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Comparing Medicinal Uses of Cochlospermaceae throughout Its Geographic Range with Insights from Molecular Phylogenetics

Susannah B. Johnson-Fulton [1,*] and Linda E. Watson [2]

[1] Department of Biology, Shasta College, Redding, CA 96003, USA

[2] Department of Plant Biology, Ecology, and Evolution, Oklahoma State University, Stillwater, OK 74078, USA; linda.watson10@okstate.edu

* Correspondence: sfulton@shastacollege.edu

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Abstract: Species of the Cochlospermaceae, a small mostly pantropical plant family, were evaluated at a continental scale for medicinal uses in traditional medicine. This ethnobotanical information was placed in a phylogenetic framework to make informed predictions in the search for new medicines and bioactive compounds. Medicinal plant-use data were mapped onto a molecular phylogeny based on DNA sequences of nuclear and chloroplast markers. Associations of medicinal uses among closely related species occurring in different geographic regions and among diverse cultures were evaluated. The most common medicinal uses for these species are those used to treat skin ailments, gastro-intestinal problems, malaria, and liver issues. The plant species with the most numerous uses is *Cochlospermum tinctorium*, which occurs primarily in West Africa. Closely related species being used by cultural groups in different geographic regions to treat the same illnesses suggests the presence of bioactive compounds with potential biomedical value, since they may represent independent discoveries of similar medicinally-active compounds. This leads to the speculation that those closely related species not currently being used to treat these ailments may also contain identical or similar medicinally-active compounds and are worthy of laboratory investigations.

Keywords: Cochlospermaceae; *Cochlospermum*; *Amoreuxia*; medicinal plants; comparative ethnobotany; phylogenetics; molecular systematics; biogeography; culture; pharmacology

1. Introduction

Humans, like much of life on Earth, depend almost entirely on plants for survival [1–3]. Most of our food comes from plants both directly and indirectly. Much of our clothing and building materials consist of plant material. And although most drugs in western medicine are produced in the laboratory, these synthesized compounds usually mimic bioactive compounds first discovered in the plants in which they naturally occur [2,4,5]. According to the World Health Organization (WHO), approximately 80% of developing countries still depend on traditional folk medicines, 85% of which are plant extracts with the other 15% being mineral, fungal, and animal based. Thus, with over 250,000 species of angiosperms alone, and a plethora of plant use knowledge available, the potential for making many new discoveries, making new connections, and finding new medicinal plants and medicinally-active compounds for drug development is enormous. With the effects of global warming, the increased loss of the world's biodiversity, and the disappearance of unique human cultures, it has become even more important to discover and conserve Earth's species, to document and conserve cultural histories, traditions, and languages, and to search for new medicines and new drought tolerant foods [6–9].

Comparing the medicinal uses of closely related plant species throughout their geographic ranges among different cultural groups can offer a new perspective into the search for effective

botanical medicines and other plant species with economic value [10]. Cochlospermaceae Planch. is a small, ethnobotanically important pantropical plant family with species distributed in west and central Africa, India, Southeast Asia, Northern Australia, Central and South America, the West Indies, Mexico, and Southwestern United States (Figure 1). It is composed of two genera, *Amoreuxia* DC., four herbaceous species, and *Cochlospermum* Kunth, 12 woody species (Figure 2). Of its 16 species, 12 are known to be used by many cultures on different continents [11–19]. The widespread distribution of its species combined with its rich ethnobotanical use makes Cochlospermaceae an ideal family to explore any tendencies for closely related species to be used in similar ways by people of diverse cultural groups. If, for example, closely related species are used in similar ways by distantly related cultures, then those species may, in fact, provide more effective medicines because they represent independent discoveries of similar medicinally-active compounds.

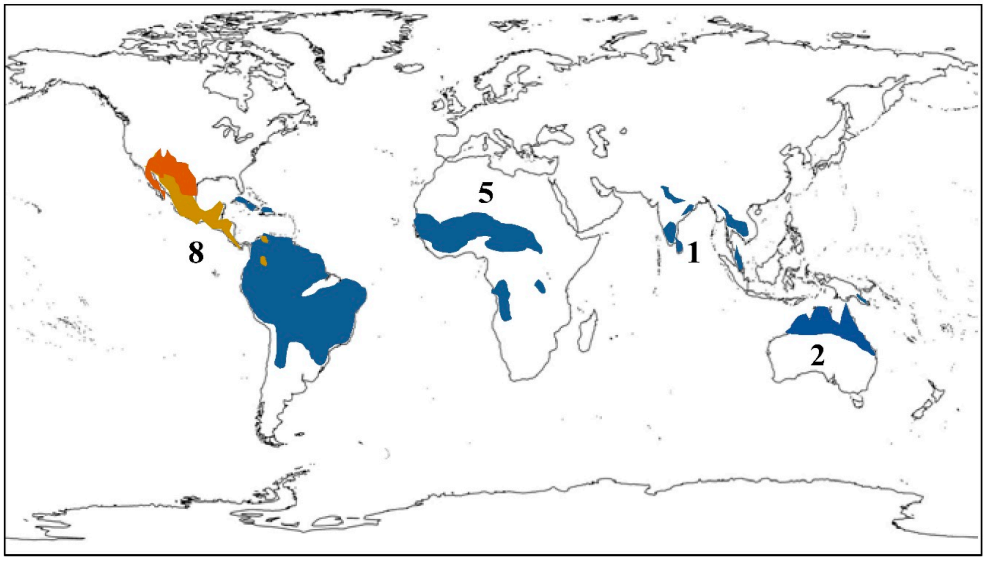

Figure 1. Distribution of the two genera of Cochlospermaceae. Blue = *Cochlospermum*; Orange = *Amoreuxia*; Yellow = overlapping ranges of the two genera. Numbers indicate the numbers of species in different geographic regions. 8—the Americas; 5—Africa; 1—Asia; 2—Australia.

