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Okoubaka Aubrevillei (Pelleg & Norman): A Synthesis of Existing Knowledge for Research and Conservation in West and Central Africa

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Abstract

Okoubaka aubrevillei is the largest parasitic plant known to man. It is a tropical tree species distributed within West and Central Africa. Concerns were drawn to the tree because of its rarity, disjunct distribution in all its native range, paucity of published scientific information and its hemi-parasitic potentials. This article gathered and synthesized all existing scientific information on the tree to provide a solid foundation for further research on the tree. This article provided detailed information on its name etymology, taxonomic history, and geographical distribution including new locations for the tree, ecological significance and behaviour within its range, supported with an updated map illustrating its distribution within West and Central Africa. The possible causes of its rarity in its range were identified and its hemi-parasitic behaviour was hypothesized. In addition, ethnobotanical uses of the tree, symbolism and dendrolatry, and its significance in modern medicine were extensively discussed. The paper concluded with highlights on prospects for immediate conservation, management and research focus areas for the tree species.

Keywords: *Okoubaka aubrevillei*, West and Central Africa, Conservation, Hemi-parasitism, Rarity.

1. Introduction

Okoubaka aubrevillei is an indigenous tree species from the tropical rainforests of West and Central Africa (Tailfer, 1989), reaching 40 m in height (Hawthorne, 1995). The generic name

comes from *oku baka*, in Anyin language (Côte d'Ivoire) meaning "a tree with allelopathic properties", or "a tree that causes the death of surrounding vegetation" (Hallé, 1987), or simply "death tree" (Lowe, 2012). This tree is of significant interest because of symbolic veneration attached to it by indigenous communities in all its native range, its numerous medicinal potentials and conservation status. The tree is perhaps one of the most controversial plants in Africa in terms of taxonomy and ethnobotanical information.

The author's attention was drawn to the tree as because of its rarity in its native range, and relative neglect in terms of research and publications. A search for publications on the tree on ISI Web of Science and JSTOR journal databases gave only 18 and 5 publications respectively, with only 4 publications with research focused directly on the tree. This paper gave a comprehensive compendium on existing knowledge on the tree from the few published research papers and from author's personal experiences and reconnaissance surveys. In this way, knowledge gaps are identified and baseline information on the tree are registered, in order to stimulate further goal-oriented studies on the tree.

2. Morphological Features

Okoubaka aubrevillei is a tropophyte which grows to a height to up to 40 metres; with trunk as wide as 3 m. The tree has huge bushy crown, cylindrical and straight bole, coarse bark surface which is usually reddish brown. The horizontal branches divide to form slightly grooved and densely hairy branchlets (Burkill, 2000). The tree is monoecious, deciduous, and the tree development fits in Mangenot architectural model (Hallé and Oldeman, 1970; Hallé et al., 1978). This model describes trees where "the trunk is formed by superposition of renewal shoots from lateral buds, the new shoot is initially orthotropic but later becomes plagiotropic, while the phyllotaxy is spiral in the orthotropic parts and distichous in the plagiotropic parts" (Hallé and Oldeman, 1970; Ladipo et al., 2008).

The following is a synthesis of leaf descriptions given by different authors: "The leaf blade is ovate to oblong, simple and entire, 7.5–15 cm long and 3.5–6 cm wide. Leaf arrangement is alternate to almost opposite (Fig. 1), stipules are absent, petiole is 2-ribbed and 3–15 mm long. The leaf base is rounded to slightly cordate while the apex is acuminate. The leaf is dark green, with 3–5 pairs of lateral veins and densely hairy when young. The axes show clear articulation. The pubescence of the leaves and axes consists of long, pointed, simple hairs, existing in tufts or bundles of 2-3 hairs, the hairs are always normal" (Stauffer, 1957; Voorhoeve, 1965; Ladipo et al., 2008).

The tree's small, greenish flowers are arranged on spines of around 15 cm in length on older branches. Inflorescences are 20-40 cm long and 6-10 cm wide. The inflorescences occur axillary on older branches, and shortly pedicellate flowers show a conical receptacle, into which the unseptate ovary is encompassed (Stauffer, 1957). Furthermore, unisexual flowers are in multiples of 5, sessile and greenish. Male flowers have triangular petals, about 2.5 mm long and 2.5 mm wide, short-hairy, with stamens about 0.5 mm long, disk cup-shaped, lobed, ovary with abortive ovules, style c. 1 mm long, stigma 4-pointed; female flowers slightly larger than male flowers, stamens sterile, disk cup-shaped, prominently lobed, hairy on upper margin, ovary superior, 4-celled, style c. 1 mm long, stigma 4-lobed (Ladipo et al., 2008).

The flowers turn into hard, yellow-coloured fruits (Fig. 2) which are ellipsoid drupes, containing a single large seed (Wagner et al., 1985; Abbiw, 1990). The fruits are glabrous, 15-16 cm long and 9-10 cm wide, weakly ribbed longitudinally; the exocarp is smooth, shiny, apple green coloured and then to yellow at full maturity; mesocarp is golden-yellow, of 1.5 -2 cm thick; endocarp of 5 mm thickness (Hallé, 1987).

The seed is ellipsoid, 7 cm long and 4.5 cm wide, with white endosperm, and longitudinally ridged (Burkill, 2000). The weight of the fresh seed was reported to be 100 g (Kyereh et al., 1999) or 101 g (Veenendaal et al., 1996a), compared to *Balanites wilsoniana* (50 g), *Mammea africana* (38 g) and *Tieghemella heckelii* (19 g), while Nagaveni and Anantha Padmanabha (1986) reported the dry seed mass to be 43 g, the largest reported for a hemiparasite. The seeds undergo cryptocotylar hypogeal germination (de la Mensbruge, 1966).

Figure 1. Leaves of *O. aubrevillei*

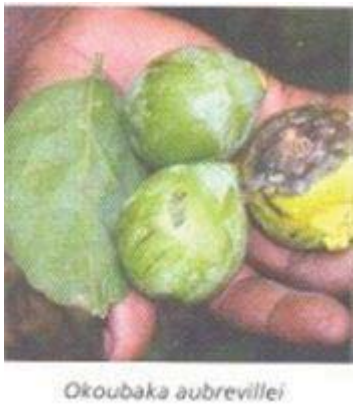

Figure 2. Fruits of *O. aubrevillei*

Source: Flora and Fauna of Liberia

The wood of *O. aubrevillei* is straight-grained, heavy and hard, with a basic density of 0.68 g/cm^3 (Bluskova et al., 1995). Anatomical descriptions of xylem of this species have been reported by Normand (1944, 1950, 1972), Lebacq and Dechamps (1964, 1967), and Normand and Paquis (1977); however, only Normand (1972) noted the occurrence of disjunctive parenchyma in the wood. Details of sections of the seed (nuts), pollen, fruit and flower have been given by Hallé (1987).

