Cochlospermum planchonii *Hook.f. ex Planch. and* Cochlospermum tinctorium *Perrier ex A. Rich.: extent of knowledge and prospects for sustainable use in West Africa*

Gnimansou Abraham Favi, Gbèwonmèdéa Hospice Dassou, Aristide Cossi Adomou, Adandé Belarmain Fandohan, E. O. Dêêdi Sogbohos et

Genetic Resources and Crop Evolution
An International Journal

ISSN 0925-9864

Genet Resour Crop Evol
DOI 10.1007/s10722-020-01062-8

Springer

Genet Resour Crop Evol
https://doi.org/10.1007/s10722-020-01062-8

REVIEW

Cochlospermum planchonii Hook.f. ex Planch. and *Cochlospermum tinctorium* Perrier ex A. Rich.: extent of knowledge and prospects for sustainable use in West Africa

Gnimansou Abraham Favi · Gbèwonmèdéa Hospice Dassou · Aristide Cossi Adomou · Adandé Belarmain Fandohan · E. O. Dêêdi Sogbohossou · Hounnankpon Yedomonhan · Monique G. Tossou · Akpovi Akoègninou

Received: 27 March 2020 / Accepted: 5 November 2020

Abstract *Cochlospermum planchonii* Hook.f. ex Planch. and *Cochlospermum tinctorium* Perrier ex A. Rich. are two wild edible plant species (WEPs), widely used in the West African Sudanian zone. Their parts are used as food additive, fodder, medical-magic and ethnoveterinary purposes, dye and arts. Unfortunately, the overexploitation of their rootstocks constitutes a great threat. While, an increasing number of studies reported on their uses, socio-economic importance, biological properties, and the anthropogenic pressure, knowledge on their reproductive biology, threats, domestication, and conservation status are still lacking. It therefore becomes crucial to systematically review literature on the current knowledge to identify research gaps and future research. Hence, this review aimed to critically synthetize knowledge, and gaps therein, to highlight future research for sustainable use and conservation of both species. To this end, publications were searched online in Web of Science, PubMed, Google Scholar, Science Direct, Springer Online and Research Gate, using following keywords: "taxonomy", "distribution", "ecology", "botanical description", "structural characteristics", "vernacular names", "uses", "plant parts used", "phytochemical" and "pharmacological properties", "economy", "propagation", "pollination", "reproduction", "threats", "conservation" and "domestication" in combination with "*C. planchonii*" or "*C. tinctorium*", "False-cotton". Out of 423 publications initially recorded, 165 were retained, of which 153 conducted in West Africa; the remaining 12 tackled botanical and taxonomical issues. Most of the publications addressed ethnobotany, chemical and pharmacological properties. Information obtained was compiled, critically analyzed, and discussed; knowledge gaps were keyed out and potential future research was highlited. The review confirmed the over-exploitation of both species mainly for human livelihoods. Both species were valuable sources of compounds and showed various pharmacological activities. A risk of genetic erosion was reported due overharvesting of their rootstocks whose powder was highly marketable. Future studies on their reproductive biology could enable their cultivation in order to reduce anthropogenic pressure and promote their sustainable use and conservation.

G. A. Favi (✉) · G. H. Dassou · A. C. Adomou · H. Yedomonhan · M. G. Tossou · A. Akoègninou
Laboratoire de Botanique et Ecologie Végétale, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, 01 BP 4521, Cotonou, République du Bénin
e-mail: gnimfavi@gmail.com

A. B. Fandohan
Unité de Recherche en Foresterie Agroforesterie et Biogéographie, Ecole de Foresterie Tropicale, Université Nationale d'Agriculture, BP 43, Cotonou, République du Bénin

E. O. D. Sogbohossou
Laboratoire de Génétique, Horticulture et Sciences des Semences, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 01 BP 526, Cotonou, République du Bénin

Published online: 19 November 2020

Keywords Cochlospermum · Wild edible plants · Conservation ecology · Sustainable management · West Africa

Introduction

In Western Africa *et alibi* in the tropics, Wild Edible Plants (WEPs) play a central role in the livelihoods of rural communities. Millions of people, mostly in developing countries, owe their daily needs and income to products derived from WEPs (Uprety et al. 2012). Importance of WEPs for rural communities in West Africa has been thoroughly documented in the last two decades (Lykke et al. 2002; Shackleton and Geach 2004; Assogbadjo 2006; Heubach et al. 2011; Sieglstetter et al. 2011). Services associated to WEPs include food, fodder, medicines, timber, and fuelwood, to mention just a few (Kristensen and Lykke 2003; Kahane et al. 2013). With contemporary problems facing crop production (variation in climate, land degradation and pest attacks), WEPs are of critical importance in local coping strategies (Neuenschwander et al. 2011). Unfortunately, in most cases, no formal strategy is put into place to ensure sustainable use of major WEPs. WEPs including *Caesalpinia bonduc* (L.) Roxb. and *Garcinia kola* Heckel (Assogbadjo et al. 2012) disappeared in the wild while populations of other WEPs such as *Lippia multiflora* (Adomou 2005); *Vitex doniana* Sweet (N'Danikou et al. 2011); *Bombax costatum* (Assogba et al. 2018) and West African *Cochospermum* species (Oyen 2010; Inácio et al. 2011) are declining.

Cochlospermum spp., subshrub species, are among the major food additives in semi-arid lands of West Africa (Johnson-Fulton 2014). All their organs, but mainly the rootstocks, are involved in a wide range of uses such as food additives (Adjanohoun et al. 1989), fodder for cattle (Ouachinou et al. 2018), medical-magic purposes (Olotu et al. 2011; Johnson-Fulton 2014), ethnoveterinary uses (Belem et al. 2007; Dassou et al. 2015), and art (Nikiema 2005; Belem et al. 2007). These wide range of utilisations are the main factors associated to the decline of the *Cochlospermum* spp. (Oyen 2010; Nergard et al. 2005) and expose them to genetic erosion risks (Inácio et al. 2011).

In addition to the threats related to the degradation of their habitats and their exploitation as medicines and food resources, there is a local trade around the rootstocks in many countries such as Benin and Burkina Faso (Achigan-Dako et al. 2010; Johnson-Fulton and Watson 2018). The rootstocks collection would negatively impact natural regeneration and the demographic structure of natural populations. This cannot guarantee a sustainable use of this noble species.

Although no official assessment is available, there is on-the-ground evidence that these species are highly threatened because their rootstocks are the main plant part exploited; which often results in killing individual subshrubs. Extirpation of key WEP species from traditional production systems would probably worsen vulnerability of local dwellers to contemporary environmental shocks such as climate change, land degradation and drought. Indeed, in some countries such as Benin, *Cochlospermum* spp. rootstocks exploitation constitutes a major income source for rural women (Achigan-Dako et al. 2010; Vodouhè and Dansi 2012). Conservation of WEPs however, requires substantial and consistent investments in policy and research efforts into their in situ conservation, their sustainable management, and domestication. Besides, with the current attention given to climate-smart-agriculture in the tropics, potentials of WEPs will only be realized if candidate species are well documented so as to backup policies and decision making (Assogba et al. 2018). The present review attempts to synthetize the state of knowledge, gaps and research prospects for ensuring the sustainable use and conservation of *Cochlospermum* species in West Africa. It focuses on taxonomy, botanical description, pollination, reproduction biology, ecology and distribution, uses and socio-economic importance, phytochemical and pharmacological properties, threats and conservation of *Cochlospermum* species (*C. tinctorium* and *C. planchonii*) in West Africa.

Methods

Data collection

Literature searches were conducted on *C. planchonii* and *C. tinctorium* using journals, thesis and books and presence occurences available online. The following

electronic search engines: Web of Science, PubMed, Google Scholar, Science Direct, Springer Online and Research Gate were used for literature while geographical records were sourced from GBIF (GBIF 2018) and RAINBIO (Dauby et al. 2016). Publications were considered regardless the year, while the selection of presence occurences covered the period of 1980–2016. Specimens at the National Herbarium of Benin were reviewed and Atlas of West Africa was sourced from Terrestrial Ecoregions of the World maps' (TEOW) (Olson et al. 2001). The search terms used were: "taxonomy", "distribution", "ecology", "botanical description", "structural characteristics", "vernacular names", "uses", "plant parts used", "phytochemical" and "pharmacological properties", "economy", "propagation", "pollination", "reproduction", "threats", "conservation" and "domestication" in combination with "*C. planchonii*" or "*C. tinctorium*", "False-cotton".

Data selection and compilation

All publications that mentioned both species were considered. Search results were screened through the titles, abstracts and keywords and those relating to taxonomy and botanical description were considered regardless the location of the study. However, regarding the traditional knowledge (uses and socio-economic importance), and various properties (mineral, chemical and pharmacological aspects) of both species, only those studies that were conducted in West Africa were selected. Thus, relevant publications were downloaded and arranged by species. Afterwards, publicatons were rigorously read and the information contained were compiled according to the field(s) and aspect(s) addressed. Search data compiled for this review were structured following these aspects: (1) taxonomy and botanical description, (2) distribution and ecology, (3) pollination and reproductive biology, (4) ethnobotany, (5) socio-economic importance, (6) phytochemical and pharmacological evidence and (7) threats and conservation status. Researches conducted in West Africa were sorted out by country of the study and field of study. A graphic expressing spatial distribution of publications according to aspects addressed were constructed using Excel 2013.

The species botanical descriptions were provided based on the differential reproductive and vegetative characters according to Hutchinson and Dalziel (1958), Akoègninou et al. (2006).

Considering the traditional uses, the percentage of countries reported to treat a given ailment was estimated and referred to as the therapeutic convergence. Two classes were retained for each ailment (High therapeutic convergence $\geq$ 50% and low therapeutic convergence $<$ 50%). Then, ailments were grouped into the major categories corresponding to various body systems (Heinrich et al. 1998; Faruque et al. 2018); ailment non-specific to a given system being considered as general healthcare. In order to determine for each species the plant parts or organs mainly used, the frequency of use was calculated for each organ based on the number of diseases reported for a given organ. Graphics were constructed to express and synthetise the results of the above analyses.

Occurences data were sourced online through GBIF (http://www.gbif.org) and RANBIO (http://rainbio.cesab.org/). Presence records found were check through to withdraw duplicates using excel (Warren et al. 2011; Stigall 2012). The spatial distribution maps of both species were established with occurrences selected overlaid with Atlas of Africa, using ArcGIS 10.2 (ESRI, Redlands, California, USA). The ecology of both species was documented using information on vegetation types combined with their spatial distribution.

Pharmacological activities investigated and other potential properties were synthetized in a table based on the groups of chemical compounds identified in each plant organ.

The threats and conservation status of both species was discussed using the available data in the literature including data of the International Union for Conservation of Nature (Cota 2018).