Four major strategies are generally used in the search for medicinally-active plants: (1) random approach—randomly selecting plants to sample in a particular area; (2) phylogenetic approach— choosing species that are closely related to other species with known medicinally-active compounds; (3) ecological approach—selecting plants that live in certain habitats or that exhibit specific characteristics, such as anti-herbivory compounds; and (4) ethnobotanical approach—choosing plants that are used by local people to treat illness [2]. The ethnobotanical approach is currently known to be the most successful of the major strategies [10,20]. Here we have combined both the phylogenetic and ethnobotanical approaches by choosing a geographically-widespread plant family, reconstructing a molecular phylogeny for the family, mapping ethnobotanical data onto the resulting phylogeny, and evaluating correlations between the evolutionary relatedness of the species and their ethnobotanical uses by different cultural groups who live in different geographic regions. Studies such as this that utilize phylogenetic patterns of medicinal properties within plant lineages are few [10,21–29]. Saslis-Lagoudakis et al. [10] concluded that phylogenetic cross-cultural comparisons can focus screening efforts on the closest relatives of medicinal plants already in use as traditional medicines.

Few comparative ethnobotanical studies, in general, have been conducted, and those that have been conducted usually compare the total use of plants among different cultural groups rather than examining the uses of a single plant lineage across its geographic range [10,30–32]. This research focuses on a single plant family with a widespread distribution and compares how diverse ethnic groups from different geographic regions use the closely related species medicinally.

(**a**) (**b**) (**c**)

Figure 2. Examples of Cochlospermaceae: (**a**) herbaceous *Amoreuxia wrightii* flowering and fruiting in Nuevo Leon, Mexico; (**b**) *Cochlospermum planchonii* (sub-shrub) exhibiting characteristic large yellow flowers and palmately lobed leaves in Senegal, West Africa; (**c**) *Cochlospermum tinctorium* (sub-shrub) blooming straight from the ground after a savannah fire in Senegal, West Africa.

Through the course of this study, we aimed to: (1) compare how people of different geographic regions use the species of Cochlospermaceae as medicines; (2) determine which species are more commonly used; (3) distinguish which medicinal uses are most common among the different plant species and between different geographic regions; (4) identify which species have received the most attention in pharmacological research, and which are candidates that lack pharmacological research attention; and (5) map ethnomedicinal data onto a molecular phylogeny and evaluate correlations between the evolutionary relatedness of the plant species and the medicinal uses in different geographic regions.

2. Materials and Methods

Literature related to the medicinal ethnobotany of the geographic regions where species of Cochlospermaceae grow was examined, as well as all published pharmacological research conducted on its species. Some plant use data was gathered in the field for *Amoreuxia wrightii* A. Gray in Yucatan, Mexico (2006), *Cochlospermum orinocense* (Kunth) Steud. in the Peruvian Amazon (2005), and *C. planchonii* Hook.f. ex Planch. and *C. tinctorium* Perr. in the region of Kedougou, Senegal (2002 & 2017). Field data were gathered through formal and informal interviews following the interview methods described by Alexiades [33] and Martin [34].

Medicinal uses were divided into the following categories: Gastro-intestinal, Respiratory, Kidney, Urinary Tract, Female Health, Male Health, Muscular/Skeletal, Infections/Fevers, Vascular/Blood, Hepatitis/Jaundice, Skin, Neurological, Pain, Snake Bites, Eyes, Malaria, and Unspecific. Selected medicinal uses of Cochlospermaceae were coded as character states and traced onto the previously published majority rule consensus tree resulting from a Bayesian inference analysis of the combined nuclear (ITS (internal transcribed spacer)) and chloroplast (*trnG* and *trnL-F*) DNA matrix by the authors of this paper, Johnson-Fulton and Watson [35], using MacClade 4 [36]. Exploration of character trait evolution was conducted using ACCTRAN optimization assuming Fitch parsimony, equal weighting of all characters, equal transitioning probability among all states, and characters as unordered.

3. Results and Discussion

Of the 16 species of Cochlospermaceae examined in this study, nine have documented medicinal uses. Table 1 lists the medicinal use, general locality, and plant parts used. Of the different uses, many are shared by two or more plant species throughout the geographic range of the plant family. Of the nine ethnomedicinal species of Cochlospermaceae, we found that *Cochlospermum tinctorium*, a subshrub from Africa that usually flowers at ground level after fire (Figure 2), and *C. religiosum* (L.) Alston, a tree originating in India, far surpass all other species in number of medicinal uses with *C. inctorium* having 54 medicinal uses and *C. religiosum* with 52 (Figure 3). The next most highly used species are *C. vitifolium* Spreng. (19 uses), a tree with a widespread range in the Americas, and *C. regium* Pilg. (16 uses), a subshrub from South America (Figures 1 and 3).

Table 1. Major medicinal uses of species of Cochlospermaceae, including general geographic regions where uses occur, plant parts used, and references.

Plant Species	Geographic Regions	Plant Parts	Medicinal Uses/Ailments Treated
Amoreuxia wrightii A. Gray	Mexico	Leaves	Headache
Cochlospermum vitifolium Spreng.	Mexico	Bark	Snakebites, diarrhea, skin rashes, hepatitis, jaundice, liver issues, hypertension, high blood pressure, hyperglycemia, diabetes, asthma, cleanse vagina, veterinary
	Panama	Bark	Liver issues, kidney issues
	Mexico, Guatemala	Wood, leaves	Chest issues, jaundice, liver issues, kidney issues, hasten childbirth
	Costa Rica	Wood	Jaundice
	Mexico, Cuba	Leaves	Ulcers
	Mexico	Flowers	Chest issues, hepatitis
	Mexico, Cuba	Root	Stimulate menstruation, abscesses, intestinal issues
	Panama	Fruit	Blood circulation
		Not specified	Eating disorders, anti-hypertensive
	[11,14,37–45]		
Cochlospermum regium Pilg.	Brazil	Roots	Inflammation of the intestine, uterus, and ovaries; skin problems (boils, pimples, dermatitis, and blotchy skin), arthritis and rheumatism, acne, infections of the reproductive and urinary systems
		Bark	Rheumatoid arthritis, and in a compress to help heal abscesses
		Not specified	Headaches, internal cleansing agent (removing wastes and toxins), heal wounds, cleanse blood, laxative, internal pains, leucorrhea (abnormal vaginal discharge), inflammation/infection of prostate, gastritis, ulcers
	[11,46–52]		
Cochlospermum orinocense (Kunth) Steud.	Amazon	Bark	Fevers
		Not specified	Bruises, wounds, promotes formation of scar tissue
	[53,54]		
Cochlospermum planchonii Hook.f. ex Planch.	Burkina Faso	Roots	Malaria, hepatitis, jaundice, liver issues, constipation
	Ivory Coast	Roots	Fevers, malaria
	Nigeria	Roots	Jaundice, fevers, and malaria
	Niger	Roots	Jaundice, malaria, fevers, lactation issues
	Benin	Leaves	Edema
	West Africa	Not specified	Stomach troubles, burns, indigestion, leprosy, jaundice, testicular inflammation, and urethral discharges
	[11,55–63]		
Cochlospermum tinctorium Perr.	West Africa, including: Ivory Coast, Ghana, Cameroon, Nigeria, Gambia, Guinea-Bissau, Guinea, Togo, and Senegal,	Roots	Jaundice, liver diseases, yellow fever, and malaria
	West Africa	Not specified	Epilepsy, schistosomiasis, leprosy and other skin infections, burns, edema, urethral discharge, menstrual cramps, testicular inflammation, pneumonia and other lung infections, conjunctivitis, indigestion, stomachache, diarrhea, rickets, intestinal worms, and beriberi, stimulate blood flow in the uterus and pelvic region and aid in childbirth