3. Taxonomic history: Octoknemaceae, Santalaceae or Cervantesiaceae?

Having made a first collection in Ivory Coast (Côte d'Ivoire) in 1936, the species was first described, in French, in 1937 and named *Octoknema okoubaka* Aubrév. & Pellegr by Aubréville and Pellegrin (1937), based on the description of the placenta of *Octoknema klaineana* by Pierre (1897). The genus *Octoknema* originally comprised 7 species found and described in different parts of West, Central and East Africa between 1897 and 1932 (Gosline and Malecot, 2011). As a result, this species was placed in the monogeneric family Octoknemaceae (often wrongly spelled Octoknemataceae) in the order Santalales (Gosline and Malecot, 2011). However, Norman (1944) discovered the anatomical study of wood did not agree with *Octoknema* and also, another important discovery, that the species is closely

connected to Santalaceae (Norman, 1950). Pellegrin and Norman (1946) proposed a new genus and a validated new name, *Okoubaka aubrevillei* (Pelleg & Norman). Without considering placentation, the new genus remained within Octoknemaceae (Hallé, 1987). In December 1947, a new variety, *glabrescentifolia*, was discovered in Yangambi, Democratic Republic of Congo (formerly Zaire) by Leonard (1947) with similar hemi-parasitic traits. This new variety was formally named *Okoubaka aubrevillei* var *glabrescentifolia* in Octoknemaceae and listed in the Flora of Belgian Congo (Hallé, 1987). However, Stauffer (1957), having revised the floral characters of *Okoubaka aubrevillei*, confirmed that it is indeed Santalaceae, and its affinity with *Scleropyrum*, an Indomalaysian genus with several species. Subsequently, the monogeneric Octoknemaceae family was dissolved, as the only genus, *Octoknema* was moved to Olaceae family. However, certain publications wrongly placed *Okoubaka aubrevillei* under Olaceae family under the *Octoknema* genus (Gosline and Malecot, 2011). A second species, *Okoubaka michelsonii*, was collected by A. Michelson in 1948 and 1949, and described by Leonard and Troupin (1950).

In spite of this changes in its taxonomic classification, 30 years after, the error of placing it under Octoknemaceae family is still persistent in Floras and herbaria (Hallé, 1987). Such examples include Lucas (1968)'s Flora of East Africa, Aubrevillei (1959)'s Forest Flora of Ivory Coast, Keay (1958)'s revision of Hutchinson and Dalziel's Flora of West Tropical Africa, as well as Keay (1989)'s Trees of Nigeria, among others. Even till date, some authors still place it under Octoknemaceae family in recent publications. However, Burkill (2000)'s The Useful Plants of West Tropical Africa (UPTWA) published the tree under Santalaceae; while Mangenot and Mangenot (1962) reported the chromosome number for *O. aubrevillei* to be 2n = 72. Since a second variety was discovered, it is appropriate to call the first one, *Okoubaka aubrevillei* var *aubrevillei.*

However, recent molecular phylogenetic studies (Nickrent and Malécot, 2001; Malécot 2002) showed *Okoubaka* to be member of a clade of paraphyletic Santalaceae; and Dar & Nickrent (2008) and Nickrent et al. (2010) placed it in a new family, Cervantesiaceae Nickrent & Der still within the order Santalales. Currently, *Okoubaka* consists of two species, and a variety; *O. aubrevillei* being the primary West African species, and *O. michelsonii* endemic to Democratic Republic of Congo (DRC). *O. michelsonii* is distinguished from *O. aubrevillei* by its glabrous branchlets and disk, shorter inflorescence and smaller fruits (Leonard and Troupin, 1950; Ladipo et al., 2008). Leonard and Troupin (1950) developed a key to describe the 3 members of the Genus *Okoubaka* and distinguished it from Genus *Octoknema*, where it was previously placed:

A. Parts young (branchlets, petioles, inflorescences) glazes of spangled hairs; not articulated petioles; staminodes deprived of anthers; 3-(4)-locular ovary almost until the top, becoming unilocular by tearing of the partitions; 1.5-3 cm length drupes; endocarp emitting towards the interior 6 -10 thin blades .....*Octoknema*.

B. Young parts (branchlets, petioles, inflorescences) glabrous or glazes of hairs simple, bifurcate or sometimes stellate; articulated petioles; staminodes with anthers; unilocular ovary; 4-16 cm length drupes; endocarp not emitting thin blades towards the

interior.....*Okoubaka*

The genus *Okoubaka* Pellegr. & Norman currently includes 2 species and 1 variety:

A. Pubescent branchlets and disks; panicles borne on old wood, of 18-40 cm length; drupes sessile, with 3.5-5 mm thick endocarp:

I. Blade densely pubescent, glabrous; receptacle and external face of the covered sepals with many stellate hairs; 9 cm long drupes…….....1. *O. aubrevillei var aubrevillei*

II. Blade glabrescent to glabrous even in a very young state; receptacle and external face of the sepals covered with scattered, simple, bifurcate or stellate hairs; 15-16 cm long drupes.....2. *O. aubrevillei* var. *glabrescentifolia*

B. Glabrous branchlets and disks; racemes spiciform, axillary (or borne on old wood?), of 1-3 cm length; drupes pedicellate, + 4 cm long, with 0.3 mm thick endocarp. .....3. *O. michelsonii*

Herbarium records available online for the tree are found in Forestry Research Institute of Nigeria (FRIN), Ibadan, Nigeria; Museum National d'Histoire Naturelle, Côte d'Ivoire; University of Ghana herbarium, Ghana; Université de Kinshasa and Institut National pour l'Etude et la Recherche Agronomiqué Centre de Recherches Herbier, both in Democratic Republic of Congo. In addition, non-African herbaria with *Okoubaka* records include Royal Botanic Garden, Kew; Nationaal Herbarium Nederland, National Botanic Garden of Belgium, Wageningen University (WUR) herbarium, The Netherlands and Missouri Botanic Garden, USA, with their herbarium collections coming from Ghana, Côte d'Ivoire, Sierra Leone, Liberia and Democratic Republic of Congo.

4. Literatures

Scientific knowledge for this tree species are scanty (Cunningham, 1993) and relatively little is known about the two species and their sister variety. Veenendaal et al. (1996a) reported hemi-parasitism in *O. aubrevillei* which they noted from 6 months old seedlings. The victims of the tree's hemi-parasitism were *Entandrophragma angolense* (Wei.) DC, *Pericopsis elata* (Harms) Van Meeuwen, *Pterygota macrocarpa* K. Schum., and *Tieghemella heckelii* Pierre ex Chev; but *P. macrocarpa*, and the nitrogen fixing legume, *P. elata* were reported to be the most infected. Furthermore, Kitin et al. (2009) worked and described a poorly known type of xylem parenchyma with disjunctive walls in the tree. Recently, van Andel et al. (2014) reported the first ever species distribution modelling for the tree in West Africa. These are in addition to a few studies reported on its pharmacological properties.

5. Geographical Distribution

The tree is distributed from Sierra Leone east to Cameroon and DRC (Ladipo et al., 2008); however, the largest population of the tree was found in the Upper Guinea region comprising Sierra Leone, Liberia, Ghana and Côte d'Ivoire (Poorter et al., 2004). Generally, the tree is reported to be restricted to closed cover evergreen forest (Burkill 1985), but also reported on rocky hills (Dovi, 2013) or slopes, usually solitary in most locations, but there are reports from

Côte d'Ivoire and Ghana that it is found in pure stands (Ladipo et al., 2008). In addition, the tree is also found to grow in open places in the forest. Akotto et al. (2014) reported the tree in high slopes and midslopes in Côte d'Ivoire.

The tree was first reported from Côte d'Ivoire (Ivory Coast) by Aubréville and Pellegrin (1937), later by Mensbruge (1966) and again by Hallé and Oldeman (1970), while other occurrences were reported from other parts of West Africa. Lemee (1959) and Letouzey (1960) cited in Hallé (1987) discovered the tree in Cameroon; Irvine (1961) reported it in Ghana, and Villiers (1973) in Gabon. Hallé (1987) cited Bold (1963) recording the tree in Niger Republic but no scientific data supports this, as Maercklein (2008)'s biodiversity report for Niger Republic reported only tree species that are generally adapted to Savanna ecoregions. Therefore, the occurrence of *O. aubrevillei* in Niger Republic is highly unlikely. Furthermore, the tree was reported from Sapoba Forest Reserve (FR), which were probably the ones planted by J.D Kennedy in 1930 (Hardie 1963).