Results

Selected publications and spatial distribution

A total of 423 publications records were initially identified through electronic search engines. During the screening and refining steps, 258 non-eligible publications (studies with unrelated topic, outside the West Africa, and duplicates) were excluded. Hence, 165 publications published from 1847 to 2019, of

which 158 articles, 4 thesis, and 3 books were finally considered in this review. Out of those, 153 (109 mentioning *C. tinctorium* and 86 mentioning *C. planchonii*) were conducted in West Africa and addressed the ethnobotany (e.g. traditional uses, local name, socio-economic importance), chemistry, pharmacology, ecology, and distribution range. Very few publications focused on the botanical description (anatomy), pollination ecology, reproduction biology, and conservation status (Fig. 1). The Fig. 2 shows the spatial distribution across the twelve West African countries where studies have been carried out on *C. planchonii* (Fig. 2a) and *C. tinctorium* (Fig. 2b). Indeed, concerning *C. planchonii* (Fig. 2a), ethnobotanical (ETH) studies were reported in almost all countries (with Benin, Nigeria and Ivory Coast showing the highest number of publications) and were followed by chemical and pharmacological researches (MCP) mostly conducted in Nigeria and Burkina-Faso. Only two countries (Benin and Burkina Faso) showed the top five aspects addressed. The trends was almost the same for *C. tinctorium* (Fig. 2b) with Benin, Burkina-Faso, Senegal and Nigeria showing the highest number of studies on ETH while Nigeria, Mali and Burkina-Faso revealed the greates number of studies on MCP. It was noted that other aspects such as reproductive biology, propagation trials, and species abundance on both species were very poorly addressed. A total of 1004 records (959 from GBIF and 45 from RAINBIO) for *C. tinctorium* and 1070 records (996 from GBIF and 74 from RAINBIO) for *C. planchonii* were downloaded. After the refinement of the data set, 449 records (420 from GBIF and 29 from RAINBIO) for *C. tinctorium* and 521 records (463 from GBIF and 58 from RAINBIO) for *C. planchonii* and covering the period 1980–2016, were considered for mapping the geographical distribution.

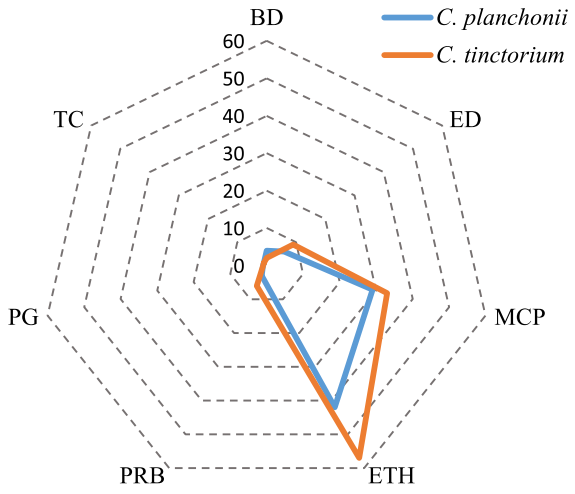

Fig. 1 Aspects addressed in studies on *C. planchonii* and *C. tinctorium*. *BD* botanical description, *ED* ecology and spatial distribution, *MCP* mineral, chemical and pharmacological studies, *ETH* ethnobotany, *PRB* pollination and reproduction biology, *PG* propagation and growth, *TC* threats and conservation status

Taxonomy and botanical description

Cochlospermum Kunth, established by Planchon (1847), is the sole genus of Bixaceae (previously Cochlospermaceae, order Malvales) in West Africa, and was named from the Greek words "kochlos", meaning snail or snail shell and "sperma", corresponding to seed (Quattrocchi 1999). The genus is represented in West Africa by two species among the twelve worldwide, *Cochlospermum tinctorium* Perrier ex A.Rich. and *Cochlospermum planchonii* Hook.f. ex Planch.(Hutchinson and Dalziel 1958; Hepper 1977). Suffrutescent shrubs, xeromorphic (Ogundipe and Olatunji 1991; Johnson-Fulton and Watson 2017), they are characterized essentially by woody subterranean stems (rootstocks), palmately-veined and lobed to dissected leaves and capsular fruits (Poppendieck 1980). Annual leafy shoots are produced from woody subterranean rootstocks in the rainy season, reaching 80 cm tall in *C. tinctorium* (Jansen 2005) and 1.5–2.5 m tall in *C. planchonii* (Akoègninou et al. 2006). *C. planchonii* flowers towards the end of the rainy seasons and fruits appear 1–2 months after flowering (Jansen 2005). Flowering of *C. tinctorium* is in the dry season after the savanna burns, and the fruits are ripe about 1 month after flowering (Jansen 2005; Akoègninou et al. 2006). Both species are diploid with $2n = 12$ chromosomes (Morawetz 1986; Molero et al. 2006) and show some key morphological characters (Table 1 and Fig. 3). The genus *Cochlospermum* was originally arranged in Cochlospermaceae (Takhtajan 1980; Cronquist 1981; APG 1998). This family was afterwards considered as synonym family of Bixaceae by Angiosperm Phylogeny Group II (APG 2003) and finally was included in Bixaceae family (APG 2009, 2016).

Moreover, presence of the intermediate form, *C. intermedium* Mildbr. was reported in the Sudanian

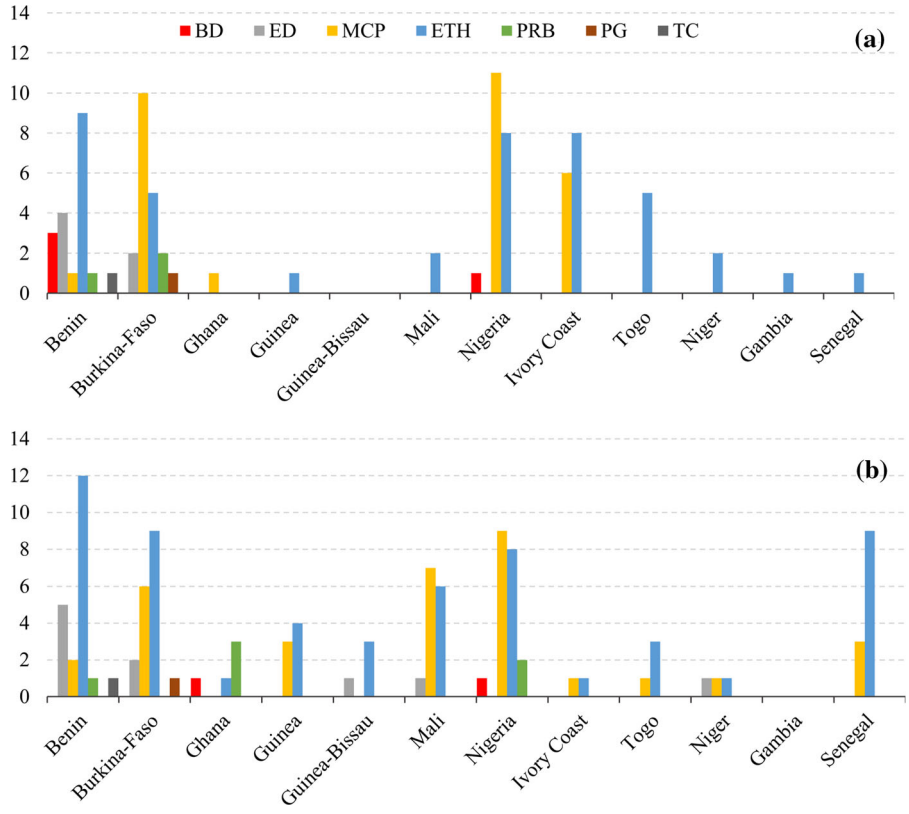

Fig. 2 Graphics showing spatial distribution of aspects studied on **a** *C. planchonii* and **b** *C. tinctorium* across West Africa

zone of Benin, but still neither collected nor formally identified (Akoègninou et al. 2006). *C. intermedium*, certainly a hybrid, combines the terminal inflorescence of *C. planchonii* and the acute and deeply lobed leaves of *C. tinctorium*. It is confined to Central Africa (Johnson-Fulton and Watson 2017) and

Table 1 Diagnostic morphological characters differentiating *C. planchonii* from *C. tinctorium*. *Source*: Hutchinson and Dalziel (1958), Poppendieck (1980), Akoègninou et al. (2006)

Characters	*C. planchonii*	*C. tinctorium*
Leaf shape	Palmately lobed; seldom deeply lobed, lobes rounded, usually broadly oblong, seldom markedly serrate; lower surface of mature leaves more or less densely woolly (Fig. 3a)	Palmately lobed; usually deeply lobed with acute lobes, sometimes with lobes narrowly lanceolate, lobes usually serrate; lower surface of mature leaves glabrescent or pubescent (Fig. 3d)
Inflorescence	Terminal, with 3–7 fascicled branches, rarely lax; bracts triangular	Few-flowered panicle or raceme, usually produced at ground level from the rootstocks, sometimes appearing on top of leafy shoots; bracts triangular
Flower	Radial, actinomorphic (5–7 cm in diameter) (Fig. 3b)	Radial, actinomorhic (6–9 cm in diameter) (Fig. 3e)
Fruit	Capsules (5–7 cm long), ovoid/obovoid/pyriform, thick-walled developing before the fire season to protect the seeds during fires	Capsules (4–5 cm long), fusiform/obovoid, slightly ridged, brown, grey or black, thin-walled developing at ground level just after the fire
Seed shape	Reniform, loosely attached to long cottony hairs (Fig. 3c)	Cochleate (spiral), reniform, closely adhering by long cottony hairs

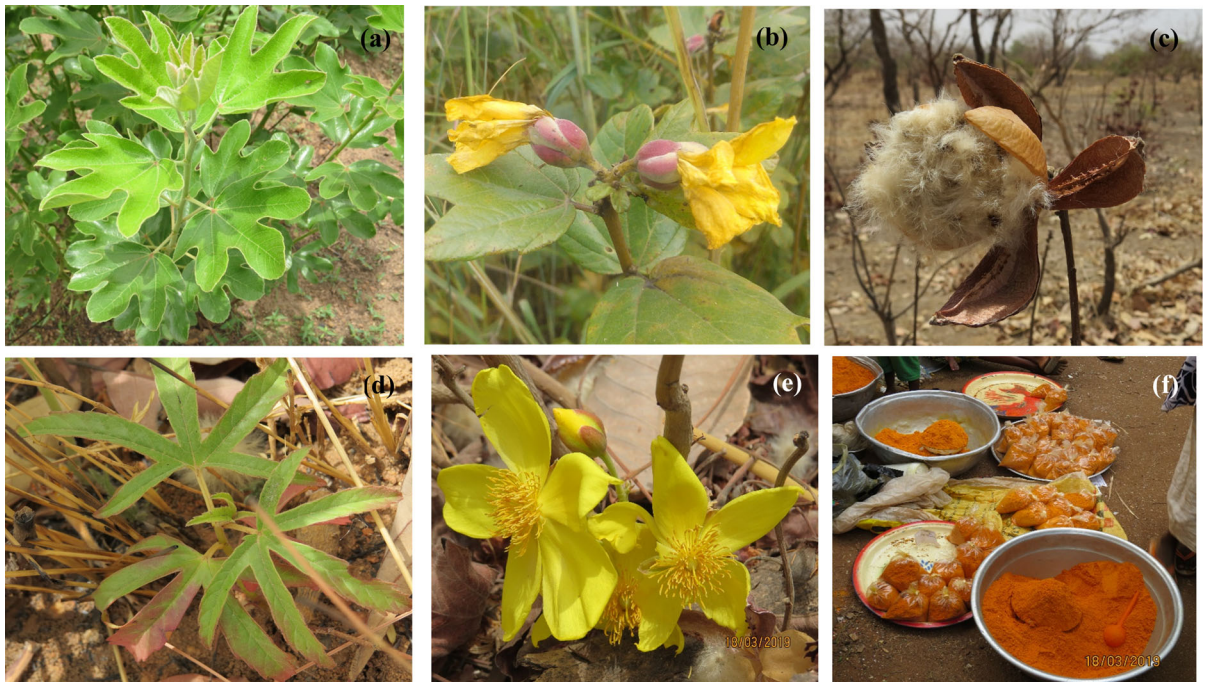

Fig. 3 West African *Cochlospermum* species **a** *C. planchonii* leafy stem, **b** *C. planchonii* flowers, **c** dry fruit (dehiscent capsule) of *C. planchonii* showing seeds covered in cotton-like fibres, **d** *C. tinctorium* leafy stem, **e** *C. tinctorium* flowers near the soil surface, **f** *C. tinctorium* rootstock powder in bowls and packets for sale *Source*: Favi G. Abraham, 2018

reportedly occurs in places where *C. planchonii* and *C. tinctorium* co-occur (Hutchinson and Dalziel 1958).