Table 1. *Cont.*

Plant Species	Geographic Regions	Plant Parts	Medicinal Uses/Ailments Treated
	Mali	Roots	Urinary issues, schistosomiasis, gastrointestinal problems, such as ulcers, stomachaches, constipation, and flatulence, abdominal pains, wounds, hemorrhoids, intestinal worms, schistosomiasis, and hepatitis, snakebites
		Leaves	Malaria, ulcers, and flatulence
		Flowers	Constipation
	Senegal	Roots	Rickets, colic, indigestion, ascite, beriberi, hemorrhoids, testicular inflammation, schistosomiasis, syphilis, bronchitis, convulsions, epilepsy, fever, imflammation of lymph nodes, measles, malaria, blepharitis (inflammation of eyelid), gonorrhea, boils, worms
	Togo	Root	Painful menstruation, rectal prolapse, jaundice
Cochlospermum tinctorium	Benin	Root	Jaundice, inner hemorrhaging, headache
		Whole plant	Weakness
	Nigeria	Root	Promote general body health
		Root, stem	Veterinary medicine
		Fruit	Snakebites
		Seed (oil)	Leprosy
	Niger	Roots	Jaundice
	Ghana	Roots	Bronchial problems (pneumonia, lung inflammation), epileptic convulsions, eye issues (conjunctivitis, trachoma, sore eyes), fevers, hernias, chest pain, leprosy, absence of menstruation, female sterility, hemorrhoids, sprains, burns, bruises, stomachaches, indigestion, inflammation, venereal diseases, snakebites, bleeding diarrhea, rheumatic muscle and back pain
	Burkina Faso	Root	Malaria
	Ivory Coast	Root	Inflammation of the testes, schistosomiasis, jaundice, fevers, epilepsy, pneumonia, chest pain, bronchial problems (pneumonia), conjunctivitis, indigestion, stomach pain, snakebites, skin diseases
		Leaves	Abscesses and boils
		Stems, roots	Urinary and genital pain and disorders, kidney pain, chest pain
	[15,56,63–74]		
Cochlospermum angolense Welw.	Angola	Bark, roots	Protect and heal liver, jaundice, hepatitis, prophylaxis and treatment for malaria, stomach, liver, gallbladder, spleen, and urinary tract, and also used externally as a wash for skin problems, such as herpes and open sores
	[11,75,76]		
Cochlospermum religiosum (L.) Alston	India	Not specified	Dry cough, tuberculosis, bronchitis, laryngitis, colds, sneezing, mucus inflammation in the nose, throat, and sinuses, varicose veins, malaria, weakness, fever, headache, earache, hard of hearing, optic inflammation, and inflammation of the stomach, liver, kidney, and urinary tract. Other uses include expelling phlegm from the lungs, dissolving bladder and kidney stones, removing warts, relieving and moisturizing sore, irritated, and/or congested eyes, and enhancing ejaculation while controlling excessive and/or involuntary emissions, stop or slow bleeding by contracting tissues and/or blood vessels, excessive menstrual bleeding, blood in the urine, bleeding hemorrhoids, lower intestinal bleeding, and vomiting blood. Aphrodisiacs, cerebral tonics (relaxes and soothes anxiety and nervous twitches), astringents, diuretics, general anti-inflammatories, internal cooling agents, and assists with opium addictions
		Leaves, flowers	Stimulant
		Whole plant	Coughs
		Gum	Pain reliever, sedative, and laxative, and is thought to be thermogenic. It is also used to treat cough, diarrhea, dysentery, pharyngitis, gonorrhoea, syphilis, trachoma, and stomach and urinary tract disorders, protection from heat strokes
	[11,16,18,77–80]		
Cochlospermum fraseri Planch.	Australia	Root	Treat sores, boils, and cuts
		Leaves, bark, flowers	Treat fevers
	[81,82]		

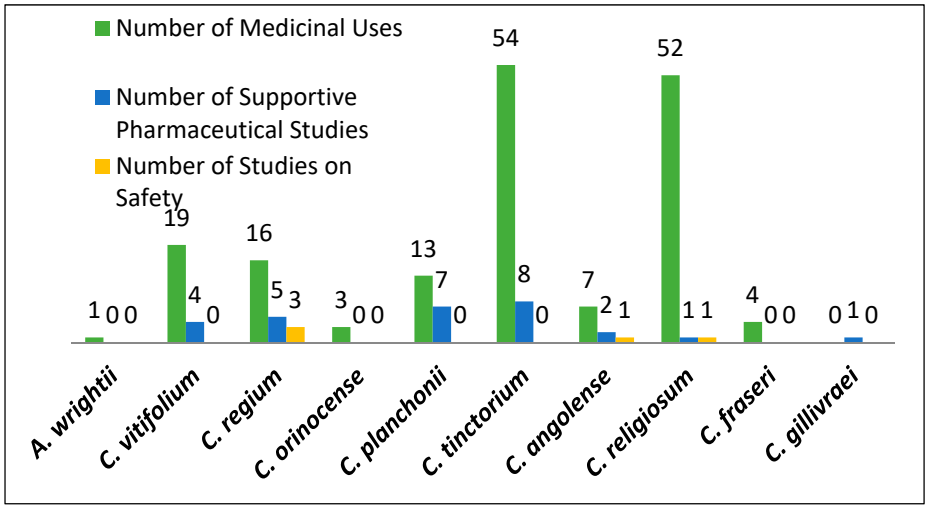

Figure 3. Numbers above bars indicate medicinal uses per species and pharmacological studies that support medicinal activity and safety.