Sapoba FR was the only recorded location for the tree in Nigeria as collected and filed in 1975 at the Federal Herbarium Ibadan (FHI) of FRIN, Ibadan and confirmed recently in personal communications with Mr. B.O Daramola. New locations for the tree have been reported in recent times. Ihenyen et al. (2009, 2010, 2011) reported the tree from Ehor FR, Edo State, Nigeria, with a reported density/hectare of 0.127. However, Ihenyen et al. (2011) reported not sighting the tree in Sapoba FR, as well as in Okomu National Park and Ozalla-Ora-Iulleha FR. Borokini and Clement (2012) reported its barks being sold in Bode Ibadan herbal market, which was traced to Onitsha, Anambra State. Furthermore, a stand was reported in Iwara town, Osun state, which is being worshipped as a sacred tree (god) till date (Ladipo et al., 2008). Ishikuemen and Iduozee (2008) reported coppices of this tree in Urhonigbe FR with *Myrianthus arborea* stands beside it (Fig. 3). Ita and Offiong (2013) reported the tree and its use in Cross River State. In the author's personal trip, the tree was encountered in Boki, Cross River but the traditional rulers refused access to the tree. Therefore, it appears that the tree is confirmed from Edo, Cross River and Osun States and probably Anambra State.

Figure 3. Coppiced Saplings of *Okoubaka aubrevillei (Left of O. aubrevillei is Myrianthus arborea) Source: Isikhuemen and Iduozee (2008).*

JSTOR filed the tree as reported by Leonard (1947) from forest reservations in Yapo, Agboville and Yakassé; Mampong Scarp Vigne, Krakaw, on N.E. corner of Kade Bepo F.R., Kwahu and Mpraeso, in Côte d'Ivoire. However, the tree has been further reported from Taï Forests National Park (Rompaey, 1993) and forests of Sanaimbo (Kassi et al., 2012). Akotto et al. (2014) reported it in their study sites in Akye country, southeastern Côte d'Ivoire. A few specimens of *O. aubrevillei* were reported from Dodo Hills and Gola Forest Reserves in Sierra Leone (Savill and Fox, 1967), while it was also listed in Bossou, Republic of Guinea, with leaves reportedly consumed by chimpanzees (Hockings, 2007). The tree was also listed in Deng Deng Forest, Cameroon (Ariz. Univ. Office of Arid Land Studies, 1981). Recent additional sightings have been recorded in Tiwai Islands (Sierra Leone), around Ndian community and Réserve de Faune de Pangaret Djérem (Cameroon).

The tree was reported in Atewa Range Forest reserve (Asiakwa South) in Ghana by Hawthorne (1998), and also confirmed by Okyeman Environment Foundation (2003). Myren (2011) reported the tree in sacred forests/shrines in Akoase, Southern Ghana; Houghton (2003) mentioned another stand from another study site in southern Ghana, while recent GBIF (2010) records indicate its presence in Boin Tano and Tano-Nimire Forest Reserve. Marshall (2011) reported two stands in a ridge top forest in Karlowleh and Pennoken communities, Liberia, however in recent communications with Liberian Forestry officers, new locations were noted in Grand Gedeh-Pennoken, River Gee – Proposed Grebo National Park, River Cess and Gbarpolu Gola Forest. Marshall (2011) further reported the limited distribution of the tree in the scattered Upper Guinea hills in Liberia. The genus has its center of diversity in DRC, as both varieties *aubrevillei* and *glabrescentifolia* of *Okoubaka aubrevillei* as well as *Okoubaka michelsonii* have been reported in the country. Louis (1948) reported *O. aubrevillei* from the Central Forests at Yangambi, DRC, while GBIF and African Plant Database records indicate herbarium collections in Kwango, Yaboseo, Lilanda and Bena Longo communities.

The tree was also reported from one of the quadrant points in a study in Dzanga Sangha Protected Area complex of Central African Republic (Balinga et al. 2006), its ethnobotanical use was reported from Burkina Faso, a strong indication of its distribution in the country (Kone et al., 2008). There is no specific herbarium record or sighting of *O. aubrevillei* in Benin Republic but van Andel et al. (2014), using Maximum Entropy (MaxEnt) species distribution

modelling (SDM) tool and GIS-based mapping, estimated suitable habitat for the tree in the country; while Codjia and Boer (2014) wrote on attempts to use it in agroforestry within oil palm plantations in Benin Republic. Central African Republic, Burkina Faso and Benin Republic are new locations not previously reported in UPTWA, FWTA and other global or continental plant databases. Furthermore, the tree's range extended to Liberia and Burkill (1985) reported a ban by Liberian Government on its bark sale. The Flora and Fauna of Liberia website listed it as one of the country's native species, with a note that it is endemic to West Africa. In an Environmental Impact Assessment (EIA) studies conducted in Nimba Western Area, Liberia, one stand was found far up Yuelliton in Bentor, another stand in Tokadeh forest, Makinto, and another one, called Zo tree in Zolowee, and other stands in Vanyampa and Sehyigeh communities (URS, 2013).

Tropicos online Plant database of the Missouri Botanical Garden listed two specimens for the tree from Nzérékoré, Guinea Republic and Haut, DRC (Tropicos, 2014). Furthermore, a list of occurrence of the tree on Global Biodiversity Information Facility (GBIF, 2010) produced results of registered 86 locations many of which have incomplete information, while some of the reported coordinates for the tree are inaccurate when plotted on ArcGIS map version 10.2 (ESRI, 2013). Furthermore, many of the herbaria collections were made in the mid-20th century and personal communication with some experts indicate that the stands were no longer found in some of these reported locations of herbarium specimens.

All the reported distributions of the tree are based on sightings and available herbarium records, portraying a disjunct distribution within the subcontinent (Poorter et al., 2004). However, herbarium records from Nigeria were not included in the GBIF database and CJB African Plant database records available for this plant; in spite of the fact that the tree has been reported from Nigeria. Therefore, it is very likely that the "gap in distribution" between Ghana and Nigeria would disappear if the tree is sighted and reported from Togo, while it is suspected that the tree might also be in Equatorial Guinea mainland and Congo Republic.

The presence of local names for a plant indicate the nativity of that plant in the local area. Local names for the tree include igi-nla (Yoruba), akoelisi, akuobisi and okoubisi (Bini names, meaning big tree), Etokukim (Cross River State), Nigeria; odii/ode (Twi language of Akan and Asante peoples), duyin (Fante language of Akan people), Ghana; oku baka (Anyi), Côte d'Ivoire; yai yili or Yein-yelee (Mano, meaning a lonely tree), Kahn tu/Sarlyea tu (Krahn language), Liberia; yɔua (Kono), yuwe (Mende), Sierra Leone (Hutchinson and Dalziel, 1958; Burkill, 1985; Marshall and Hawthorne, 2012a; Ita and Offiong, 2013; URS, 2013).

Scientific information are lacking on *Okoubaka aubrevillei* var. *glabrescentifolia* J.Léonard and *O. michelsonii* till date (Ladipo et al., 2008). It was recorded that *O. michelsonii* was located as scattered solitary trees (African Plant Database, 2015) at the edge of the Guinean Forests, in the transitional forest zone bordering the East African Rift valley, probably close to Goma and Bukavu in the Democratic Republic of Congo (Figure 4). No scientific research publication exist for *O. michelsonii*, and it was only mentioned in two articles (see Leonard and Troupin, 1950; Ladipo et al., 2008). Likewise, the only herbarium collections for *O. aubrevillei* var. *glabrescentifolia* was made in 1938 and 1947 by J. Louis and J. Leonard respectively. The

herbarium specimens were deposited in National Botanic Garden of Belgium. In summary, the tree is distributed in at least 12 countries in West and Central Africa (Figure 4).