Distribution and ecology of habitats

Cochlospermum has a classical pantropical distribution, with species present in Africa, America (e.g. *Cochlospermum vitifolium* (Willd.) Spreng. and *Cochlospermum regium* (Schrank) Pilg.), India, Southeast Asia (e.g. *C. regium*), and northern Australia (e.g. *C. fraseri*) (Johnson-Fulton 2014; Johnson-Fulton and Watson 2017). *C. planchonii* and *C. tinctorium* mostly occur in semi-arid and arid regions of West Africa (Fig. 4a) (Ogundipe and Olatunji 1991). *C. planchonii* occurs from Senegal eastwards to Chad, from sea level up to 1700 m altitude in savanna and forest-savanna mosaic and fallows, sometimes in hedges, while *C. tinctorium,* is widespread from Senegal to southern Sudan and Uganda, at 300–1500 m altitude through the dry savanna, and preferring devastated, rocky and annually burnt regions (Burkill 1985; Jansen 2005; Johnson-Fulton 2014). The distribution of both species overlaps as far east as southwestern Sudan and north-western Uganda. In Benin, although *C. planchonii* occurs almost countrywide, it is sparser in the north while *C. tinctorium* is spread from the transition zone to the sudanian zone. Based on the map generated from occurrence data sourced from GBIF (GBIF 2018) and RainBIO (Dauby et al. 2016), *C. tinctorium* is mainly confined to the sudanian zone of Benin, while *C. planchonii* exhibits a wider distribution (Fig. 4b).

Pollination and reproduction

Information on pollination and reproduction biology of *Cochlospermum* plants is very scant, showing research gaps as already reported by many authors such as Bosch and Borus (2006). Very few pollinator observations have been documented outside the Americas (Johnson-Fulton 2014). Within West African countries, Ahouandjinou et al. (2016) in Benin, Cencettia et al. (2019) in Burkina-Faso and Omoloye and Akinsola (2006) in southwest Nigeria reported respectively *C. planchonii* and *C. tinctorium* to be visited and pollinated by bees. This is confirmed through a buzz pollination by large tropical bees foraging on Neotropical plant species (Erancheri et al.

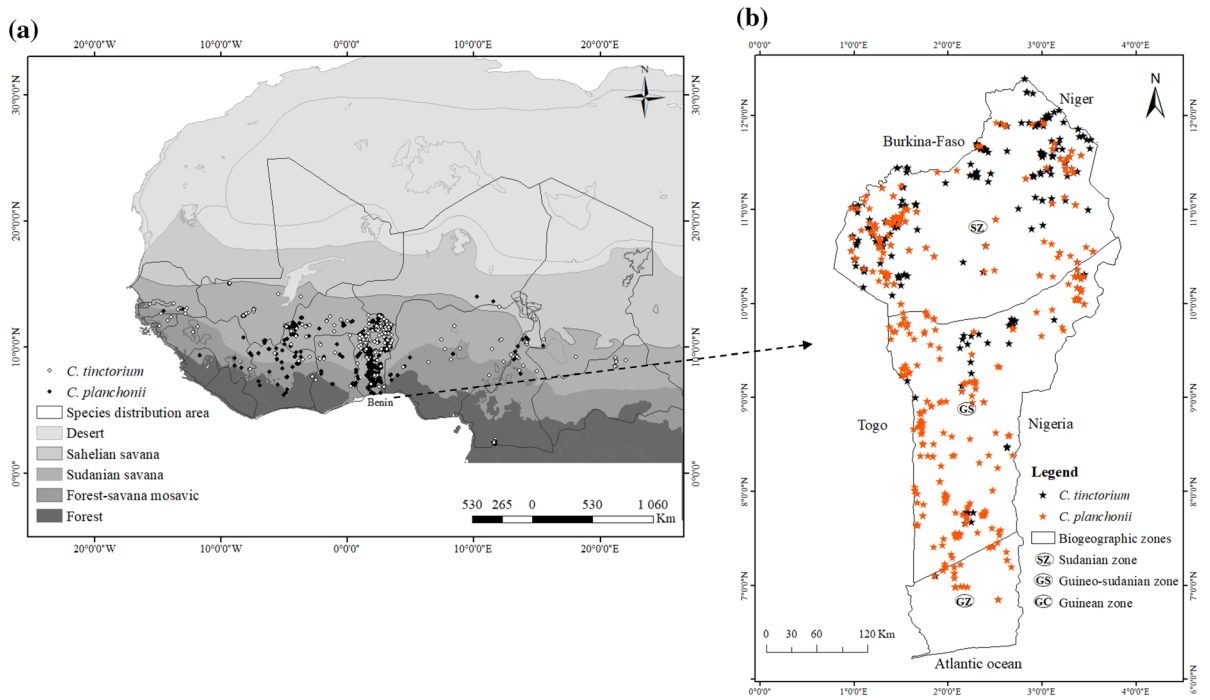

Fig. 4 **a** Distribution ranges of *C. planchonii* and *C. tinctorium* in Africa mosaic in legend of map. **b** Geographic distribution of *C. planchonii* and *C. tinctorium* in Benin.

2013). Furthermore, owlet moths (Noctuidae) were mentioned as pollinators of *C. intermedium* flowers in the Democratic Republic of the Congo (Mildbraed 1923).

According to reproduction biology, *C. planchonii* and *C. tinctorium* species as well as all other *Cochlospermum* grow as common weeds of cultivation, reproducing naturally from seeds (Oyen 2010). They usually vegetatively regenerate by rootstocks that are fire-tolerant (Achigan-Dako et al. 2010). Therefore, further research is needed for the West African *Cochlospermum* species (Johnson-Fulton 2014) and would be of great interest to better understand the best reproduction ways and the roles of pollinators in their propagation and likely their domestication and conservation.

Common names, traditional uses, nutritional and socioeconomic importance

Common names

Literature provides extensive information on local names of *C. tinctorium* and *C. planchonii* for all West African ethnic groups. Both species are commonly named "False cotton" and "Faux cotonnier" respectively in English and French. Likewise, some ethnic groups named both species identically, e.g. in Benin (Achigan-Dako et al. 2010) and Burkina-Faso (Belem et al. 2007), Wama and Moré people name respectively both species "Busoron'bu" and "Sonsè" (Table 2). However, both species also have distinct names elsewhere (Table 2). Diversity of local names expresses their local importance.

Food uses and nutritional value

C. tinctorium and *C. planchonii* are important and valuable food resources in the Sudanian and Sahelian zones (Pousset et al. 1987) where the market value of food increases during the dry season due to the decline

Table 2 Common names of *C. tinctorium* and *C. planchonii* in some West African countries

Countries	*C. tinctorium*	*C. planchonii*	References
Benin	Busoron'bu (Waama), N'buburumin (Anii), Kota (Dendi, Zerman), Kubologun (Gourmantché), Pararou, Kpararou (Bariba), Wunsonlihoun, Ousonliwoun (Berba)	Adjinakouvocanfoun (Fon), Busoron'bu (Waama), Lisayani (Gourmantché), Lomboukou (Kotokoli), Gbétu (Tchabè), Omronlugboko (Ifè), Tcholi (Idatcha)	Adjanohoun et al. (1989), Akoègninou et al. (2006) and Achigan-Dako et al. (2010)
Burkina-Faso	N'dribala (Dioula), Sôasga (Moore), Gotoro (san), Sosga (Mooré), Diapolo (Lyele), Yansinguinin (Tingso), Yaansegere (Dono soo), Yaansenjere (Tenju-kan), Yensenrin (Tomoso), Yansenjinrin (Tenju soo) and Solu anji (Duguloso, Dogolonso, Dongoso, Tommo soo, Donno soo, Toro soo), sonsè (Moré)	Sonsè (Moré), Biripin (San)	Nergard et al. (2005), Pare et al. (2016) and Sawadogo et al. (2017)
Ghana	Gbelonbile (Wale)		Asase et al. (2005)
Guinea	Tourouban kèman (Maninka), Diarounde (Pular), Tiriba (Malinké), Filimaguese (Sousou), Turubaw (Manika), Rèmè (Pular)	Tourouban musoman (Maninka)	Somopogui (1998), Kéita et al. (1999) and Magassouba et al. (2017)
Guinea-Bissau	Djánderé/diarunde (Fulani), filira gaese (Susu), tiriban/turuban (Malinke)		Diniz et al. (1996), Neuwinger (1996)
Mali	Tribara (Bambara), Solo andji (Dogon), N'dilibara (Bambara)		Nergard et al. (2005), Sangare et al. (2012) and Diarra et al. (2015)
Togo	Soulefadine, Frado (Ewe)	Zogbedeti (Ewe)	Kpodar et al. (2016)

of agricultural product availability (de Merode et al. 2014). The rootstocks of both species are collected from the wild, dried, and crushed to a reddish-yellowish powder to be sold on local market for various purposes, mostly as food additive (Achigan-Dako et al. 2010; Segnon and Achigan-Dako 2014). In African arid and semi-arid areas, the rootstock powder is used as tea (Aliyu et al. 1995) or colouring or flavouring item for sauces, when palm oil is not available (Vodouhè and Dansi 2012; Ohwoavworhua and Adelakun 2005). Anii communities consume the tender leaves of *C. tinctorium* in Benin as nutrient source (Segnon and Achigan-Dako 2014) and seeds are eaten raw in West Africa to quench thirst (Johnson-Fulton 2014). People in Nigeria and Ivory Coast chew the rootstocks as tonic to help promote general health (Ouattara et al. 2016). Leaves and flowers of *C. tinctorium* are respectively used as fodder for livestock and as food additives in Burkina Faso (Butare 2003; Nikiema 2005). According to Ouachinou et al. (2018), leaves and fruits of *C. planchonii* and leaves of *C. tinctorium* are among fodders consumed by cattle in Benin.

C. planchonii rootstocks exhibited some mineral constituents such as Na, K, Ca, Mg, Mn, Pb, Cd, Fe, Cu, Se (Nafiu et al. 2011) of which the first four are some of vital macronutrients to human health and nutrition (Yamashita et al. 2005), Zn, Ni and Cr (Aliyu et al. 1995) with zinc salt as hepatoprotective components by inhibition of cytochrome P450 enzyme in the liver (Anaga and Oparah 2009). Likewise, monosaccharides (glucose, galactose, fructose, arabinose, glucuronic acid, galacturonic acid, xylose, mannose and rhamnose) are found in *C. tinctorium* rootstocks (Inngjerdingen et al. 2013), playing a critical role in the human well-being (e.g. glucose ensures an antidiabetic role). Protein in both species (Olotu et al. 2011; Inngjerdingen et al. 2013) promotes health.