Of the many documented uses, a high number fall into the categories of gastro-intestinal, skin, and female health afflictions, with many of the gastro-intestinal uses occurring in Africa (Figure 4). The highest number of species (eight species) are used to treat skin related issues, such as abscesses, boils, infections, burns, bruises, and cuts in all four major geographic regions, with many of the uses occurring in Africa and the Americas: *C. tinctorium*, *C. planchonii*, and *C. angolense* in Africa, *C. vitifolium*, *C. regium*, and *C. orinocense* in the Americas, *C. religiosum* in India, and *C. fraseri* Planch. in Australia (Figures 4–6). Six different species are used to treat gastro-intestinal issues, such as indigestion, ulcers, intestinal parasites, and diarrhea in three major geographic regions: *Cochlospermum tinctorium*, *C. planchonii*, and *C. angolense* Welw. in Africa, *C. vitifolium* and *C. regium* in the Americas, and *C. religiosum* in India (Figures 4–6). The female affliction category has the same number of uses in Africa as in the Americas (Figure 4). Five species are used to treat female afflictions, such as uterine and ovarian infections and menstruation and childbirth issues in three major geographic regions: *Cochlospermum tinctorium* and *C. planchonii* in Africa, *C. vitifolium* and *C. regium* in the Americas, and *C. religiosum* in India (Figures 4–6).

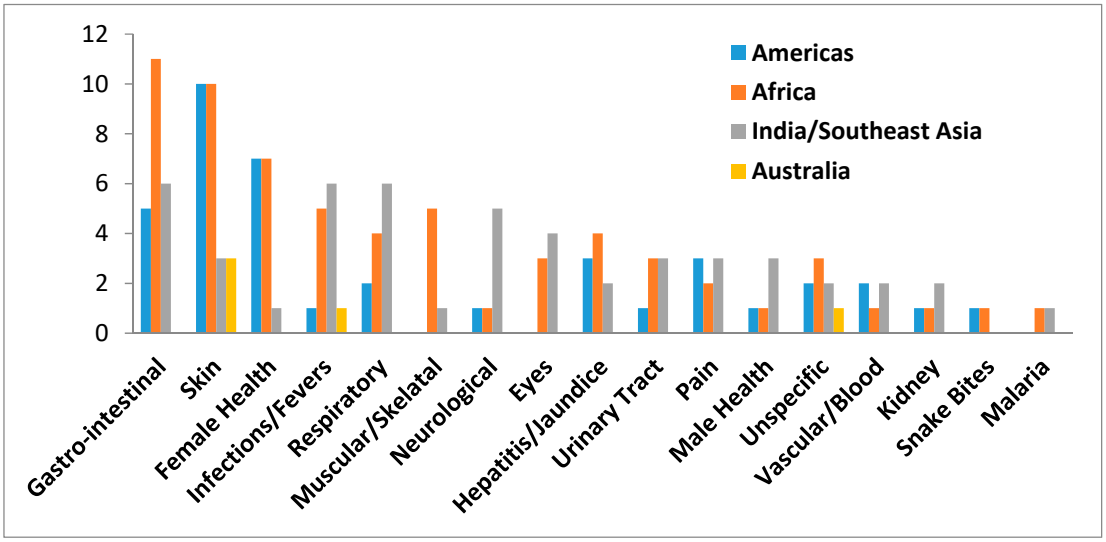

Figure 4. Number of different types of uses (*y*-axis) per major category of medicinal use (*x*-axis) for species of Cochlospermaceae in the Americas, Africa, India/Southeast Asia, and Australia.

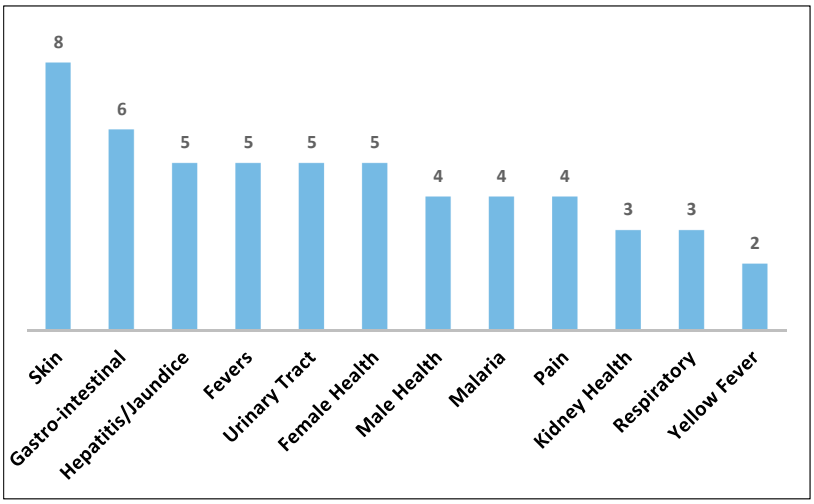

Figure 5. Number of species of Cochlospermaceae (indicated above bar) used for selected medicinal uses.

