber, mukwa disease, seed germination, threatened

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Pterocarpus angolensis DC is a member of the family Leguminosae: Fabaceae[1]. The genus Pterocarpus is composed of about 30 species found throughout the tropics except Australia and Madagascar. Four species including *angolensis* are found in Africa[2]. *Pterocarpus angolensis* is found in the miombo woodlands of East and Southern Africa as well as in the dry evergreen and dry deciduous forests[3]. Miombo woodland cover between 2.7 and 3.6 million km^2 in 11 African countries[4] that include, Angola, Botswana, Democratic Republic of Congo, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe[5-11]. The tree has also been planted on a small scale in Kenya[12] and Mozambique[13]. It grows in woodland and wooded grasslands[14] from 300-1550 m above sea level[15]. It is an occasional or common tree in all woodland types on Kalahari sands and savanna woodland on alluvial transition soils[16]. *Pterocarpus angolensis* is the most prominent tree in the miombo woodland[16,17] found growing in association with *Brachystegia speciformis*, *Julbernardia paniculata*, *Julbernardia globiflora*, *Parinari curatellifolia*, *Syzygium guineense*, *Uapaca* species and *Isoberlinia angolensis*[6,10,17-20].

Pterocarpus angolensis grows well in well-drained, medium soil[21] and most often in deep sandy[22] or light soils with low-moderate fertility[12] and pH of 5.5-7. Miombo woodland soils are poor in organic matter, N and P[23], but *Pterocarpus angolensis* possess a vesicular-arbuscular mycorrhizae[24] and functional N-fixing root nodules[25] that enable it to efficiently utilise available nutrients[23]. The species is adapted to survive and tolerate severe environmental conditions such as fire and drought[23]. It grows well in areas with a well-defined wet and dry season and can tolerate rainfall as low[12,26] as 500 mm year^{-1} and as high[12] as 1500 mm year^{-1}. *Pterocarpus angolensis* can withstand temperatures[2,15,27,28] as low as 4°C.

DESCRIPTION OF THE TREE

Pterocarpus angolensis is a deciduous tree with a straight stem and leafy open flat or rounded spreading crown[16,29]. It is a medium to large sized tree growing up to 16 m high, reaching 28 m under favourable conditions[3,29]. A height of 36 m was recorded from some trees growing in Mozambique[5]. Stems are occasionally swollen at the base[3] and can reach a breast height diameter of 50-60 cm[5,12]. A stem diameter of up to 122 cm was recorded in trees growing in favourable conditions[12,16]. Currently, there are no or very few stems in the younger age classes to eventually replace their mature counterparts in the wild. This has been exacerbated by loggers who have resorted to harvesting these immature trees to supply timber to the ever expanding market for this valuable species[28]. The lack of young trees indicates that the species is under threat of extinction and therefore calls for an urgent need and measures to conserve it. The bark is grey to brown or black, rough and fissured with deep cracks that make rectangular sections[5,22,29,30] resembling a crocodile skin[16,29]. The thick bark is very resistant to fire[14] and secretes a blood-red sap that contains colorant and other organic compounds such as tannin (76.7%) and muningin when damaged[31].The leaves are drooping, alternate[5,12,16,29], growing up to 38 cm long[5] and in pairs[29,30] of 5-9 with a thin and oval central leaf let up to 7 cm[30]. Leaflets are elliptic-lanceolate to oval, 2.5-7×2-2.5 cm; upper surface is hairless and surface hairy when young and becomes hairless at maturity[29]. The leaf base is rounded to slightly cordate, apex accumulate, hairy on both sides when young, with 10-14 pairs of fine lateral veins[12]. Leaves fall between May and June[3,30] to give way to their new counterparts that emerge between September and October[14]. Flowers are sweet-scented, orange-yellow[21,22,29,30] pear shaped and appearing in large branched sprays of 10-20 cm long[29,30]. They are bisexual[12] and appear between August and December, just before the appearance of new leaves[3,29,30]. Flowers are sweetly-scented and succeeded by a distinctive round bristly pods surrounded by a stiff papery[3] wing 26.

Fruits or seed pods are round with a distinctive papery wing and contain one seed[30]. The pods are borne in hanging clusters and can grow up to 10 cm in diameter[21]. They appear between January and June[3,29,30] and the paper-like wing of the pod enables it and seeds within to be carried or blow away by wind from the mother tree[21,25]. Wind is the main seed dispersal mechanism that can even spread pods[32] for several km. The hard, spiny center of the pod does not split open on its own without external forces such as physical abrasion or fire[25]. Fire breaks down the woody pod and facilitate germination in the wild[33]. Trees start flowering and seeding between 15 and 20 years of age[7] and continue producing seeds until they die. The wood has a grey or creamy-white sapwood and heartwood which varies from pale golden brown to a darker reddish or purplish brown[3,5]. It has a density of 640 kg m^{-3} at 12% moisture content[34], durable and resistant to fire, decay, wood rotting fungi, termite attack, terrestrial and marine borers[12,35]. The wood grain is straight to inter-lock with a medium to course texture[12]. It is easily worked with hand and machine tools[36].