Uses in traditional medicine and veterinary practices

Medicinal uses turned to be the most important use category with several ailments treated. A total of 91 ailments are treated by both species. The therapeutic value of *C. tinctorium* turns out to be higher than that

Table 3 Some ailments treated by *C. tinctorium* and *C. planchonii*

Plant parts	*C. tinctorium*	*C. planchonii*	References
Common ailments			
Rootstock	Conjunctivitis, diabetes, diarrhoea, enteric fever, epilepsy, gonorrhoea, helminthiases, viral hepatitis B and C, indigestion, infertility, jaundice, liver ailments, malaria, pneumonia, premenstrual pain, stomach disorders, typhoid fever, urinary tract infections		Togola et al. (2005, 2008), Dassou et al. (2015) and Ouattara et al. (2016)
Leaf	Malaria, fevers, jaundice, diabetes, diarrhoea, stomach disorders, typhoid fever, urinary tract infections		Nafiu et al. (2011) and Isah et al. (2013)
Specific ailments			
Rootstock	Snackbites, beriberi, blennorrhoea, bronchial affections, colique, constipation, dysuria, eye instillations, fevers, flatulence, haemorrhoids, intercostal pains, oedema, orchites, painful menstruation (dysmenorrhea), rectal prolapse, rickets, schistosomiasis, ulcer, yellow fever	Leprosy, blood stimulant, burns, dysentery, oedema, febrile attack, headaches, heart palpitations, lung infections, menstrual cramps, skin infections, tonic, urethral discharge	Mann et al. (2003) and Adamu et al. (2005)
Leaf	Abcesses, boils	Diabetes, dysentery, helminthiases, oedema, headaches	Achigan-Dako et al. (2010)
Flower	Constipation		Nergard et al. (2005)
Seed	Leprosy		Jansen and Cardon (2005)

of *C. planchonii*. Thus, *C. tinctorium* cures 79 ailments (with 58 exclusive) and exceed the 54 ailments reported by (Johnson-Fulton and Watson 2018), while *C. planchonii* treats 36 ailments (including 12 exclusive) (partly in Table 3). Among these ailments, Table 4 highlights seventeen diseases (reported at least in tree countries) with their therapeutic convergence. Thus, jaundice (100%), malaria (92.31%), yellow fever (76.92%) and liver ailments (76.92%) are treated with *C. tinctorium*, revealed high therapeutic convergence versus enteric fever and hepatitis (15.38%) were less reported and accordingly showed a low convergence (Table 4). For *C. planchonii*, only malaria (53.85%) revealed a high therapeutic convergence while bronchitis, epilepsy, and haemorrhoids were not reported to be cured by *C. planchonii*. The high frequency of citation of malaria medication for both species is consistent because *C. planchonii* and *C. tinctorium* have already been reported amongst the top five antimalarial medicinal plants (Lamien-Meda et al. 2015). Of the above, *C. tinctorium* was more frequently used than *C. planchonii*. However, the variation in therapeutic convergence could be scientifically justified. An ailment could have a high therapeutic convergence if the traditional medicine is held by an ethnic group common to some neighbouring countries, e.g. Hausa people using *C. tinctorium* against jaundice in Nigeria (Mann et al. 2003) but also in Niger, Benin, Ghana, etc. (Sabiu et al. 2018). It could be due to human migration such as by the Fulani who are present in almost West African countries (Nissen 2014), using both species in medical-magic and veterinary uses (Olotu et al. 2011). This could also be justified by species availability hypothesis because most West African countries have arid or semi-arid regions (preferred habitats of *Cochlospermum* spp.). On the other hand, a plant species used to treat an ailment in geographically distant countries could mean an efficiency despite the low therapeutic convergence of the ailment treated, e.g. of hepatitis treatment by *C. planchonii* (Aliyu et al. 1995) in Benin, Burkina-Faso and Senegal and by *C. tinctorium* (Akinloye et al. 2012) in Benin and Mali (Table 4).

All ailments recorded were grouped into sixteen (16) categories, the most important of which are as

Table 4 Therapeutic convergence in terms of percentage of countries where *C. tinctorium* and *C. planchonii* treat a given ailment

Ailments	Nigeria	Niger	Benin	Togo	Burkina-Faso	Ghana	Ivory Coast	Mali	Guinea	Guinea-Bissau	Gambia	Senegal	TC (%)	
													ct	cp
Jaundice	ct, cp	ct, cp	ct	ct	ct, cp	ct	ct, cp	ct, cp	ct	ct	ct	ct, cp	100	46.15
Malaria	ct, cp	cp	ct, cp	ct, cp	ct, cp	ct	ct, cp	ct, cp	ct	ct	ct	ct	92.31	53.85
Yellow fever	ct	ct			ct	ct	ct	ct	ct		ct	ct, cp	76.92	7.69
Liver ailments	ct			ct, cp	cp	ct	ct	ct	ct	ct	ct	ct	76.92	15.38
Snackbites	ct		ct, cp			ct	ct	ct					38.46	7.69
Schistosomiasis	ct						ct, cp	ct				ct, cp	30.77	15.38
Fevers	cp	cp				ct	ct, cp	cp				ct	23.08	30.77
Stomach disorders						ct	ct, cp	ct, cp					23.08	15.38
Helminthiases		ct	cp					ct				ct	23.08	7.69
Bronchitis						ct	ct					ct	23.08	0
Epilepsy						ct	ct					ct	23.08	0
Haemorrhoids						ct		ct				ct	23.08	0
Indigestion						ct	ct					ct	23.08	0
Rickets	ct	ct										ct	23.08	0
Enteric fever	ct, cp		ct, cp					cp					15.38	23.08
Hepatitis			ct, cp		cp			ct				cp	15.38	23.08

TC: therapeutic convergence, ct: *Cochlospermum tinctorium*, cp: *Cochlospermum planchonii*

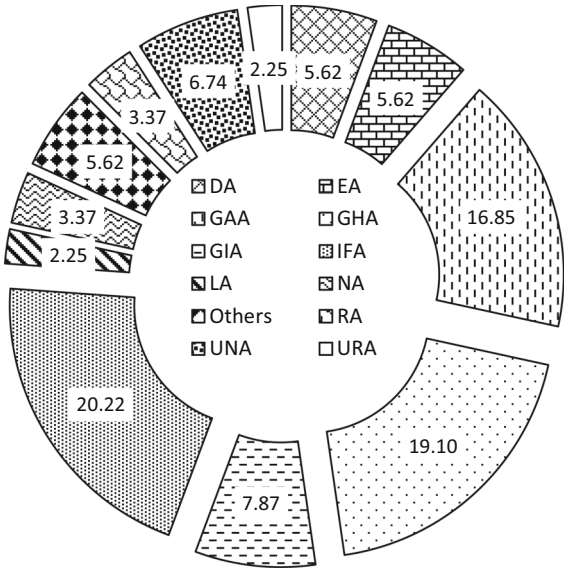

Fig. 5 Spectrum of body system-based ailment categories. *IFA* infectious/fever ailments, *GHA* general health ailments, *GAA* gynecological/andrological ailments, *GIA* gastro-intestinal ailments, *UNA* unspecified ailments, *DA* dermatological ailments, *EA* eye ailments, *NA* neurological ailments, *RA* respiratory ailments, *LA* liver ailments, *URA* urological ailments

follows: infectious/fever ailments (20.22% of the total), general health ailments (19.10%), and gastro-intestinal ailments (16.85%) (Fig. 5). The frequent uses of *C. tinctorium* and *C. planchonii* as antimicrobials in traditional medicine was emphasised by Magassouba et al. (2017). Taking into account the number of ailments treated per country, Ghana (32 ailments), Ivory-Coast (26), Senegal (25), Mali (18), and Nigeria (15) made the top five of countries treating the most of ailments using *C. tinctorium* (Fig. 6). Lowest values (8–12 ailments) were obtained in *C. planchonii*. Nevertheless, the market value of *C. planchonii* is high in Burkina-Faso since it is widely used and sold in pharmacies as improved traditional medicine against malaria (Benoit-Vical et al. 2003; Willcox 2011).

Based on the number of ailments treated using the rootstocks, they appeared to be the most frequently used plant parts of *C. tinctorium* and *C. planchonii* in traditional medicine in West African (Fig. 7). Thus, 84.62% and 34.07% of ailments recorded are treated respectively with *C. tinctorium* and *C. planchonii* rootstocks (Fig. 7). Leaves and stem were used to a considerably lower extent.

The strong role of rootstocks in medicine and veterinary uses is frequently mentioned in literature (Togola et al. 2005; Yerbanga et al. 2012; Ouachinou et al. 2017; Sawadogo et al. 2017) and by this, exposes the species to threat because rootstock harvesting involves killing the plant. According to Nergard et al. (2005), the harvesting of *C. tinctorium* rootstocks from the wild, as main raw material, causes a growing

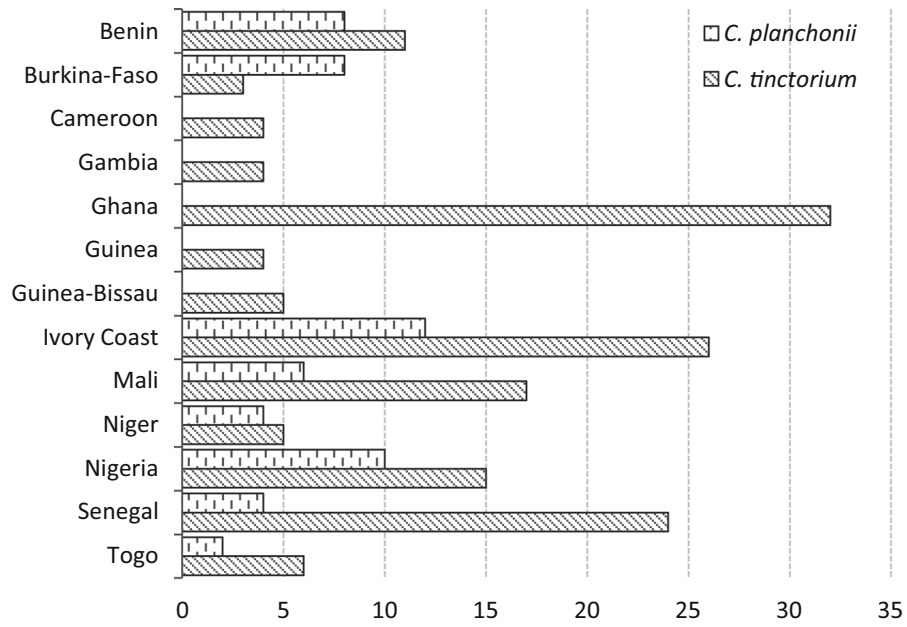

Fig. 6 Number of ailments treated by each species per country

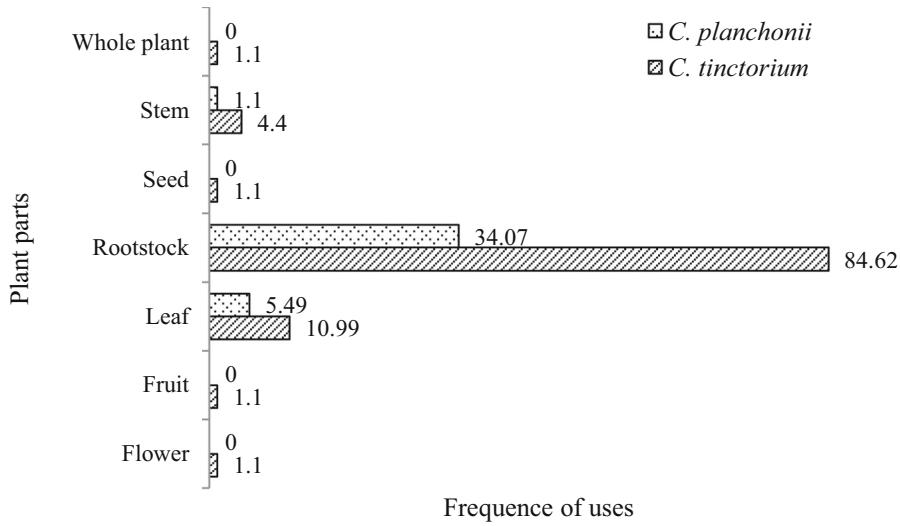

Fig. 7 Percentages of uses of each species plant parts

concern on diminishing plant populations that might lead to local extinction.