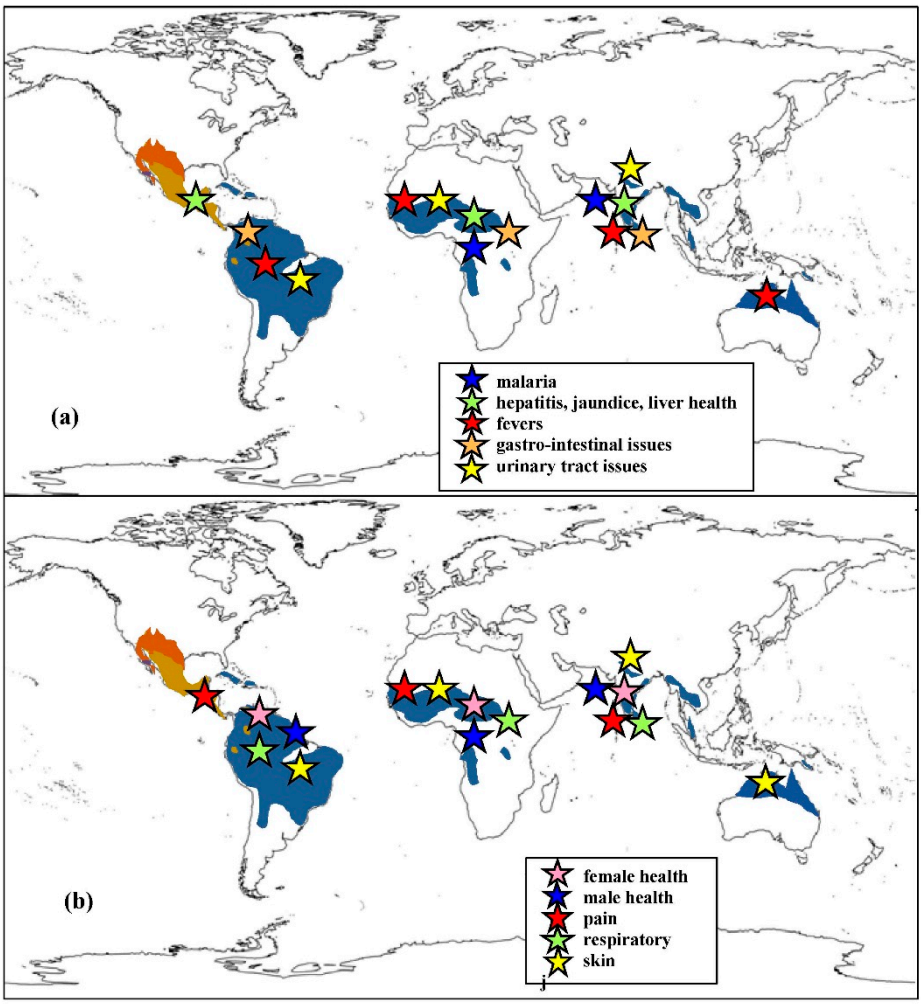

Figure 6. Comparing medicinal use throughout the geographic range of Cochlospermaceae. World maps illustrating general geographic regions where species of Cochlospermacea are being used to treat similar ailments: (**a**) malaria, hepatitis/jaundice/liver ailments, fevers, gastro-intestinal issues, and urinary tract issues; (**b**) female and male health issues, pain, respiratory ailments, and skin issues. Medicinal uses were divided between two maps to avoid overlapping stars.

Cochlospermum vitifolium (Mexico, Central America, South America), *C. religiosum* (India), *C. angolense* (Angola), and *C. planchonii* and *C. tinctorium* (West Africa) are all used as treatments for jaundice and hepatitis, and also for general liver health (Figures 5 and 6). Five species are used to treat fevers in all four of the major geographic regions: *C. orinocense* in South America, *C. religiosum* in India, *C. planchonii* and *C. tinctorium* in West Africa, and *C. fraseri* in Australia (Figures 5 and 6).

As well as illustrating the number of medicinal uses per species, Figure 3 also shows the number of pharmacological studies conducted which have tested the bioactivity of many of the species, including one species, *Cochlospermum gillivraei* Benth., that doesn't have any documented medicinal uses. Many of these pharmacological studies found extracts from tested species to be potentially effective and safe medicines through in vitro and/or in vivo laboratory studies [42,48,50–52,59–61,72,83–107]. *Cochlospermum tinctorium*, from West Africa, was found to be the species with the highest number of medicinal uses and has been the focus of many bioscreening studies (Figures 3 and 7).

Figure 7. Dried tuberous root of *Cochlospermum tinctorium* being prepared to be sold at a market in Bamako, Mali, West Africa. Photo used with permission. Copyright Sergio Giani, Archives d'Aidemet Ong.

Extracts of *Cochlospermum tinctorium* from West Africa were found to be antimicrobial, antiviral, antimalarial, anti-tumor, anti-ulcer, and hepatoprotective [52,72,85,87,98,104,107]. *Cochlospermum planchonii*, also from West Africa, was also found to be antimalarial and hepatoprotective in laboratory studies [60,61,108,109]. Another African species exhibiting positive laboratory results as an antimalarial is *C. angolense*, from Angola [76,90,91]. *Cochlospermum vitifolium* and *C. regium*, from the Americas, were both found to be analgesic and anti-inflammatory. In addition, *C. vitifolium* was discovered to be antihypertensive and antidiabetic and *C. regium* was found to be antimicrobial and toxic to cancer cells [97,100–103,110]. One pharmacological study supports the use of *C. religiosum* as a treatment for eye afflictions. Devi et al. [111] discovered that a bioactive flavonoid (IR3G) isolated from the leaves of *C. religiosum* protected enucleated rat lenses from sodium selenite-induced cataract formation in vitro. These pharmacological studies provide substantial evidence that many of the traditional medicines from *Cochlospermum* species are effective and may even be more effective than modern treatments due to the rise of parasite and bacterial resistance [112,113]. Many species of Cochlospermaceae have yet to be studied for pharmacological activity.

In this study, ethnomedicinal data were mapped onto a previously-published molecular phylogeny [35] to be used as a framework to identify and evaluate correlations between the evolutionary relatedness among species and ethnobotanical uses by multiple ethnic groups in different geographic regions (Figures 8–11). Species sharing a most recent common ancestor generally produce

similar secondary metabolites (bioactive compounds) because they share the same or similar metabolic pathways. This predictive nature of phylogenies can be used for drug discovery and to guide studies that provide additional support of effectiveness of target species [23,28,29,114].