THE USES MUKWA

Pterocarpus angolensis produces one of the best timbers in Southern Africa[22,29,33] which is in high demand for its high value[8]. The wood is widely used for furniture, veneer and carving and as multi purpose timber[3,8,12,29,37,38]. It is extensively used by artists producing wild animals to supply the curio industry[21]. It is flexible, resistance to marine borers and light weight which make it suitable for making boats, doors and window frames[12]. The wood shrink's very little during drying from fresh condition and this together with its high durability, makes it suitable for boat and canoe building[29]. It is also used to make dishes, drums and mortars[29] and constitutes the largest volume of wood carvings found in curio shops in Southern Africa[39]. Due to its high value, the timber is only occasionally used as firewood or to make charcoal[12,30]. The wood produces a rich, resonant sound and can make many different musical instruments[29].

The bark, roots, flowers, sap and seeds are used in traditional medicine[30] to cure various diseases. The sap is used to stop nose bleeding[29], kill ring worms and cure ulcers[40]. Several studies reported that the sap is used to treat eye cataracts, malaria, blackwater fever, skin inflammation[29,31] and urinary schistosomiasis[41,42]. The bark can be heated in water and mixed with figs to message breasts to stimulate milk production[29]. A cold infusion from the bark provides a remedy for nettle rash and is also used to relieve stomach disorders, headaches and mouth ulcers[29]. The bark can be peeled off with its red sap and used to treat diarrhoea, heavy mensuration, nose bleeding, headache, stomach-ache, schistosomiasis, sores and skin problems[12]. The bark has also been used to poison fish. The bark or roots can be boiled with fresh meat and used as a preliminary accelerator in treating gonorrhoea[13]. Cleaned roots can be soaked in clean water to produces an eye wash and used in cleaning corneal ulcers[29]. The powder from crushed seeds can be applied as a wound dressing[12] to speed up the healing process.

The heartwood from roots can be pounded to make a brownish red dye that has been used in the cottage industry in Namibia and Zimbabwe to dye palm-leaf fibres used in the basket weaving industry[12]. *Pterocarpus angolensis* fixes atmospheric nitrogen[12,30] which is beneficial to the soil. It has also been used in soil conservation projects to fix sand dunes[12] and as an ornamental tree. Leaves and shoots are browsed by wild animals, especially elephants[43]. The tree is liked by elephants and evidence show that many trees in Botswana and Zimbabwe have been pushed over to make leaves more accessible[44,45]. Elephants strip off the bark to access the red sap and this exposes trees to fire damage and mukwa disease[33,46-48]. Flowers are a source of forage for bees[12]. Pods are eaten by baboons and monkeys[43].

MANAGEMENT OF MUKWA

Regeneration of *Pterocarpus angolensis* in the wild is poor and sparsely[9,49,50] because of poor seedling surviva during establishment[10]. The low survival rates have been attributed to forest fires, hostile climate, animal browsing[8,24,28,51] and recurrent annual dieback of seedlings, competition from other plants for light and delayed seed production[9]. Boaler[25] estimated that only 2% of seeds produced germinate in the wild. Studies conducted in the Copper belt of Zambia recently did not record seeds to a depth of 20 cm and observed only 95 saplings ha^{-1} in disturbed miombo woodlands[52,53]. Caro *et al.*[9] recorded few seedlings in areas covered by thick grass and dense tree canopy suggesting that *Pterocarpus angolensis* requires light to achieve its potential growth rates. *Pterocarpus angolensis* is a pioneer species in burnt areas[2].

Natural regeneration in the wild has shown to be a bottleneck due to failure by young seedlings to survive during establishment[10]. Seed germination *in situ* is positively influenced by forest fires[25,54] that burn and supress existing vegetation to minimise competition for nutrients, moisture, sunlight and growing space[23]. Forest fires also remove wings and bristles from pods, crack the seed and improve contact with soil[2,24,25,55]. Forest fire slows seedling development but accelerate the growth of saplings[25]. Several attempts to raise seedlings in the nursery[38] and establish commercial plantations have not succeeded in many countries[1,39,40,49,55]. This has been attributed to delayed seed production, failer of pods to open without seed being damaged, low seed germination rates, slow tree growth, competition from dense grass and other trees for sunlight[9,25]. However, small scale plantings were successful in warm areas of Mozambique, where clear-cutting, fire control and weeding was done in the first 10 years after planting[13].