Other uses

C. tinctorium and *C. planchonii* are well known for multipurpose issues such as magical protection ascribed to leaf infusions used by Fulani people of Northern Nigeria (Olotu et al. 2011). They are also used as dye or sources of fiber (Poppendieck 1980; Abbiw 1990; Sala 1994; Hodgson 2001) and popular in art and crafts. The dried or mature fruits contain cotton-like fibers that are twisted into necklace cords in Togo (Jansen and Cardon 2005), or used for stuffing cushions, pillows, mattresses, and for padding upholstery work in Ghana (Butare 2003; Nikiema 2005) or making beads in Nigeria with the seeds (Johnson-Fulton 2014). In Ghana, the dye from *C. tinctorium* rootstocks is widely produced and exported (Jansen 2005). Rootstock extract as a yellow dye is used by Nupe-Fulani people of Nigeria and some tribes in Sudan to make tattoo colorants, inks, mordants and stains. Elsewhere, it is reported to paint fabric, leather mats, baskets, shea butter (Abbiw 1990) and masks in Benin (Fagbohoun 2014). Ropes are made from stem bark for fixing mats. Edible oil is obtained from seeds of *C. tinctorium* (Cheesbrough 2000). The Hausa tribe of Nigeria and some tribes in Northern Sierra Leone make strings and ropes from bark fibres while Chambas people in Sokoto (Nigeria) use the threaded seeds as beads (Olotu et al. 2011). The leaf infusion is believed to bestow magical protection on the Fulani people of Northern Nigeria (Olotu et al. 2011). Bosch and Borus (2006) considered *Cochlospermum* species among the good candidates for commercial production and ornamental uses that are not yet well explored.

Socio-economic importance

C. tinctorium and *C. planchonii* appear very useful for rural households' cash income (Tabuti et al. 2003; Djègo et al. 2011) according to ''N'dribala'' (*C. planchonii* rootstocks) and ''Saye'' (a mixture of *C. planchonii*, *Phyllanthus amarus* and *Cassia alata*) approved in Burkina-Faso as improved traditional medicine and sold in pharmacies against malaria (Lamien-Meda et al. 2015) to treat over 85,000 patients each year (Willcox 2011). In northern Benin, rootstocks of *C. tinctorium* and *C. planchonii* (Fig. 3f), available year-round, are often powdered and sold on local markets (Achigan-Dako et al. 2010). In this region, *C. tinctorium* contributed to household income generation from 20 and 144$ according to Vodouhè and Dansi (2012). Furthermore, Ahouandjinou et al. (2016) in Cobly district (Northern Benin), Omoloye and Akinsola (2006) in Southwest Nigeria identified respectively *C. planchonii* and *C. tinctorium* as melliferous plants. Commercial issues may be explored for ornamental use with regard to the beautiful yellow flowers of *C. tinctorium* and its multipurpose uses (Bosch and Borus 2006). Many post stamps from Chad, Angola, India, Nicaragua and Cuba

spotlight *Cochlospermum* species such as *C. planchonii* and *C. tinctorium*, an indication of the importance and conspicuous beauty of this plant genus (Johnson-Fulton 2014).

Phytochemical and pharmacological evidence

Chemical constituents of *C. planchonii* and *C. tinctorium* plant parts have been extensively reported through various studies supporting their great therapeutic values (Diallo et al. 1987, 1991, 1992; Ouattara et al. 2007; Bossou et al. 2013). More than hundred compounds have been identified in various organs of both species ranging into three bioactive groups (Table 5) such as phenols/polyphenols, terpenoids and alkaloids. Some of these compounds are somewhat similar in both species. Thus, Benoit-Vical et al. (1999) showed that essential oils obtained from both species rootstocks revealed that major components are qualitatively close, but differ in their relative ratios. Likewise, wild and cultivated plants of *C. tinctorium* showed similar bioactive monosaccharide and polysaccharide components (Inngjerdingen et al. 2013) that revealed a significant mitogenic activity (Nergard et al. 2005).

All of the components identified in both species parts revealed a wide range of important biological activities of which fifteen (15) have already been investigated (Table 5) with antimicrobial (Inngjerdingen et al. 2014; Oumar et al. 2014), antimalarial (Vonthron-Senecheau et al. 2003; Traoré et al. 2008) and antioxidant (Da et al. 2014) activities are documented. Some of these compounds are specific to *Cochlospermum* as Cochloxanthine and Dihydrocochloxanthine (two major carotenoids) (Lamien-Meda et al. 2015) and Cochlospermine A, B, C, D (Triacylbenzenes) (Achenbach, 1986) that showed antibacterial activity (Malcolm and Sofowora 1969). Accordingly, Abondo et al. (1990) placed *C. tinctorium* in the third position among African hepatoprotective remedies based on the number of countries in which its use is cited. Beyond the biological properties mentioned so far, some other potential properties have not yet been investigated (Table 5) such as anti-allergic, anti-cancer, anti-tumour, antituberculosis, anti-hypertensive activities and should therefore be further studied. To test antimalarial effects of *C. planchonii*, Benoit-Vical et al. (2003) conducted in Burkina-Faso, a clinical trial for uncomplicated *Plasmodium falciparum* malaria. Among the 46 patients treated with *C. planchonii* root powder (N'Dribala) versus 21 patients treated with chloroquine, 57% and 52% respectively of chloroquine-treated and of N'Dribala-treated patients were cured at day 5, with more than 90% of whole patients asymptomatic and showing no detectable parasitemia.

Among the plant parts involved in pharmacological studies on both species, the rootstocks were the plant part showing the highest number of pharmacological activities (60% for *C. tinctorium* versus 46.6% for *C. planchonii*), followed by the leaves (26.6% for *C. tinctorium* and 20% for *C. planchonii*) (Fig. 8). Although the rootstocks of both species seem to have the strongest biological properties, there is a need to test extracts from other parts of the plants as they may still have pharmacological properties unknown so far.

Threats and conservation

This review highlights how each part of West African *Cochlospermum* species is much involved usefully in household livelihoods as food additive, folk medicine, craft, etc. Unfortunately, the anthropic pressure linked to the over-harvesting of rootstocks is proving to be harmful to species sustainability (Vermeulen 2006), due to the method of harvesting and the number of ailments treated (Dassou 2016). Indeed, harvest the rootstocks implies the systematic digging out of the plants and by this, causing the decline of *C. planchonii* populations as reported in Benin by Dassou (2016). This practice exposes the plant species to genetic erosion as reported for *C. regium* (Mart. ex. Schrank) in Brazil's savanna (Cerrado) (Inácio et al. 2011). Even worse, *Cochlospermum tetraporum* Hallier f., confined to South America (Prado 1998), was identified as an internationally endangered plant species (Prado 1998). Hence, vulnerability of *C. planchonii* has been expressed due to the destructive harvesting of its rootstocks for medicine, food condiment, dye (Oyen 2010), and ethnoveterinary uses (Dassou (2016). Furthermore, in West African countries such as Mali, some surveys revealed that the harvesting of *C. tinctorium* from the wild, as main raw material, causes a growing concern on decline, which might lead to local extinction (Nergard et al. 2005). A decrease of its local abundance was mentioned in

Table 5 Pharmacological activities currently discovered for *C. tinctorium* and *C. planchonii* and further potential properties to investigate

Secondary metabolites		Plant organs	Biological activities	
Groups	Subgroups		Activities investigated	Potential properties
Phenols/ polyphenols	Shikimates (phenols and phenolic acids, lignin, tannins, flavonoids)	R^{ab}, Rb^{ab}, L^{ab}, Stb^{b}, Stl^{b} (Doughari et al. 2008; Isah et al. 2013)	Analgesic, anti-inflammatory, CNS depressant, antibacterial, anti-oxidant, antihepatotoxic, antiplasmodial, antimalarial, antimicrobial, anti-fungical, anti-ulcer, anti-hepatic, anti-diabetic, antihyperglycemic (Abdulsalaam et al. 2013; Inngjerdingen et al. 2014; Dluya et al. 2017)	Anti-allergic, anti-carcinogenic, anti-mutagenic, anti-septic, anti-viral, cardiovascular protective, diuretics, haemostatic (Falcone Ferreyra et al. 2012; Chikezie et al. 2015; Anulika et al. 2016)
Terpenoids and steroids	Monoterpenes, diterpenes, triterpernes (saponosides), steroids, carotenoids and sesquiterpenes	R^{ab}, Rb^{a}, L^{ab}, Stb^{b}, Stl^{b} (Anaga and Oparah 2009; Ahmed et al. 2011)	Analgesic, anti-inflammatory, CNS depressant, analgesic, anti-inflammatory, antiplasmodial, antibacterial, antihepatotoxic, antimalarial, antimicrobial, anti-fungical, anti-diabetic, anti-trypanocidal, antihyperglycemic (Diallo et al. 1987; Atawodi 2005; Abdulsalaam et al. 2013)	Anti-viral, anti-helmintic, anti-cancer, anti-tumour, immunostimulant, anti-coagulant, neuroprotective, antituberculosis (Kanokmedhakul et al. 2005; Capasso et al. 2003; Shakya 2016; Man et al. 2010)
Alkaloids	Cochloxanthin, dihydrocochloxanthin	R^{a}, Rb^{a}, L^{ab}, Stb^{b} (Abraham et al. 2017; Ahmed et al. 2011)	Analgesic, Anti-inflammatory, CNS depressant, analgesic, anti-inflammatory, antiplasmodial, anti-oxidant, antimicrobial, anti-fungical, antihyperglycemic, anti-diabetic (Ballin et al. 2002; Doughari et al. 2008; Dluya et al. 2017)	Anti-asthmatic, anti-hypertensive, anti-spasmodic, bactericidal, diuretic, local anesthetic (Woolley 2001; Chikezie et al. 2015; Shakya 2016)

R rootstock, *Rb* rootstock bark, *L* leaves, *St* stem, *Stl* stem leaf, *Stb* stem bark

[a]*C. tinctorium*

[b]*C. planchonii*

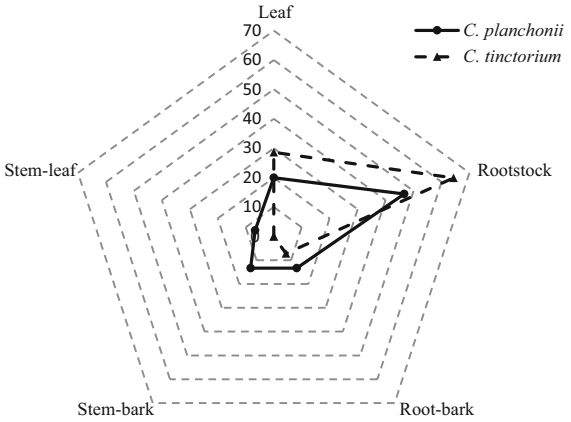

Fig. 8 Percentage of pharmacological activity per plant part of *C. tinctorium* and *C. planchonii*

Ghana, due to the effective use against malaria (Asase et al. 2005). Also, great pressure on *C. tinctorium* was also reported in northeast Benin (Sinsin and Oumorou 2000; Lesse et al. 2017). So far, the literature on the current geographical distribution of *Cochlospermum* species, particularly those occurring in West Africa is sparse and the threat status remains not yet completely evaluated in Benin (Achigan-Dako et al. 2010). Nevertheless, the "Department of Traditional Medicine" in Mali initiated the cultivation of *C. tinctorium* (Nergard et al. 2005) and Chamba people of the Shebshi Mountains of eastern Nigeria also occasionally cultivate *C. planchonii* (Oyen 2010). So far, there is no focus on conservation efforts for these multipurpose plant species. It is imperative to work out

strategies of *C. tinctorium* and *C. planchonii* conservation in order to prevent their genetic erosion.