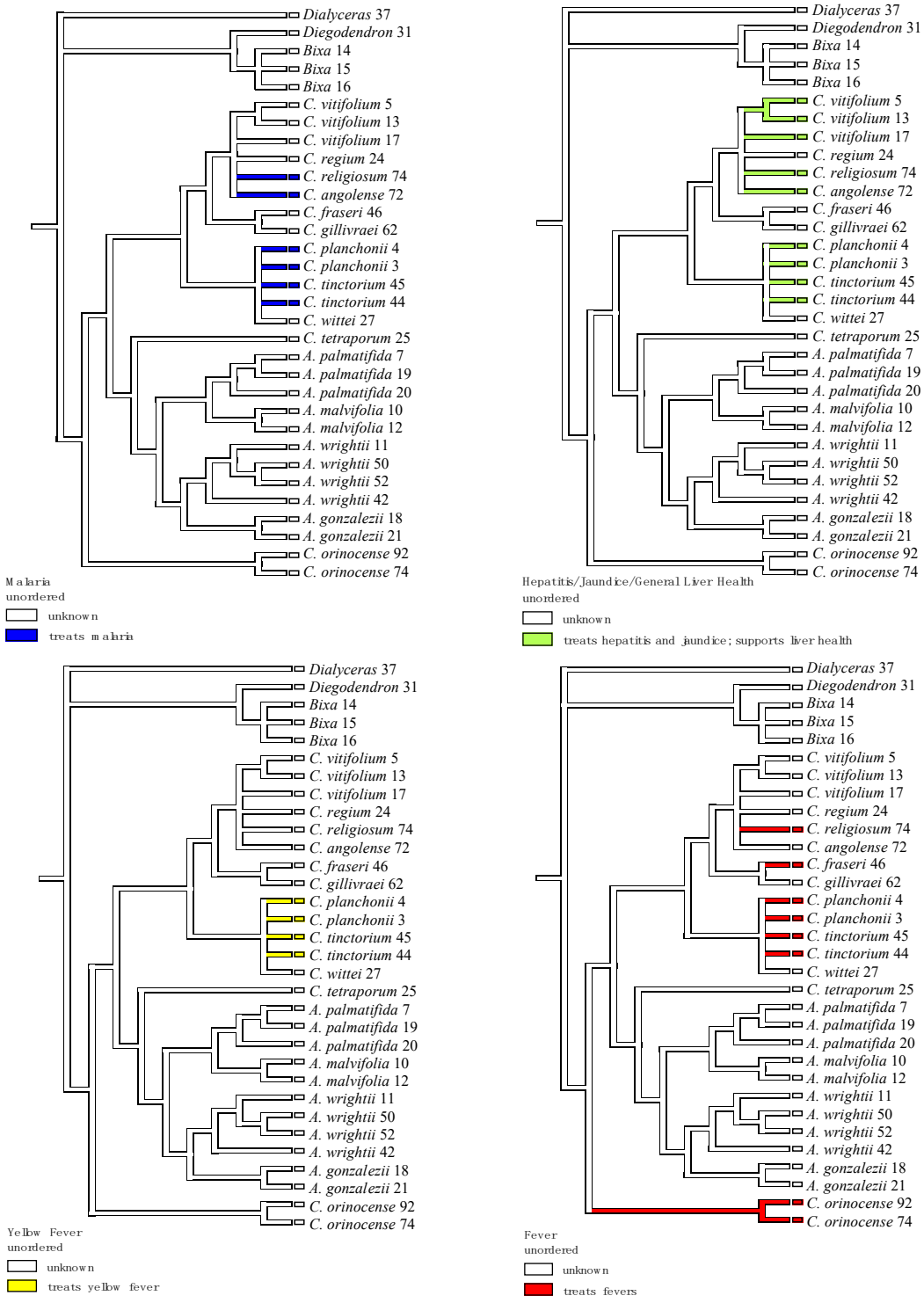

Figure 8. Medicinal uses (treatments for malaria, hepatitis/jaundice/other liver issues, yellow fever, and general fever) shared by two or more species mapped (as unordered character states) onto the Bayesian inference phylogeny of Cochlospermaceae of the combined nuclear (ITS) and plastid (*trnG* and *trnL-F*) regions from Johnson-Fulton and Watson [35].