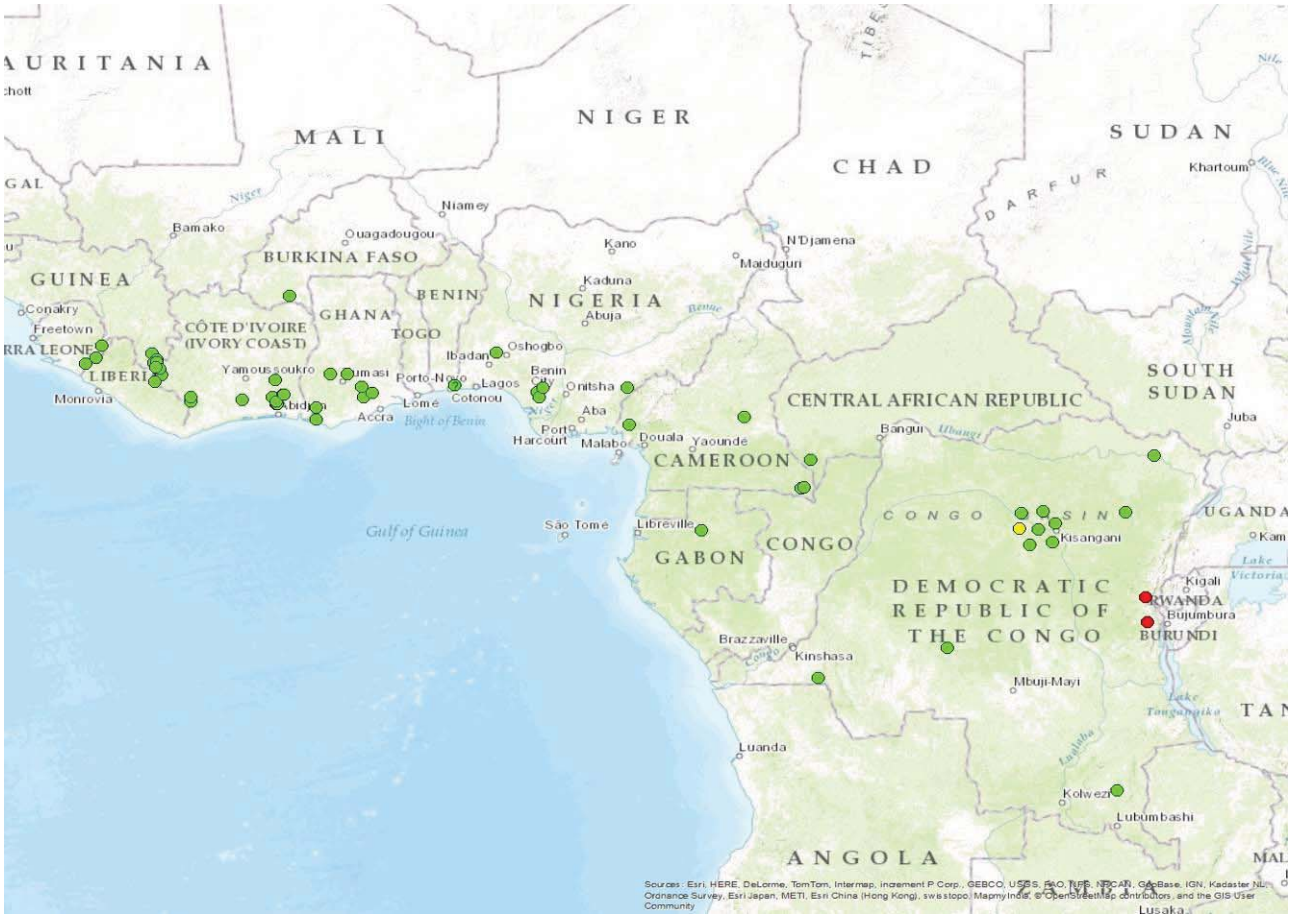

Figure 4. Map of distribution of Genus *Okoubaka* in West and Central Africa

(Green markers show the distribution of *O. aubrevillei* var *aubrevillei* in the region, while red and yellow markers in Democratic Republic of Congo illustrate the distribution of *O. michelsonii* and *O. aubrevillei* var. *glabrescentifolia* respectively. Question mark on the Benin Republic point indicate uncertainty of the tree location in the country). Basemap source: ESRI ArcGIS version 10.2 topography map.

6. Ecological Significance of *O. aubrevillei*

Perhaps the most important ecological significance of the tree is its hemi-parasitic potentials. Throughout its range, the species is locally reputed to kill other trees (Keay et al., 1964) and is often found in openings in the forests (Veenendaal et al., 1996a). The presence of haustoria on the roots of *O. aubrevillei* has been reported (Swaine and Hall, 1986; Veenendaal et al., 1996a). Veenendaal et al. (1996a) further reported the hemi-parasitic behavior of the tree starting from 6 months old seedlings, using haustoria to kill surrounding plants. They further suggest that the tree prefers nitrogen-fixing leguminous trees like *Pericopsis elata* (Veenendaal et al., 1996a). The tree is said to prevent any undergrowth forming beneath it – although some species are immune to the effect (Burkill, 1985). Hardie (1963) reported that no tree was found within 80 feet of a 60 feet *Okoubaka* tree, except for *Myrianthus arborea, Musanga cecropoides* and a woody *Vernonia*. In addition, Akotto et al. (2014) reported *Cola attiensis* growing closely to

the tree stands in Akye country in southeastern Côte d'Ivoire. Veenendaal et al. (1996a) believed this parasitic strategy was to reduce the growth of neighbouring trees so as to give slow-growing *O. aubvrevillei* a competitive edge in a light-limited environment.

The tree's seed mass is large and thus Hawthorne (1995) suggested that the species is dependent on large animals such as forest elephants for its dispersal. To corroborate this, Hawthorne (1995) observed *O. aubrevillei* saplings in large forest gaps where elephant populations have been sighted. Therefore, "limited dispersal possibilities and a smaller number of large seeds are likely to decrease the number of encounters with potential hosts and a selective strategy would therefore seem less advantageous in the species-rich rainforest" (Veenendaal et al., 1996a). Furthermore, the tree was also reported to be a non-pioneer light demander (NPLD) tree (Okyeman Environment Foundation, 2003; Marshall and Hawthorne, 2012b). The tree was also observed to be a phorophyte for the epiphytes (Fig. 5). In addition, the leaves of the tree was reported to be a source of food to chimpanzees in Bossou, Republic of Guinea (Hockings, 2007), and the seeds and fruits are eaten by porcupines (Ladipo et al., 2008). Planting trials for the tree indicated that after about 10 years 54% of the plants had survived and had reached an average height of 4.2 m and a maximum height of 8.6 m (Ladipo et al., 2008).