Knowledge gaps and prospects

This literature survey provides evidence that West African *Cochlospermum* species are important multipurpose plants with socioeconomic value for sociocultural groups from the Sudanian and Sahelian Zones according to their wide spectrum of uses, chemical constituents and pharmacological activities. Unfortunately, the overexploitation of *Cochlospermum* species rootstocks combine with the wide range of uses (e.g. food additive, medicine, dye, and veterinary uses) could induce their genetic erosion and accordingly a loss of biodiversity. Extensive data are available in literature related to taxonomic, traditional uses, mineral and chemical compounds, pharmacological activities and spatial distribution. Aspects such as reproductive biology, pollination, ecology, seed dissemination and natural regeneration remain poorly documented (Inngjerdingen et al. 2013) while those related to conservation strategies, domestication, and genetic diversity are not addressed at all. Beside human pressure through the overuse of rootstocks, environmental hazards in tropical regions where *C. planchonii* and *C. tinctorium* mostly occur, agriculture, bushfires and climate variability become impediment against these plant resources conservation. The growing demand and the market value of the rootstocks that are harvested from the wild, decreases the natural populations of these species. So, there is an urgent need to start monitoring and conservation programs so as to reverse or alleviate the ongoing pressure (Bosch and Borus 2006). It appears vital to assess the spatial and temporal dynamics of the natural populations of these plant genetic resources. Also since these plants are reported melliferous, it is timely to investigate the flowering and fruiting phenology along with the climate variability. This will allow mastering their reproduction, the pollination, seed dissemination etc.

Further studies could also address the nutritional value of whole plant as vegetable or fodder and their potential in honey production. In addition, morphological and molecular analysis, especially in Benin, would remove the ambiguity on the actual number of *Cochlospermum* species, and the existence or not of *Cochlospermum intermedium* Mildbr. Analysis of ecological and geographical distribution of genetic diversity using molecular tools would help to increase knowledge on patterns and drivers of genetic diversity in West African *Cochlospermum* spp. Finally, the information gathered and reported in this paper supports the socio-economic values of these two *Cochlospermum* species and provides the basis for further investigations in line with sustainable use and management.

Conclusion

C. tinctorium and *C. planchonii* are multipurpose plants with many benefits for local populations. The present review provides information available on botany, reproduction and pollination, traditional uses, phytochemistry and pharmacological relevance of *C. tinctorium* and *C. planchonii*. They are among the major food additives in semi-arid West Africa that could help alleviate poverty and have a great potential for food, fodder, art and mostly for medicine issues. Indeed, both *Cochlospermum* plants have a long history of usage in treatments of a wide range of ailments throughout West African countries. By this, information gathered have shown diverse traditional uses of *C. tinctorium* and *C. planchonii* that sometimes are common to some countries such as malaria, jaundice, liver ailments and yellow fever or specific to one country as flatulence, measles, oedema and orchites. Reports on the various biological activities of *C. tinctorium* and *C. planchonii* of which antimicrobial, antimalarial, anti-inflammatory, and hepatoprotective activities reveal several chemical compounds that clearly show their strong therapeutic potential. However, knowledge on their reproductive biology, the current conservation status, the genetic and environmental factors affecting locally preferred traits as well as intra-specific variations remain incompletely known. Further studies are required to investigate traditional uses, pollinators and best propagation mode, nature of bioactive compounds and pharmacological properties of others plant parts in order to reduce pressure on rootstocks.

Acknowledgements This research was funded by the International Foundation for Science (IFS), which is gratefully acknowledged. The authors express also their sincere gratitude

to reviewers for their critical reviews and useful comments and contributions to the improvement of the scientific quality of this paper.

Author contributions GAF, GHD and ACA conceptualized the study. GAF researched and compilated data, and wrote the manuscript; EODS assisted in documentation and read the manuscript; GHD, ACA and ABF read and corrected the manuscript; GAF, GHD and ACA designed, performed and approved the final version; GAF, GHD, ACA, HY, MGT and AA assisted in the revision and editing of the manuscript.

Funding This research was financially supported by the International Foundation for Science (IFS) through a research grant provided to Gnimansou Abraham Favi under the Project I-1-C-6188-1.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests in this manuscript. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

Abbiw DK (1990) Useful plants of Ghana. Intermediate Technology Publication/Royal Botanic Gardens, London/Kew

Abdulsalaam AO, Idris MM, Salawu OW (2013) Preliminary phytochemical screening and antibacterial activity of medicinal plant: *Cochlospermum tinctorium* A. Rich. Res J Sci IT Manag 02:03

Abondo A, Mbenkum F, Thomas D (1990) Ethnobotany and the medicinal plants of the Korup rainforest project area, Cameroon. In: Mshigeni KE (ed) Proceedings of international conference on traditional medicinal plants. Arusha, Tanzania, Feb 18–23. Dares Salam University Press, pp 112–124

Abraham BF, Olarewaju SA, Ronke A, Oladipo AE (2017) Antidiabetic and antidyslipidemic activities of the aqueous extract of *Cochlospermum planchonii* leaves in streptozotocin-induced diabetic rats. Iran J Med Sci 42(6):553–560

Achigan-Dako EG, Pasquini MW, Assogba-Komlan F, N'danikou S, Yédomonhan H, Dansi A, Ambrose-Oji B (2010) Traditional vegetables in Benin: diversity, distribution, ecology, agronomy, and utilisation. Institut National des Recherches Agricoles du Bénin, Benin

Adamu HM, Abayeh OJ, Agho MO, Abdullahi AL, Uba A, Dukku HU, Wufem BM (2005) An ethnobotanical survey of Bauchi State herbal plants and their antimicrobial activity. J Ethnopharmacol 99:1–4

Adjanohoun EJ, Adjakidje V, Ahyi MRA, Ake Assi L, Akoegninou A, d'Almeida J, Akpovo F, Bouke K, Chadare M, Cusset G, Dramane K, Eyme J, Gassita J-N, Gbaguidi N, Goudoté E, Guinko S, Hougnon P, Issa LO, Keita A, Kiniffo HV, Kone-Bamba D, Musampa A, Nseyya A, Saadou M, Sodogandji T, de Souza S, Tchabi A, Zinsou Dossa C, Zohoun T (1989) Contribution aux études ethnobotaniques et floristiques en République Populaire du Bénin. Médecine Traditionnelle et Pharmacopée. ACCT, Paris

Adomou CA (2005) Vegetation patterns and environmental gradients in Benin: implications for biogeography and conservation. PhD dissertation, Wageningen University, Wageningen, Netherlands

Ahmed TS, Magaji MG, Yaro AH, Musa AM, Adamu AK (2011) Aqueous methanol extracts of *Cochlospermum tinctorium* (A. Rich) possess analgesic and anti-inflammatory activities. J Young Pharm 3:237–242

Ahouandjinou STB, Yedomonhan H, Adomou AC, Tossou MG, Akoegninou A (2016) Technical characteristics and socio-economic importance of beekeeping in the Northwest of Benin: case of Cobly district. Int J Biol Chem Sci 10(3):1350–1369

Akinloye OA, Ayankojo AG, Olaniyi MO (2012) Hepatoprotective activity of *Cochlospermum tinctorium* against carbon tetrachloride induced hepatotoxicity in rats, ROM. J Biochem 49:3–12

Akoègninou A, van der Burg WJ, van der Maesen LJG (2006) Flore analytique du Bénin. Backhuys Publishers, Wageningen

Aliyu S, Okoye ZSC, Thomas SW (1995) The hepatoprotective cytochrome P450 enzyme inhibitor isolated from Nigerian medicinal plant *C. planchonii* is a zinc salt. J Ethnopharmacol 48:89–97

An update of The Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III Bot J Linnean Soci (2009) 161(2):105–121

Anaga AO, Oparah NQ (2009) Investigation of the methanol rootstocks extract of *Cochlospermum planchonii* for pharmacological activities in vitro and in vivo. Pharm Biol 47(11):1027–1034

Angiosperm Phylogeny Group (1998) An ordinal classification for the families of flowering plants. Ann Mo Botnnu Gard 85:531–553

Angiosperm Phylogeny Group II (2003) An updated classification of the angiosperms. Bot J Linn Soc 141:399–436

Anulika NP, Ignatius EO, Raymond ES, Osasere OI, Abiola AH (2016) The chemistry of natural product: plant secondary metabolites. Int J Technol Enhanc Emerg Eng Res 4:1–8

Asase A, Oteng-Yeboah AA, Odamtten GT, Simmondsb MSJ (2005) Ethnobotanical study of some Ghanaian antimalarial plants. J Ethnopharmacol 99:273–279

Assogba GA, Fandohan AB, Gandji K, Salako VK, Assogbadjo AE (2018) *Bombax costatum* (Malvaceae): state of knowns, unknowns and prospects in West Africa. Biotechnol Agron Soc Environ 22(4):267–275

Assogbadjo AE (2006) Importance socio-économique et étude de la variabilité écologique, morphologique, génétique et biochimique du baobab (*Adansonia digitata* L.) au Bénin. Thèse de doctorat. Faculty of Bioscience Engineering, Ghent University, Belgium

Assogbadjo AE, Kakaï RG, Vodouhê FG, Djagoun CAMS, Codjia JTC, Sinsin B (2012) Biodiversity and socioeconomic factors supporting farmers' choice of wild edible trees in the agroforestry systems of Benin (West Africa). Forest Policy Econ 14:41–49

Atawodi SE (2005) Comparative in vitro trypanocidal activities of petroleum, methanol, and aqueous extracts of some Nigerian Savannah plants. Afr J Biotechnol 4(2):177–182

Ballin NZ, Traore M, Tinto H, Sittie A, Mølgaard P, Olsen CE, Kharazami A, Christensen SB (2002) Antiplasmodial compounds from *Cochlospermum tinctorium*. J Nat Prod 65:1325–1327

Belem B, Nacoulma BMI, Gbangou R, Kambou S, Hansen HH, Gausset Q, Lund S, Raebild A, Lompo D, Ouedraogo M, Theilade I, Boussim IJ (2007) Use of Non Wood Forest Products by local people bordering the "Parc National Kaboré Tambi", Burkina-Faso. J Transdiscip Environ Stud 6(1):1–14

Benoit-Vical F, Valentin A, Mallie M, Bastide JM, Bessiere JM (1999) In vitro antimalarial activity and cytotoxicity of *Cochlospermum tinctorium* and *Cochlospermum planchonii* leaf extracts and essential oils. Planta Med 65(4):378–381

Benoit-Vical F, Valentin A, Da B, Dakuyo Z, Descamps L, Mallié M (2003) N'Dribala (*Cochlospermum planchonii*) versus chloroquine for treatment of uncomplicated *Plasmodium falciparum* malaria. J Ethnopharmacol 89(1):111–114