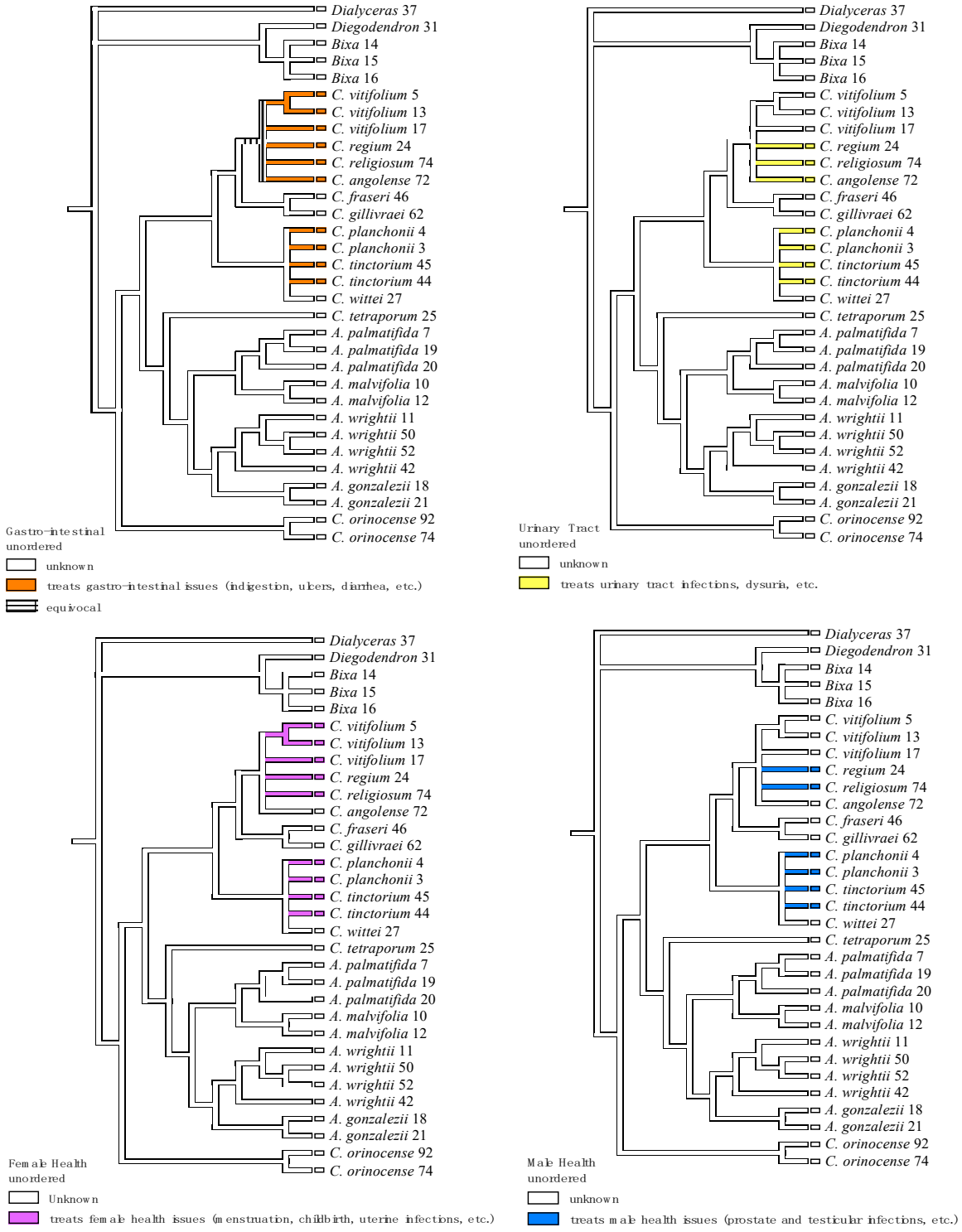

Figure 9. Medicinal uses (treatments for gastro-intestinal, urinary tract, female health, and male health issues) shared by two or more species mapped (as unordered character states) onto the Bayesian inference phylogeny of Cochlospermaceae of the combined nuclear (ITS) and plastid (*trnG* and *trnL-F*) regions from Johnson-Fulton and Watson [35].

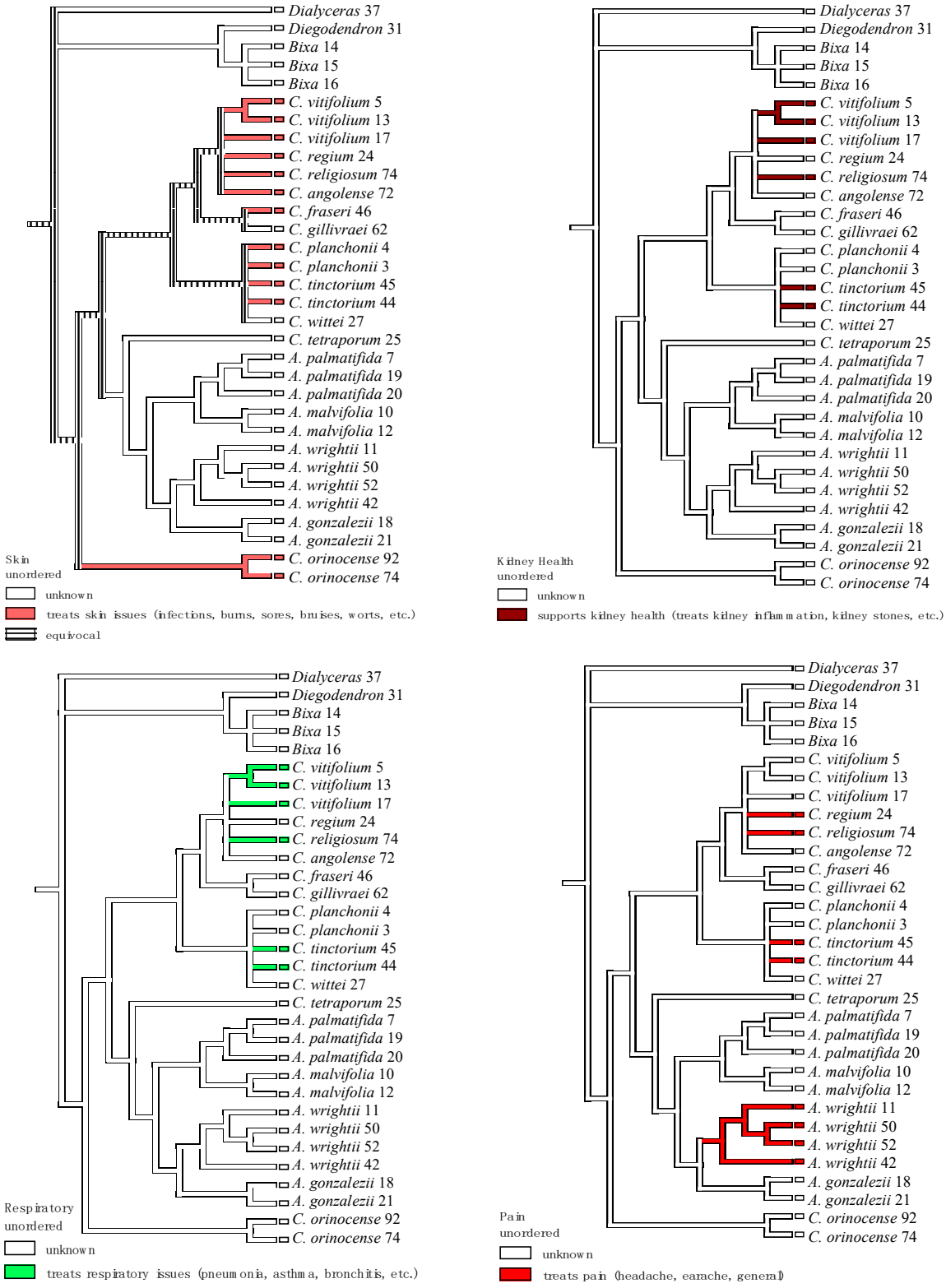

Figure 10. Medicinal uses (treatments for skin, kidney, and respiratory ailments and general pain) shared by two or more species mapped (as unordered character states) onto the Bayesian inference phylogeny of Cochlospermaceae of the combined nuclear (ITS) and plastid (*trnG* and *trnL-F*) regions from Johnson-Fulton and Watson [35].