Studies on species rarity is lacking in African tropical forest ecoregions, however ecological studies in the temperate regions suggest negative density dependence as one of the ecological factors that sustain rare species and prevent them from going extinct (Wright, 2002). In addition, *O. aubrevillei* was reported occupying open area in the forest (Veenendaal et al., 1996a) and as a NPLD (Marshall and Hawthorne, 2012b), there is strong indication that forest gap and openings in the forest canopy is important for its establishment and growth in the forest. This adaptation among tree species has been reported by several authors (Whitmore, 1978; Denslow, 1987; Bazzaz and Sipe, 1986). Furthermore, Veenendaal et al. (1996b) reported the significance of forest gap and edaphic factors on the seedling establishment and survival of some West African trees species. In view of this, its hemi-parasitic potential is probably a natural process to create open spaces for the tree to ensure its growth and establishment. Similarly, forest gaps associated with some stands could have been created by the tree employing its hemi-parasitic potentials.

Therefore, rarity and discontinuous spatial distribution of *O. aubrevillei* could be attributed to its low dispersal capacity due to relatively large seed mass, medium to low germination and inadequate forest gap that characterized naturally closed Guinean forests of West Africa. If the assumption that the tree seeds are dispersed by elephants is true, then decimation of elephant populations within the tree's range could be considered a causal factor for its rarity.

7. Reproductive Biology and fecundity of *O. aubrevillei*

The tree is monoecious, therefore it is likely that it undergoes self-fertilization (allautogamy), unless there is mechanism to avoid self-fertilization. Since the matured individuals are widely distant from each other in most cases, chances for cross pollination is very low. Though self-fertilization ensures the survival of widely spaced individuals of a species and maintains genetic stability of traits; it leads to inbreeding depression, low genetic variation and reduced biological fitness which are vital to evolutionary potential of a species in changing

environmental conditions. In Ghana and Côte d'Ivoire where pure stands of the tree are reported, it is possible that the tree could undergo mixed mating system. Mixed mating system has been reported in over 42 % of flowering plants (Goodwillie et al. 2005). The tree flowers between May and July, and fruits in January of each year (Hutchinson and Dalziel, 1958; Poorter et al., 2004).

Since little is known about its pollination, it is assumed that pollination of *O. aubrevillei* flowers follows similar pollination types used by other West African trees, which in most cases, is either by ants (myrmecophily) or bats (cheiropterophily). Like other West African trees, the small greenish flowers of *O. aubrevillei* are not likely to attract birds for pollination. However, scientific investigations and studies are needed to provide accurate information on the tree's reproductive biology. Furthermore, inverse modelling (IM) is recommended for studying and modelling the tree's seed dispersal and fecundity (Jones and Muller-Landau 2008).

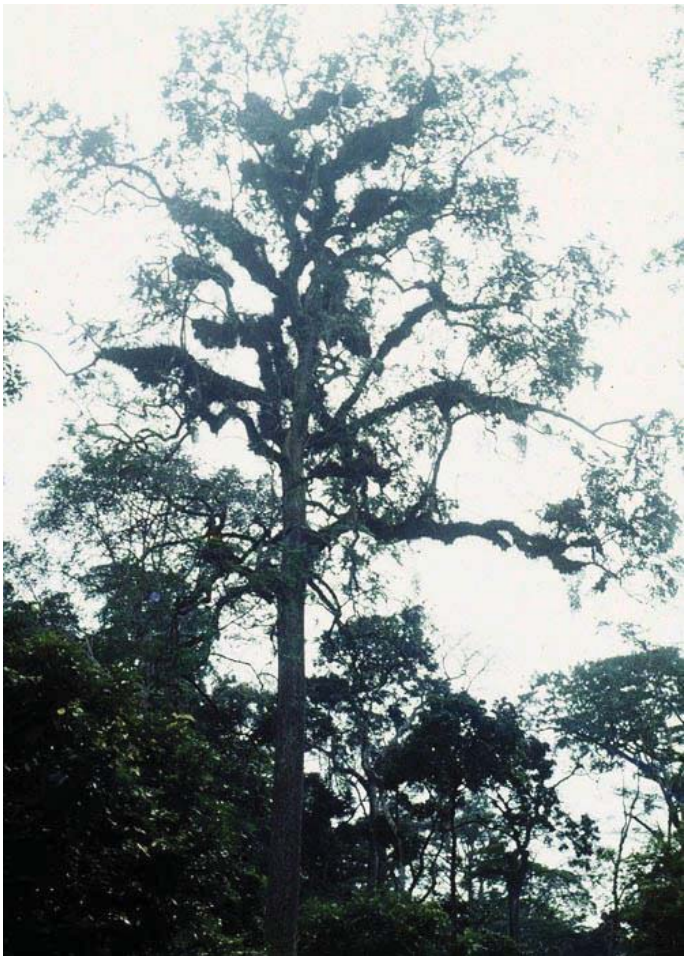

Figure 5. *O. aubrevillei* with epiphytes on it in Ghana (Source: M.D Swain, 1977)

8. Ethnobotanical and Commercial use of *O. aubrevillei*

8.1 Ethnomedicine

In all its native range, the tree is used for various medicinal purposes. The main parts used are the bark and the seeds. The bark is used for treatment of insanity (Osemeobo, 2007). van Andel

et al. (2012) reported the use of the tree bark and seed for treatment of convulsions, as an aphrodisiac, for rituals and prevention of miscarriage. Idu and Onyibe (2007) reported the use of the bark and leaves for reducing swollen testicles (orchitis) among Edo people of Nigeria. In Akoase, Southern Ghana, the seeds were used for ante and postal natal care, and *O. aubrevillei* branch is tied on a broken limb along with other plants for the healing of the limbs (Myren, 2011). Burkill (2000) reported the use of the bark infusion or maceration in water for the treatment of skin problems (including those caused by syphilis and leprosy), while external applications of the bark preparations is used to counteract poisoning. Furthermore, the bark maceration is taken orally to treat tachycardia and is taken as a vapour bath or as nose drops to cure oedema (Burkill, 2000). The bark is also reported to be used as antidotes for venomous stings and bites etc., and in the treatment of dropsy, swellings, gout, heart, leprosy and venereal diseases. In Ghana, the seed of *O. aubrevillei* is being used for the treatment of boils (Dovi, 2013). Kone et al. (2008) reported the use of the tree for antiseptic treatment of wounds.

In addition, the pounded bark of *Milicia excelsa* mixed with the kernel of *Okoubaka aubrevillei* fruits is taken internally in alcohol to cure piles (FAO, 1986; Iwu, 2014). Ita and Offiong (2013) compiled 6 polyherbal mixtures involving *Okoubaka aubrevillei* barks for the treatment of malaria fever, elephantiasis, poisoning and abscess. The authors further noted the high demand and use of the tree bark for diverse medicinal purposes. In addition, the tree is also reported to be used for treating intestinal infection, food intolerances and elimination of metabolic wastes. It is also used in porridge in combination with other plants to strengthen children's bones and allow them to walk early (Myren, 2011). In addition, the European Agency for the Evaluation of Medicinal Products (EMEA, 2000) reported that the pulverized bark of *O. aubrevillei* is used prophylactically at doses of several teaspoons per day by the native Africans for treatment of alimentary poisonings and infections of the gastrointestinal tract. Furthermore, *O. michelsonii* bark is taken as a febrifuge and tonic (Neuwinger, 2000; Ladipo et al., 2008).