Individual seedlings of *P. angolensis* remain in a suffrutex stage for a number of years with yearly diebacks during the dry season until the root system has grown deep enough to extract sufficient moisture and nutrient to support a shoot to survive harsh conditions during the dry season[2,25,32]. This phenomenon makes it difficult to use the species to establish plantations[25]. High densities of suffrutescent structures have been reported within the population in the wild[25,56]. The suffrutex stage last for about 14 years[25], but many seedlings fail to survive this stage because of drought, forest fires, lack

of nutrients and browsing. The suffrutex stage is stimulated by above average rainfall, protection from fire or browsing and release from competition to enter stages of rapid above ground growth[25,32]. Rapid growth of *P. angolensis* from seedling to sapling stage is stimulated by availability of light, lack of fires and competition for resources[25]. Trees growing in suitable sites can start flowering and seeding 15-20 years after reaching the sapling stage[7,34].

The species can be propagated by seeds and stem cuttings[12]. However, stem cuttings have a low survival rate in the nursery[57] and poor results were reported in Malawi, Mozambique, South Africa Swaziland and Zimbabwe[32]. A single tree can produce 100-400 fruits and 1 kg of seeds holds 3400-4000 seeds[12,58]. Seed collection is difficult because the pods are not easy to open without damaging seeds. The hard, spiny centre of the pod does not split open without physical abrasion or other mechanisms for seeds to germinate[25]. Pods can be opened using secateurs. Several studies found that germination of untreated seeds was irregular both in the wild and nursery[39,57,59] because seeds require moderate levels of fire to stimulate their germination[33]. Germination rates of 30-70% were recorded 3 weeks to 6 months after sowing[32,60]. Germination of *P. angolensis* seeds is not hindered by dormancy caused by water impermeable hard seed coat[61,62]. In addition to fire, physical, mechanical and chemical scarification treatments may also be used to stimulate seed germination[28]. Chisha-Kasumu *et al.*[10] used different pre-treatment methods and recorded 72-99% germination in seeds that were nicked which was significantly higher than other treatments.

FACTORS THREATENING MUKWA

The unregulated exploitation of *Pterocarpus angolensis* started way back in the 1950s or earlier in the Democratic Republic of Congo, Tanzania, Zambia and Mozambique[7,63-65]. The tree has been harvested either legally or illegally to supply its market which is constantly expanding[66]. Timber exploitation for either the local market or export[7] has significant enhanced decline in populations[39]. Harvesting big trees has led to a truncated size class profile[39]. Loggers have resorted to immature small diameter trees due lack of big trees[28]. Immature trees are felled before they become fertile to produce seeds for the next generation trees, which has probably contributed to the decline in the population density noted all over southern Africa[2,32]. Land clearing for a arable agriculture, housing, infrastructural development, human population expansion and heavy browsing of small trees also contribute to the decline in the species. Several studies have attributed he decline in the population density to annual forest fires and damage by elephants[47,48,67]. The World Conservation Monitoring Centre carried out an assessment of *P. angolensis* status[68], after which it was introduced on the IUCN Red List as near threatened[69].

A disease that is killing *P. angolensis* is well documented in Botswana[47,48], South Africa[23,70,71], Zambia and Zimbabwe[23,72]. The disease is commonly known as mukwa disease which refers to the common name of the tree in these areas[23,73]. The characteristics of the disease differ from country to country. In Botswana, Zambia and Zimbabwe the disease is characterized by wilt, dieback, bark discoloration, vascular and phloem streaking and the production of epicormic shoots[48,72]. In South Africa branch dieback, heart rot and the death of mature trees are characteristics of the disease[70,71]. Symptoms are most intensive during the rainy season[23] and infected trees occur in patches and die 2-3 years after infection[74,75]. Isolation of *Fusarium oxysporum* Schltdl from discoloured wood revealed that the fungus cause the disease that is attacking and killing *P. angolensis* trees[23,32,72,74-76]. Rainfall records from Zambia and Zimbabwe correlated the disease and death of *P. angolensis* to several years of drought[23]. This fungus causes damping off, crown and roots rots as well as wilting diseases[77] in many leguminous trees[78].

CONCLUSION

Pterocarpus angolensis is a very useful multipurpose tree in east and Southern Africa that is threatened by excessive exploitation for is valuable timber and by land use changes. Over exploitation which is unsustainable endangers natural populations of *Pterocarpus angolensis* in its habitat. Forest fires, elephant damage and failure of seedlings to survive during establishment are also implicated in low population densities of mukwa. Attempts to use it in commercial plantations were not successful. A large scale collaborative research is required to find ways of improving *Pterocarpus angolensis* seed germination rates, reducing the suffrutex stage of seedlings and accelerate the growth of saplings if this valuable resource is to be saved from extinction.

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