Bosch CH, Borus DJ (eds) (2006) Dyes and tannins of Tropical Africa, conclusions and recommendations based on PROTA 3: 'dyes and tannins'. PROTA Foundation, Wageningen

Bossou AD, Mangelinckx S, Yedomonhan H, Boko YM, Akogbeto MC, De Kimpe N, Avlessi F, Sohounhloue DCK (2013) Chemical composition and insecticidal activity of plant essential oils from Benin against Anopheles gambiae (Giles). Parasit Vectors 6:337

Burkill HM (1985) The useful plants of West Tropical Africa, vol 1, 2nd edn. Families A–D. Royal Botanic Gardens, Kew

Butare I (ed) (2003) Pratiques culturelles, la sauvegarde et la conservation de la biodiversité en Afrique de l'Ouest et du Centre: Actes du Séminaire-atelier de Ouagadougou, du 18 au 21 juin 2001. IDRC/Zoom Editions, Ottawa

Capasso F, Gaginella TS, Grandolini G (2003) Phytotherapy: a quick reference to herbal medicine. Springer, Berlin. ISBN 978-3-540-00052-5

Cencettia T, Lippib MM, Nombréc I, Orioli L (2019) Pollen analysis of some Burkina Faso honey samples. Webbia. https://doi.org/10.1080/00837792.2019.1627455

Cheesbrough M (2000) District laboratory practice in tropical countries. The Press Syndicate of the University of Cambridge, Cambridge, pp 132–143

Chikezie PC, Ibegbulem CO, Mbagwu FN (2015) Bioactive principles from medicinal plants. Res J Phytochem 9(3):88–115

Cota M (2018) *Pseudocalotes khaonanensis*. The IUCN Red List of Threatened Species 2018: e.T104651572A104651577 http://dx.doi.org/10.2305/IUCN.UK.20182.RLTS.T104651572A104651577.en

Cronquist A (1981) An integrated system of classification of flowering plants. Columbia University Press, New York

Da O, Traore-Coulibaly M, Yerbanga RS, Koama B, Ouedraogo N, Tamboura S, Dakuyo ZP, Sekhoacha MP, Nikiema JB, Ouedraogo GA, Matsabisa MG, Ouedraogo JB (2014) Antiplasmodial and antioxidant activities of saye: a traditional herbal remedy for malaria. Am J Biochem Mol Biol 4:155–166

Dassou GH (2016) Diversité, Ethnobotanique, Ecologie et Statut de conservation des plantes utilisées en médecine vétérinaire traditionnelle au Bénin. Thèse de doctorat. Faculté des Sciences et Techniques, Université d'Abomey-Calavi, Bénin

Dassou GH, Adomou AC, Yédomonhan H, Ogni AC, Tossou GM, Dougnon JT, Akoègninou A (2015) Flore médicinale utilisée dans le traitement des maladies et symptômes animaux au Bénin. J Anim Plant Sci 26:4036–4057

Dauby G, Zaiss R, Blach-Overgaard A, Catarino L, Damen T, Deblauwe V et al (2016) RAINBIO: a mega-database of tropical African vascular plants distributions. PhytoKeys 74:1–18

de Merode E, Homewood K, Cowlishaw G (2014) The value of bush meat and other wild foods to rural households living in extreme poverty in Democratic Republic of Congo. Biol Conserv 118:573–581

Diallo B, Vanhaelen M, Kisob Y, Hikinob H (1987) Antihepatotoxic actions of *Cochlospermum tinctorium* rhizomes. J Ethnopharmacol 20:239–243

Diallo B, Vanhaelen M, Vanhaelen-Fastre R (1991) Triacylbenzences and long-chain volatile ketones from *Cochlospermum tinctorium* rhizomes. Phytochemistry 30(12):4153–4165

Diallo B, Vanhaelen M, Vanhaelen-Fastre R (1992) Further studies on the hepatoprotective effects of *Cochlospermum tinctorium* rhizomes. J Ethnopharmacol 36:137–142

Diarra N, Klooster C, Togola A, Diallo D, Willcox M, de Jong J (2015) Ethnobotanical study of plants used against malaria in Sélingué, subdistrict, Mali. J Ethnopharmacol 166:352–360

Diniz MA, Silva O, Paulo MA, Gomes ET (1996) Medicinal uses of plants from Guinea-Bissau. In: van der Maesen LJG (ed) The biodiversity of African plants. Kluwer, Dordrecht

Djègo J, Djego-Djossou S, Cakpo Y, Agnani P, Sinsin B (2011) Evaluation du potentiel ethnobotanique des populations rurales au Sud et au centre du Bénin. Int J Biol Chem Sci 5:1432–1447

Dluya T, Daniel D, Umar Y (2017) In vitro antioxidant activity and phytochemical evaluation of five medicinal plant extracts. Pharmac Chem J 4(5):73–82

Doughari JH, El-mamhood AM, Phillip B (2008) Evaluation of antimicrobial potential of stem bark extracts of *Cochlospermum planchoni*. Afr J Phar Pharm 2(8):167–172

Erancheri P, Sunojkumar P, Dilsha Das M (2013) Bat pollination in medicinally important *Cochlospermum religiosum*. Ann Plant Sci 2(8):292–295

Fagbohoun L (2014) Etude chimique de colorants naturels et matériaux résineux traditionnels du Bénin dans le domaine artisanal. Thèse de doctorat en Chimie Organique et Substances Naturelles. Université d'Avignon et des Pays de Vaucluse. France

Falcone Ferreyra ML, Rius SP, Casati P (2012) Flavonoids: biosynthesis, biological functions, and biotechnological applications. Front Plant Sci Plant Physiol 3:222

Faruque MO, Uddin SB, Barlow JW, Hu S, Dong S, Cai Q, Li X, Hu X (2018) Quantitative ethnobotany of medicinal plants

used by indigenous communities in the Bandarban district of Bangladesh. Front Pharmacol 9:40

GBIF (2018) Occurrence download. GBIF.org. https://doi.org/10.15468/dl.zjqgfo. Accessed 01 Dec 2018

Heinrich M, Ankli A, Frei B, Weimann C, Sticher O (1998) Medicinal plants in Mexico: healers' consensus and cultural importance. Soc Sci Med 47:1859–1871

Hepper BT (1977) Changes in blood serum protein levels during the moulting cycle of the lobster, *Homarus gammarus* (L.). J Exp Mar Biol Ecol 9:9. https://doi.org/10.1016/0022-0981(77)90098-3

Heubach K, Wittig R, Nuppenau E-A, Hahn K (2011) The economic importance of non-timber forest products (NTFPs) for livelihood maintenance of rural West African communities: a case study from northern Benin. Ecol Econ 70:1991–2001

Hodgson WC (2001) Food plants of the Sonoran Desert. University of Arizona Press, Tucson

Hutchinson J, Dalziel JM (1958) Flora of West Tropical Africa (2nd ed, vol 1, Part 2). Royal Botanic Garden, Kew

Inácio MC, Bertoni BW, de Castro França S, Pereira AMS (2011) In vitro conservation and low cost micropropagation of *Cochlospermum regium* (Mart. ex Schrank). J Med Plants Res 5:4999–5007

Inngjerdingen KT, Ballo N, Zhang B-Z, Malterud KE, Michaelsen TE, Diallo D, Paulsen BS (2013) A comparison of bioactive aqueous extracts and polysaccharide fractions from rootstocks of wild and cultivated *Cochlospermum tinctorium* A. Rich Phytochem 93:136–143

Inngjerdingen KT, Thöle C, Diallo D, Paulsen BS, Hense A (2014) Inhibition of *Helicobacter pylori* adhesion to human gastric Adenocarcinoma epithelial cells by aqueous extracts and pectic polysaccharides from the rootstocks of *Cochlospermum tinctorium* A. Rich. and Sch. Bip ex Walp Fitoterapia 95:127–132

Isah Y, Ndukwe IG, Ayo RG (2013) Phytochemical and antimicrobial analyses of stem-leaf of *Cochlospermum planchonii*. J Med Plant Herb Ther Res 1:13–17

Jansen PCM (2005) *Cochlospermum tinctorium* Perr. ex A. Rich. (Internet) In: Jansen PCM, Cardon D, (Eds) Record from PROTA4U PROTA, Wageningen, Netherlands. http://www.prota4uorg/searchasp

Jansen PCM, Cardon D (2005) Dyes and tannins. PROTA Foundation, Wageningen

Johnson-Fulton S (2014) Systematics, biogeography, and ethnobotany of the pantropical family cochlospermaceae (malvales). (Electronic Thesis or Dissertation). Retrieved from https://etd.ohiolink.edu/

Johnson-Fulton SB, Watson LE (2017) Phylogenetic systematics of cochlospermaceae (malvales) based on molecular and morphological evidence. Syst Bot 42(2):271–282

Johnson-Fulton SB, Watson LE (2018) Comparing medicinal uses of cochlospermaceae throughout its geographic range with insights from molecular phylogenetics. Diversity 10:123

Kahane R, Hodgkin T, Jaenicke H, Hoogendoorn C, Hermann M, Keatinge JDH, d'Arros Hughes J, Padulosi S, Looney N (2013) Agrobiodiversity for food security, health and income. Agron Sustain Dev 33:671–693

Kanokmedhakul K, Kanokmedhakul S, Phatchana R (2005) Biological activity of Anthraquinones and Triterpenoids from *Prismatomeris fragrans*. J Ethnopharmacol 100:284–288

Kéita SM, Arnason JT, Baum BR, Marles R, Camara F, Traoré AK (1999) Etude ethnopharmacologique traditionnelle de quelques plantes médicinales anthelminthiques de la Haute-Guinée (République de Guinée). Revue de Médecine et Pharmacie Africaine 13:49–64

Kpodar MS, Karou SD, Katawa G, Anani K, Gbekley HE, Adjrah Y, Tchacondo T, Batawila K, Simpore J (2016) An ethnobotanical study of plants used to treat liver ailments in the Maritime region of Togo. J Ethnopharmacol 181:263–273

Kristensen M, Lykke AM (2003) Informant-based valuation of use and conservation preferences of savanna trees in Burkina-Faso. Econ Bot 57(2):203–217

Lamien-Meda A, Kiendrebeogo M, Compaoré M, Meda RN, Bacher M, Koenig K, Pacher T, Fuehrer HP, Noedl H, Willcox M, Novak J (2015) Quality assessment and antiplasmodial activity of West African Cochlospermum species. Phytochemistry 119:51–61

Lesse A, Rether K, Gröger N, Braun K, Bock J (2017) Chronic postnatal stress induces depressive-like behavior in male mice and programs second-hit stress-induced gene expression patterns of OxtR and AvpR1a in adulthood. Mol Neurobiol 54:4813–4819. https://doi.org/10.1007/s12035-016-0043-8

Lykke AM, Mertz O, Ganaba S (2002) Food consumption in rural Burkina Faso. Ecol Food Nutr 41:119–153

Magassouba FB, Diallo A, Kouyaté M, Mara F, Maraa O, Bangoura O et al (2017) Ethnobotanical survey and antibacterial activity of some plants used in Guinean traditional medicine. J Ethnopharmacol 114:44–53

Malcolm SA, Sofowora EA (1969) Antimicrobial activity of selected Nigerian folk remedies and their constitutent plants. J Nat Prod 32(4):512–517

Man S, Gao W, Zhang Y, Huang L, Liu C (2010) Chemical study and medical application of saponins as anti-cancer agents. Fitoterapia 81:703–714

Mann A, Gbate M, Umar AN (2003) Medicinal and economic plants of Nupeland. Jube-Evans Books and Publications, Bida