8.2 Okoubaka in Modern Medicine

In Nigeria, the stem bark is used for the production of modernized anti-malarial herbal drug, Maloff-HB (Ogunkunle et al., 2014). However, major use of the tree products in modern medicine is in Europe and the USA, where the bark is used extensively for the production of homeopathic drugs and in veterinary medicine. For instance the European Agency for the Evaluation of Medicinal Products (EMEA, 2000) has reported its use in homeopathy (man and animal) with no adverse effect. In studies, *Okoubaka* has demonstrated its potentials to stimulate the body's defense mechanisms against poisonings. The bark extract has been proven to be effective against stomach upsets and body reactions caused by food-poisoning, pesticide poisoning, many self-poisoning (auto toxic) diseases, lethargy, depression and allergies. This is because *Okoubaka* helps the body regain control and normalizes the immune system to fight off other potential aggressors. In addition, the tree is infused into topical solutions which are utilized to treat skin problems resulting from leprosy and syphilis, as well as to counter the effects of external poisoning. Minter (2009) listed *Okoubaka* as one of the top 300 herbal medicinals sold in the UK. In Germany the tree bark is especially known in paediatric medicine and some colleagues use it more frequently than Nux-vomica for gastro-intestinal disorders in dogs (Kohlrausch, 2011).

The history of the medicinal use of this plant in Europe involved Dr. Magdalena Kunst from Frankfurt, a homeopath, being told by a West African native of the uses of the tree to neutralize poisons in food. The curious Dr. Kunst and Dr. Schwabe conducted experiments which validated the efficacy of the tree's bark in homeopathy in 1972, and they published around 80 case histories in the German magazine, Allgemeine Homöopathie Zeitschrift (AHZ) (Kohlrausch, 2011).

Homeopathic drugs containing *O. aubrevillei* bark extracts include Allergy relief Pollinosan (A. Vogel/Bioforce), Allergy relief (Bioforce USA), *Okoubaka aubrevillei* (VSM), Pleo Oku (Okubasan) by Biomed, Detox intestinum (Hevert, USA), Okoubaka drops (Pekana), Rubus (Biomed), Eubioflor 1 (Guna Biotherapeutics), Pollinosan Luffa nasal spray (A. Vogel/Bioforce), Pollinosan hay fever (A. Vogel/Bioforce), Okugest tablets (VSM). Furthermore, several veterinary diseases are being treated using varying preparations of the tree bark active ingredients. Several pharmacological concentrations from the tree bark are used for the drug synthesis and for pharmaceutical research. Such concentrations include *Okoubaka* C200, C30, D12 and C12 granules among others. Teut et al. (2013) screened the homeopathic efficacy of *Okoubaka* C12 on volunteer subjects.

8.3 Symbolism and Associated Taboos

O. aubrevillei is considered a sacred tree and used for magical purposes (Marshall and Hawthorne, 2012a) in most of its locations in West Africa. EMEA (2000) reported that the tree is used as a fetish by medicine men in West Africa. Azeez et al. (2010) listed the tree as one of the sacred trees among Benin people in Nigeria, while Isikhuemen and Iduozee (2008) reported that the tree is considered the king of the forest in rural Edo State, Nigeria.

It is reported to be worshipped as a god in Iwara town, Osun State (Ladipo et al., 2008) and some parts of Edo State, Nigeria. In Nigeria, some traditional incantations noted that it is the only tree that can never be struck by lightning (Akinpelu, 2009). Furthermore, Yoruba people of Nigeria believe powerful spirits in the tree are responsible for preventing other plants from growing near it, thus increasing the more respect for the tree. The tree is used for incantations for crop harvest, preparation of traditional medicines, and prevention of rainfall or forcing rain to fall for cultural ceremonies and festivals (Osemeobo, 2007), while all parts of the tree are used to ward off evil spirits and treat sundry ailments (Isikhuemen and Iduoze, 2008). In southern Nigeria, it is an important tree in religious ceremonies (Ladipo et al., 2008).

The Asante people of Ghana considered Odii (*O. aubrevillei*) among others as having spirits (Cobbinah et al., 1999). van Andel et al. (2012) reported that the tree bark is sold in Ghanaian herbal markets for making rituals. Furthermore, the tree is considered a sacred tree and located in sacred forests/shrines in Akoase, Southern Ghana. It is believed that the spirit named *Motia* lives in the tree (Myren, 2011). Sometimes, people had to be completely naked before they can visit the tree, and had to make offerings before they can collect the bark (Myren, 2011). In Nzema (Ghana), the tree is used for spiritual protection, treat spiritual problems such as frequent still births, bad luck, bad dreams and correct bad marriages (Myren, 2011). In addition, *Okoubaka aubrevillei* is reported to be used symbolically to ward off evil spirits in Côte d'Ivoire (Cunningham, 2000).

The use of the tree for spiritual protection was reported by Maundu et al. (2006) and many publications. Myren (2011) reported the use of the tree bark for spiritual protection in Akoase and Nzema, Ghana. Hardie (1963) reported the use of the tree in making charms to drive away evil from a house, and also to inflict a curse upon an enemy among Bini people. Ita and Offiong (2013) reported the use of the bark as part of the polyherbal formulations for wading off witchcraft and protection from charms in Cross River State, Nigeria. EMEA (2000) noted its symbolical use for wading off evil spirits. Burkill (1985) reported that West African natives place a piece of the bark in a house to drive out spirits and robbers and offered protection against car accidents.

As a result of the veneration given to the tree, several taboos, traditional practices and beliefs are held for the tree, which include:

1. The harvester must appease the spirit of the tree with libations or rituals before approaching the tree for harvesting (Isikhuemen and Iduoze, 2008; Myren, 2011; Falconer, 1992; Good, 1987), and sometimes, the harvester must approach the tree with complete nakedness (Myren, 2011; Hardie, 1963). After harvesting, the harvester is strongly advised to quickly run away from the tree and dress up so that in case the tree spirits are not satisfied with the appeasement, and pursues the harvester, they may not be able to identify him when fully dressed (Oliver-Bever, 1960).
2. Items used for libations include portions of kola nut, white yam, cocoyam and plantain, two cowrie shells, a piece of white drill cloth and a quantity of chalk (Hardie, 1963).
3. The bark may be harvested by day or at night – never at sunrise or sunset when the tree 'spits poison' (a dark poisonous liquid) (Hardie, 1963). In addition, the harvester must not harvest the bark in his own shadow (Myren, 2011).
4. The Bini (Benin) people of Nigeria believe that *Myrianthus arboreus* and *Musanga cecropioides* (the only plants that grow beside *Okoubaka*) are the wife and servant of the tree respectively (Hardie, 1963).
5. It is believed in Ghana that dwarfs are associated with the area where the tree grows (Owusu-Sekyere, 2008).
6. The bark of the tree can only be harvested with a wooden batten, and under no circumstances may a machete or metal implement be used. This rule is applicable in the entire West African region (Hardie, 1963; Osemeobo, 2005)

8.4 Pharmacology

Wagner *et al*. (1985) reported 6 different catechins which have been isolated from the tree's bark. These catechins include (+)-catechin and (+)-gallocatechin, as well as β-sitosterol and stigmasterol. They further reported that the bark has antimicrobial and immuno-stimulating properties that are attributed to phenolic compounds (Wagner et al., 1985). Due to its contents of tannin, catechols and phenylcarbonic acids, this plant is a typical tannin drug with strong phagocytosis promoting effects. The tree leaf was reported to contain glycosides, saponins, steroids, while the root/trunk bark contains alkaloids. Furthermore EMEA (2000) reported sterines (beta-sitosterine, stigmasterine, sterine acetate), amino acids, tannins and catechins

(catechin, gallocatechin, epicatechin, epigallocatechin, epicatechin-gallate, epigallocatechin-gallate), gallic acid, pyrogallol and di-and triglycerides.

In a study by Dovi (2013), the seeds of *Okoubaka aubrevillei* extracts showed a scavenging ability with an IC_{50} of 731.0987 µg/ml and 865.6633 µg/ml for methanolic extract and hydro-ethanolic extract respectively. Furthermore, the phenol content of hydro-ethanolic and methanolic extracts of *O. aubrevillei* seeds was quantified (0.1707 mg/ml and 0.2573 mg/ml respectively); while the seed extracts of the tree showed considerable antimicrobial activities against *Staphylococcus aureus* and *Bacillus substilis* (Dovi, 2013). The methanolic extracts of the seeds were found to contain alkaloids, while the hydro-ethanolic extracts contain both saponins and alkaloids (Dovi, 2013). Furthermore, Kone et al. (2008) investigated in vitro antimycobacterial potentials of total aqueous extracts of *O. aubrevillei* against 7 strains of *Mycobacterium ulcerans* from different regions. In Africa the wood and the dried and pulverized bark of *O. aubrevillei* is currently being studied because it could possibly have a pancreatic or similar enzyme action. (Nacci, 2010).

8.5 Other Uses

The tree yields quality wood which is used in forestry. The wood is sometimes used for construction or as firewood (Ladipo et al., 2008). *O. aubrevillei* stem bark is used as fish poison in Liberia (Neuwinger, 2004), while the seeds are used ethnobotanically as insecticide among the Asante people of Ghana (Cobbinah et al., 1999).

9. Conservation and Management of *O. aubrevillei*

9.1 Conservation Status of Okoubaka

Since there is no globally accepted conservation rating for this species, the only available ratings are the published ones from some of the native countries. All of the authors that attempted to classify the tree's conservation status noted that the tree is faced with threats in all its native range. Conservation status for the tree ranges from "vulnerable" (Ladipo et al., 2008; Maundu et al., 2006); "endangered" (Isichei, 2010; Okyeman Environment Foundation, 2003) and in Côte d'Ivoire's Union Postal stamp (Fig. 6); "rare" (Hardie, 1963; Isikhuemen and Iduozee, 2008); and "critically endangered" (Borokini and Clement, 2012). In addition, concluding from their studies, van Andel et al. (2014) recommended the tree be given an IUCN status of vulnerable A3cd.

Borokini and Clement (2012) noted that the tree bark was relatively expensive in visited herbal market in Ibadan, while the herb sellers claimed it is scarce, just as reported scarce by other medicinal vendors across West Africa (Burkill, 1985; Cunningham, 1997; van Andel et al., 2012). Isikhuemen and Iduozee (2008) reported that very few stands of the tree is remaining in the wild, and the ones they sighted were actually young coppices (Fig. 3). Osemeobo (2005, 2007) estimated that less than 20 standing trees of this species remain in Nigeria. In Ghana, the tree is considered "endangered" and assigned "gold stars" indicating that it requires conservation priority after species with highest priority, designated "black stars" (Okyeman Environment Foundation, 2003), while CUC (2010) listed it with "blue stars", which a conservation rating just below gold stars. Yet, van Andel et al. (2014) reported 241 kg of the

tree products offered for sale in Ghanaian medicinal plant markets. In a survey, *Okoubaka aubrevillei* ranked the highest among over 100 trees used for NTFPs in 7 communities (Barpa, Bentor, Gbapa, Makinto, Sehyigeh, Vanyampah and Zolowee) in Nimba Western Area, Liberia and therefore should be given priority for protection (URS, 2013). The SDM analysis indicate a very narrow suitable habitat area of less than 4 km^2 for the tree in Benin Republic (van Andel et al., 2014).

The genus *Okoubaka* has just two species and a variety, all of which have a relatively limited geographical range, and based on the records available for this species, the population of *O. aubrevillei* in its range is probably less than 250 mature individuals. Though the distribution range is more than 100 km^2, it has been shown to be rare in all its reported locations, while high demand for its bark and seeds for medicine as well as its highly priced wood has influenced the decimation of the populations in all its range. This description of the state of *O. aubrevillei* fits into the IUCN status (IUCN Categories and Criteria, version 3.1, IUCN, 2001) of "critically endangered" species based on criteria B2bc, C1 and C2a. The status of *O. michelsonii* also meets IUCN Categories and Criteria for critically endangered rank based on criteria B2ac, C2a and D.

Figure 6. Image of *Okoubaka aubrevillei* on the Union Stamp of Côte d'Ivoire

9.2 Current Management and Protection of Okoubaka

There appears to be no specific conservation programs for the tree in all its ranges. Ladipo et al. (2008) reported the attempt to propagate the tree in DRC, while Burkill (1985) reported a national ban on the possession or sale of *Okoubaka* bark in Liberia some decades ago. However, there is no evidence to support the enforcement of the law. In few locations, as described in the geographical locations, the tree is located in protected areas such as in Sapoba FR, Ehor FR, Uhronigbe FR (Nigeria), Atewa Range FR (Ghana), Parc National de Taï, forests of Sanaimbo, Yapo Forest reservation (Côte d'Ivoire), Lobeke reserve, Deng Deng Forest (Cameroon), Ituri Forest (DRC), Dzanga Sangha Protected Area complex (Central African Republic) and Gola

Forest Reserves (Sierra Leone). This tree was not reported in any ex-situ conservation site in all the countries where it is found. Although van Andel et al. (2014) reported that its natural habitat (primary rainforest) in eastern Liberia to Southwest Ghana and the Congo Basin is 73% intact, data used for that study did not include some of the countries, such as Nigeria and Gabon where occurrence have also been reported. Furthermore, it is believed that the tree population is declining rapidly, as the tree is now absent in locations where herbarium samples were collected in the 1950s.

Due to veneration and dendrolatry practices on the tree, traditional protection seems very strong and effective, especially in areas where traditional institutions are strong in West African countries. Furthermore, the general practice of pre-harvest libations and bark harvesting with wooden batten offers some form of traditional protection and reduction in harvest pressures. In addition, in many parts of West Africa where forests are cleared for farming, sacred trees are spared from destruction hence, Mafimisebi and Oguntade (2010) reported the protection of *O. aubrevillei* in farmlands. Hardie (1963) reported traditional prohibition of bark harvesting on tree among Bini people of the present Edo State, Nigeria.

9.3 Threats to Okoubaka

The tree is faced with both natural (biological) and anthropological threats. Seed germination for *Okoubaka* seedling regeneration is extremely poor (De la Mensbruge, 1966; Hawthorne, 1995), as trials carried out in National Centre for Genetic Resources and Biotechnology, Ibadan in the 2000s yielded only 3 seedlings (NACGRAB, 2004), while Ladipo et al. (2008) noted that the tree has poor natural regeneration ability and the seeds are eaten by porcupines. Based on seed classification by Roberts (1973), *O. aubrevillei* seeds are believed to have recalcitrant behavior and Veenendaal et al. (1996a) recommended planting freshly collected fruits.

Perhaps the major concern for the tree is its uncontrolled exploitation for seed and bark which are used in both ethnomedicine and modern medicine. van Andel et al. (2012) reported that the tree bark is one of the most frequently sold species in Ghanaian herbal markets, while Hardie (1963) reported scarring and heavy debarking on a stand in Sapoba FR in Nigeria in spite of traditional laws prohibiting bark harvesting. Myren (2011) noted that a tree stand in the sacred forests/shrines in Akoase, Southern Ghana was felled. Isikhuemen and Iduoze (2008) cited harvest pressure and habitat loss as threats to the tree. The tree is under serious threat as a result of habitat loss and deforestation in Ghana, Nigeria and Côte d'Ivoire, to the extent that vendors and harvesters reported it to be scarce. Though considered a sacred tree, experts in Côte d'Ivoire claim that the tree is felled to allow for farming in many areas. This is in contrast to the general practise of sparing sacred trees when clearing land for farming.