Mildbraed J (1923) Cochlospermaceae africanae. Botanische Jahrbücher für Systematik 58:234–237

Molero J, Davina JR, Honfi AI, Franco D, Rovira A (2006) Chromosome studies on plants from Paraguay II. Candollea (Genève) 61:373–392

Morawetz W (1986) Remarks on karyological differentiation patterns in tropical woody plants. Plant Syst Evol 152:49–100

Nafiu MO, Akanji MA, Yakubu MT (2011) Effect of aqueous extract of *Cochlospermum planchonii* rhizome on some kidney and liver functional indicies of albino rats. Afr J Tradit Complement Altern Med 8(1):22–26

N'Danikou S, Achigan-Dako EG, Wong J (2011) Eliciting local values of wild edible plants in Southern Benin to identify priority species for conservation. Econ Bot 65:381–395

Nergard CS, Diallo D, Inngjerdingen K, Michaelsen TE, Matsumoto T, Kiyohara H, Yamada H, Paulsen BS (2005) Medicinal use of *Cochlospermum tinctorium* in Mali: antiulcer, radical scavenging and immunomodulating activities

of polymers in the aqueous extract of the rootstocks. J Ethnopharmacol 96:255–269

Neuenschwander P, Sinsin B, Goergen G (eds) (2011) Protection de la Nature en Afrique de l'Ouest: Une Liste Rouge pour le Bénin. Nature Conservation in West Africa: Red List for Benin. International Institute of Tropical Agriculture, Ibadan

Neuwinger HD (1996) African ethnobotany: poisons and drugs: chemistry, pharmacology, toxicology. Chapman & Hall, London

Nikiema A (2005) Agroforestry parkland species diversity: Uses and management in semi-arid West Africa (Burkina Faso). PhD thesis, Wageningen University, Wageningen, Netherlands

Nissen H (2014) A guide to the Fulani people. Jernbanegade 1, DK-6070 Christiansfeld. Denmark. ISBN 978-87-92459-39-8

Ogundipe T, Olatunji A (1991) The leaf anatomy of the species of *Cochlospermum* Kunth (Cochlospermaceae) in West Africa. Feddes Repert 3(4):183–187

Ohwoavworhua FO, Adelakun TA (2005) Some physical characteristics of microcrystalline cellulose obtained from raw cotton of *Cochlospermum planchonii*. Trop J Pharm Res 4:1–7

Olotu NP, Gushit SJ, Ajima U, Olotu AI, Chinedu UC, Thomas PY (2011) Pharmacognostic and biological studies of the rhizome of *Cochlospermum planchonii* Hook.f (Euphorbiaceae). Int J Drug Dev Res 3(1):209–218

Olson DM, Dinerstein E, Wikramanayake ED, Burgess ND, Powell GVN, Underwood EC, D'Amico JA, Itoua I, Strand HE, Morrison JC, Loucks CJ, Allnutt TF, Ricketts TH, Kura Y, Lamoreux JF, Wettengel WW, Hedao P, Kassem KR (2001) Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933–938

Omoloye AA, Akinsola AP (2006) Foraging sources and effects of selected plant characters and weather variables on the visitation intensity of honeybee, *Apis mellifera adansonii* (Hymenoptera: Apidae) in the Southwest Nigeria. J Apic Sci 50:39–48

Ouachinou JM-AS, Adomou AC, Dassou GH, Yedomonhan H, Tossou GM, Akoegninou A (2017) Connaissances et pratiques ethnobotaniques en médecines traditionnelles vétérinaire et humaine au Bénin: similarité ou dissemblance? J Appl Biosci 113:11174–11183

Ouachinou JMAS, Dassou GH, Azihou AF, Adomou AC, Yédomonhan H (2018) Breeders' knowledge on cattle fodder species preference in rangelands of Benin. J Ethnobiol Ethnomed 14:66. https://doi.org/10.1186/s13002-018-0264-1

Ouattara L, Koudou J, Obame JCE, Karou DS, Traore A, Bessiere JM (2007) Chemical composition and antibacterial activity of *Cochlospermum planchoni* Hook.f. ex Planch. essential oil from Burkina Faso. Pak J Biol Sci 10:4177–4179

Ouattara D, Kouame D, Tiebre MS, Cisse A, N'Guessan KE (2016) Diversité floristique et usages des plantes dans la zone soudanienne du Nord-ouest de la Côte d'Ivoire. J Anim Plant Sci 31(1):4815–4830

Oumar YS, Nathalie GK, Souleymane M, Karamoko O, Alexis BG, David GJ et al (2014) In vitro antioxidant activity of extracts of the root *Cochlospermum planchonii* Hook. f. ex. Planch (Cochlospermaceae). J Pharmacog Phytochemist 3(4):164–170

Oyen LPA (2010) *Cochlospermum planchonii* Hook.f. [Internet] Record from PROTA4U. In: Brink M, Achigan-Dako EG (eds) PROTA (Plant Resources of Tropical Africa/Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands http://www.prota4u.org/search.asp. Accessed 27 Nov 2017

Pare D, Hilou A, Ouedraogo N, Guenne S (2016) Ethnobotanical study of medicinal plants used as anti-obesity remedies in the nomad and hunter communities of Burkina Faso. Medicines 3:9. https://doi.org/10.3390/medicines3020009

Planchon JE (1847) Sur la nouvelle famille des Cochlospermées. Lond J Bot 6:294–311

Poppendieck HH (1980) A monograph of the cochlospermaceae. Botanische Jahrbücher für Systematik 101:191–265

Pousset JL, Bassene E, Afoutou JM, Thiombiano A (1987) Plantes médicinales africaines XXI. Contribution à l'étude hépatoprotectrice de *Cochlospermum tinctorium*. Le pharmacien africain

Prado D (1998) *Cochlospermum tetraporum*. The IUCN Red List of Threatened Species. doi:10.2305/IUCN.UK.1998.RLTS.T34322A9858934.en. Downloaded on 26 Jan 2019

Quattrocchi U (1999) CRC World dictionary of plant names: common names, scientific names, eponyms, synonyms, and etymology, vol 1. CRC Press, Taylor & Francis Group, Boca Raton

Sabiu IT, Zainol FA, Abdullahi MS (2018) Hausa people of northern Nigeria and their development. Asian People J 1(1):179–189

Sala AV (1994) Indian medicinal plants: a compendium of 500 species, vol 2. Orient Longman Ltd, Madras

Sangare MM, Sina H, Dougnon J, Bayala B, Ategbo J-M, Dramane KL (2012) Etude ethnobotanique des plantes hépatotropes et de l'usage traditionnel de Gomphrena celosioides Mart (Amaranthaceae) au Bénin. Int J Biol Chem Sci 6(6):5008–5021

Sawadogo A, Koura M, Sombie I, Napon Zongo D, Bamouni S (2017) knowledge, attitudes and practices of traditional practitioners about jaundice in Bobo-Dioulasso. Int J Med Res Pharm Sci, Burkina Faso. https://doi.org/10.5281/zenodo.546201

Segnon AC, Achigan-Dako EG (2014) Comparative analysis of diversity and utilization of edible plants in arid and semi-arid areas in Benin. J Ethnobiol Ethnomed 10:80

Shackleton CM, Geach BGS (eds) (2004) Indigenous forests and woodlands in South Africa: policy, people and practice. University of KwaZulu-Natal Press, Pietermaritzburg, pp 253–256

Shakya AK (2016) Medicinal plants: future source of new drugs. Int J Herb Med 4:59–64

Sieglstetter R, Hahn K, Wittig R (2011) The use of woody species in northern Benin. Flora Veg Sudano-Sambesica 14:19–23

Sinsin B, Oumorou M (2000) Etude de la diversité spécifique du groupement à *Cochlospermum tinctorium* A. Rich. des savanes arbustives du nord-Bénin. Acta Bot. Gallica 147(4):345-360

Somopogui AS (1998) Médecine vétérinaire traditionnelle en République de Guinée. From N'Dama 1:2–6

Stigall AL (2012) Using ecological niche modelling to evaluate niche stability in deep time. J Biogeogr 39(4):772–781. https://doi.org/10.1111/j.1365-2699.2011.02651.x

Tabuti JRS, Lye KA, Dhillion SS (2003) Traditional herbal drugs of Bulamogi, Uganda: plants, use and administration. J Ethnopharmacol 88:19–44

Takhtajan A (1980) Outline of the classification of flowering plants (Magnoliophyta). Bot Rev 46:225–359

The Angiosperm Phylogeny Group, Chase MW, Christenhusz MJM, Fay MF, Byng JW, Judd WS, Soltis DE, Mabberley DJ, Sennikov AN, Soltis PS, Stevens PF (2016) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Bot J Linn Soc 181(1):1–20. https://doi.org/10.1111/boj.12385

Togola A, Diallo D, Dembele S, Barsette H, Paulsen BS (2005) Ethnopharmacological survey of different uses of seven medicinal plants from Mali, (West Africa) in the regions Doila, Kolokari and Siby. J Ethnobiol Ethnomed 1:7–24

Togola A, Austarheim I, Theis A, Diallo D, Paulsen BS (2008) Ethnopharmacological uses of *Erythnia senegalensis*: a comparison of three areas in Mali and a link between traditional knowledge and modern biological science. J Ethnobiol Ethnomed 4:6–16

Traoré M, Diallo A, Nikièma JB, Tinto H, Dakuyo ZP, Ouédraogo JB, Guissou IP, Guiguemdé TR (2008) In vitro and in vivo antiplasmodial activity of 'Saye', an herbal remedy used in Burkina Faso traditional medicine. Phytother Res 22:550–551

Uprety Y, Poudel RC, Shrestha KK, Rajbhandary S, Tiwari NN, Shrestha UB, Asselin H (2012) Diversity of use and local knowledge of wild edible plant resources in Nepal. J Ethnobiol Ethnomed 8:16

Vermeulen WJ (2006) Sustainable bark harvesting for medicinal use: matching species to prescription. Paper presented at the workshop "Trees for health—forever—Implementing sustainable medicinal bark use in southern Africa" 1–3 November 2005, Willow Park, Johannesburg, South Africa

Vodouhè R, Dansi A (2012) The "bringing into cultivation" phase of the plant domestication process and its contributions to in situ conservation of genetic resources in Benin. Sci World J 2012:1

Vonthron-Senecheau C, Weniger B, Ouattara M, Bi FT, Kamenan A, Lobstein A, Brun R, Anton R (2003) In vitro antiplasmodial activity and cytotoxicity of ethnobotanically selected Ivorian plants. J Ethnopharmacol 87(2–3):221–225

Warren Z, McPheeters ML, Sathe N, Foss-Feig JH, Glasser A, Veenstra-Vanderweele J (2011) A systematic review of early intensive intervention for autism spectrum disorders. Pediatrics 127:e1303–e1311

Willcox M (2011) Improved traditional phytomedicines in current use for the clinical treatment of malaria. Planta Med 77(6):662–671

Woolley JG (2001) Plant alkaloids. In: Encyclopedia of life sciences. Nature Publishing Group, Wiley, pp 1–11

Yamashita CI, Saiki M, Vasconcellos MBA, Sertie JAA (2005) Characterization of trace elements in Casearia medicinal plant by neutron activation analysis. Appl Radiat Isot 63:841–846

Yerbanga RS, Lucantoni L, Lupidi G, Dori GU, Tepongning NR, Nikiéma J-B, Esposito F, Habluetzel A (2012) Antimalarial plant remedies from Burkina Faso: their potential for prophylactic use. J Ethnopharmacol 140:255–260