Local and international markets abound for the tree bark and seed, with most international markets and sources for European homeopathic drug manufacturing originating from Cameroon, Ghana and Côte d'Ivoire. Heavy exploitation was reported in Nigeria, Ghana and particularly Cameroon which feeds the European medicine markets (Good, 1987). While local information indicate that the bark is sold for about US$ 20 per kg, reports on the international trade of this species is lacking (Ladipo et al., 2008). Bark harvesting in medicinal trees is very common in the entire African region where ethnomedicine is predominant, but tree recovery

after extensive debarking varies from species to species with most of the tropical trees exhibiting slow recovery (Fashola and Egunyomi, 2005).

While traditional beliefs is the main form of protection for this species, traditional institutions are losing their significance and respect in many parts of West Africa. The fears for the taboos that had helped protected some sacred trees are no longer relevant, while scientific research has explained and de-mystified some "mysterious phenomena" surrounding some sacred trees, including the hemi-parasitism potentials of *Okoubaka*. As a result of scientific enlightenment, relative economic hardship and demand for its wood, harvesters could easily approach the tree and harvest its parts without restriction in many places. Myren (2011) reported the felling of an *Okoubaka* stand even within a sacred forest in Akoase, Ghana. In spite of traditional prohibition of bark harvesting among Bini people of Nigeria, Hardie (1963) sighted stands of the tree in Sapoba FR with heavy debarking and scarring. In addition, Marshall (2011) predicted that the 2 stands in the ridge top forest in Liberia would be negatively impacted by the proposed ridge top mining operations.

The populations of the tree appears to have declined sharply in the last 60 years, as many locations in Cameroon, Ghana, Sierra Leone and Côte d'Ivoire where herbarium samples for the tree was collected in the 20th century are currently invalid because the tree is absent in those locations. As a result, over 25% of the tree population is estimated to have been lost in the last 50 years. Although the population of matured individuals for this tree is unknown, field experience indicate as low as less than 100 matured trees across the entire West and Central Africa, which are widely distant from each other. Being a monoecious plant, this could point to high inbreeding depression from self-fertilization, low genetic variation and reduced biological fitness. As a result, its chances of adapting to changing climatic conditions is low. Low genetic variation has been reported among other monoecious species of Santalaceae (Gonzalez-Perez et al., 2013).

Despite the fact that the tree is reported in protected areas in many parts of its ranges, strict protection and management of protected areas have been characterized by widespread encroachment, poor staffing, inadequate funding, presence of enclave villages, land conversion to farming and several other illegal activities in Nigeria (Meduna et al., 2009; Oseni, 2007), and other African countries (Struhsaker et al., 2005; Jachmann, 2008; Weladji and Tchamba, 2003).

10. Recommended Conservation and Research Actions

Several authors have given recommendations on urgent actions that need to be taken for the conservation of this species. Cunningham (1993) recommended carrying out "damage assessments for exported species such as *Okoubaka aubrevillei, Garcinia afzelii* and *G. kola* in West Africa, especially Ghana, Côte d'Ivoire, Nigeria." He further recommended studies on the genetic diversity and the population biology of *O. aubrevillei*, which would provide adequate information for the conservation and management of the species. Veenendaal et al. (1996a) recommended raising seedlings from freshly collected seeds for subsequent establishment in protected areas, as well as population studies on the species. Ladipo et al. (2008) advocated for monitoring of the sales and exportation of the species, as Ariz. Univ. Office of Arid Land Studies (1981) also called for its conservation. Borokini (2014) recommended IUCN

conservation rating for this species while Marshall and Hawthorne (2012a) reported that indigenous communities expressed concern for the conservation of the tree in Liberia.

In addition to these recommendations on required research efforts on this species, the following recommendations are also necessary:

1. There is an urgent need to include *O. aubrevillei* in CITES listing for countries with active exportation to Europe, especially Cameroon and Ghana. Process of doing this will require adequate statistics of international trade for the species. This will help enhance conservation management and protection for the tree.
2. Research is required to study the recovery potentials of this species to debarking
3. While there are conflicting reports on the germination rates of the seed, there would be the need to conduct standard silvicultural trials on the seeds to determine its germination success. In the same vein, studies would be important to predict the seed longevity with the use of seed longevity models and to predict the morphological characters of the seed germplasm of *O. aubrevillei* using appropriate Seed Digital Imaging tools. This will provide foundational knowledge on the best practices for the tree's seed management.
4. It will be beneficial to develop micro-propagation (tissue culture) protocols for mass production of plantlets from different provenances. However, the seedlings or plantlets produced from these experiments should be established in protected areas.
5. Furthermore, anatomical studies on the leaves, receptacle, flowers and other plant parts of taxonomical interests should be done, while existing information should be revised, including the physiology of the tree. This was supported by earlier submission of Nickrent and Der (2008) indicating disagreement on the homology of the perianth lobes.
6. Most of the knowledge on the tree is in the repository of the local people in all its range, which Osemeobo (2005) reported it being held in secrecy. This was also observed in Liberia (URS, 2013) where the communities refused to show the tree stands to the scientists. Similar situation was also observed in Cross River State, Nigeria. Therefore, collaborative studies should be carried out among botanists, ethnobiologists and the indigenous people in order to expand knowledge base on the tree, as well as the conservation of the tree. However, indigenous knowledge should be carefully protected.
7. The spatial distribution pattern of the tree (Fig. 4) suggests a disjunct distribution within West and Central Africa, however exploration may be required within the Guinean forest-savanna mosaic ecoregion in the Dahomey Gap (Togo and Benin Republic) and Congo Republic, especially in forest gaps and slopes which provide perfect sanctuary for the tree. Prospects for stands of this tree in new locations are further amplified by the new locations – Burkina Faso and Central African Republic. Aside explorations, working with herb sellers, harvesters and local communities in addition to herbarium curators have proved very effective in locating plants.
8. Though the tree has been established as hemi-parasite, further studies is required on the chemical ecology of patterns of its parasitic potentials, and the anti-parasitic potentials in *Myrianthus arboreus* and *Musanga cecropioides* is also worth investigating.

9. Foresters may want to investigate the volume prediction and inventory analysis for all the stands of the tree species, while plant physiologists may have more information to share with the scientific world on the leaf area and general physiology of the tree, with respect to its hemi-parasitic nature.
10. While Cunningham (1993) recommended studying the population biology of this species, the author wishes to emphasize the need to study population dynamics, population viability analysis, dispersal capacity and the relationship between density and population growth rate (pgr) of *O. aubrevillei* within its native range.
11. With a recent placement of the tree in a new family, Cervantesiaceae (Dar and Nickrent, 2008; Nickrent et al., 2010), further taxonomic investigations on the tree would be needed to confirm or negate this.
12. Scientific knowledge on the reproductive biology of this tree is extremely crucial to conservation planning and management of the tree. Studies are therefore, needed to provide the much needed information on its flower morphology, pollination type, fertilization type, fruiting and dispersal.

While urgent efforts need to be taken in form of conservation and research studies, various stakeholders in the value chain of this tree should be identified and actively involved. Importance should be attached to the involvement of the indigenous people, while relevant European medicine manufacturers should be encouraged to finance research and conservation efforts on the tree.

11. Conclusion

This paper have provided a compendium of baseline scientific information on this rare, threatened, hemi-parasitic and medicinal tropical tree species. New hypotheses regarding its hemi-parasitic potentials were provided, additional locations were documented, and the entire geographical distribution of the genus was represented on topo-geographic map. It is expected that this article will help provide information base for a globally-accepted conservation ranking for the species, and stimulate further research on the species.

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