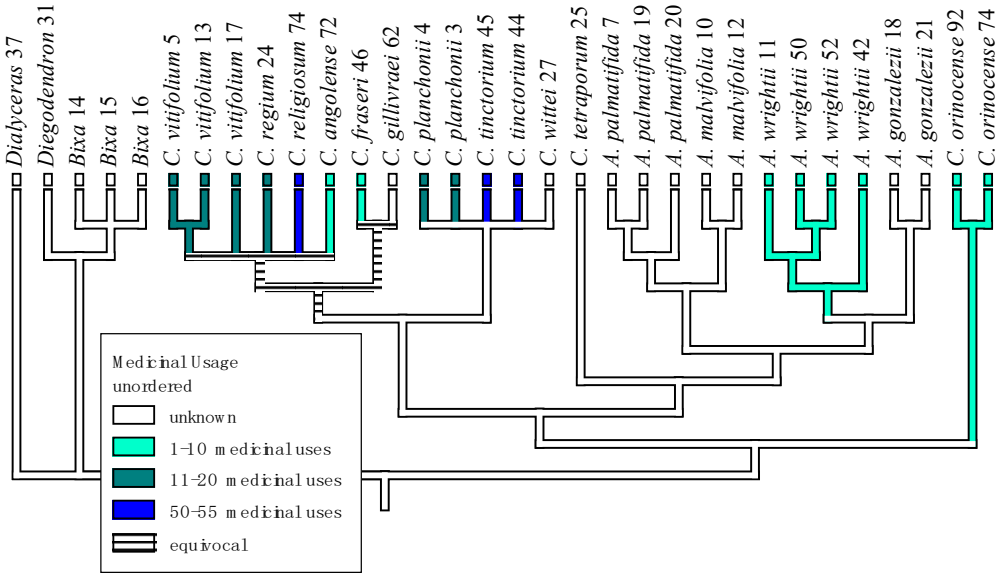

Figure 11. Number of medicinal uses of each species mapped (as unordered characters) onto the Bayesian inference phylogeny of Cochlospermaceae of the combined nuclear (ITS) and plastid (*trnG* and *trnL-F*) regions from Johnson-Fulton and Watson [35].

Based on the results of this study, it is apparent that the species used for a medicinal use are often closely related, with a strong phylogenetic signal for a specific medicinal property (Figures 8–10). The lineage showing the most medicinal uses is the small clade (branch) of African species including *Cochlospermum tinctorium*, *C. planchonii*, and *C. wittei* Robyns which are all suffrutescent subshrubs (Figure 11). Of those three species, *C. wittei* is the only species lacking documented medicinal uses. This clade in the phylogeny is sister to another closely related group of species that includes all 'core' species of *Cochlospermum* (excluding *C. orinocense* and *C. tetraporum* Hallier f.), many of which share medicinal uses.

This high level of similar medicinal uses among closely related species may be due to the shared presence of bioactive compounds. In searching for new medicines, those species not being used to treat a specific illness while their closely related species are, such as is the case for *C. wittei*, could be potential candidates for bioscreening studies and they should be examined for more geographically localized medicinal use. Since they are closely related, they likely share medicinally-active compounds. Similarly, Rønsted et al. [21] found medicinally-active alkaloids in *Narcissus* in closely related species and suggested that phylogenetic relatedness could be used to make predictions about the presence of those same compounds in uninvestigated species. Thus, placing medicinal uses and/or the presence of bioactive compounds in a phylogenetic framework can make it possible to target species for further research. Species that are closely related to species commonly used as plant medicines may be harboring those same medicinal compounds, perhaps even at higher levels or slightly modified with greater effectiveness.

Four species in the major core *Cochlospermum* clade are used to treat malaria with three of the four having been positively screened for their high level of antimalarial activity (Figure 8) [60,61,76,90,91,104,107–109]. Since malaria is such a problem in tropical regions of the world, and since *Plasmodium* resistance is so prevalent, the search for new antimalarials remains important. The other African subshrub species, *C. wittei*, the two core *Cochlospermum* species from the Americas (*C. vitifolium* and *C. regium*), and the two species from Australia (*C. fraseri* and *C. gillivraei*) may be strong candidates in the search for new antimalarial medicines, especially since some have already exhibited medicinal bioactivity. This method of combining phylogenetics, ethnobotany, and biogeography to discover new medicines appears to be much more efficacious than random screening of plants or through ethnobotanical studies alone.

The use categories with the highest number of documented uses and the highest number of species of Cochlospermaceae being used as treatments are gastro-intestinal complaints and skin issues (Figures 4 and 5). In the phylogeny optimized for skin treatments (Figure 10), nearly all of the core *Cochlospermum* species are used to treat skin ailments, in addition to *C. orinocense* which is placed outside the core *Cochlospermum* clade in the phylogeny. This includes eight species across the four major geographic regions of the Americas, Africa, India, and Australia. This global use for these closely related, similar species, and the positive results from anti-microbial, anti-tumor, and anti-ulcer research offer strong support for the effectiveness of these skin related treatments [52,72,85,87,98]. Many of these same studies also support the ethnomedicinal uses related to gastro-intestinal issues.

4. Conclusions

Within Cochlospermaceae there are many similar medicinal uses among closely related plant species of different geographic regions among diverse cultural groups. Closely related species of Cochlospermaceae being used by cultural groups of different geographic regions to treat the same illness, suggests that these species and other closely related species may contain bioactive chemical compounds with potential biomedical value because they may represent independent discoveries by different cultural groups of similar medicinally-active compounds. Some of these patterns could be due to cultural exchange, such as similar uses between South America and Africa due to diaspora of African slaves into the Americas. However, because there are so many similar use patterns among the species, and because the geographic scale of this study is so large, we propose that those instances, while possible, are few or unlikely. There is also a small chance that these common ethnobotanical patterns could be due to chance rather than the presence of bioactive properties. Perhaps some of the similarities of use could be due to the plants sharing similar morphological characters, such as yellow flowers and sap which could lead different groups to use similar species to treat illnesses that are connected with the color yellow, such as the treatments for jaundice, hepatitis, liver health, yellow fever, and urinary tract issues. This phenomenon, known as the Doctrine of Signatures, would be challenging to test [115].

This study is one of few to take a multidisciplinary approach to explore cross-cultural ethnobotanical patterns at a large geographic scale in a phylogenetic framework. For such a small family, Cochlospermaceae harbors many species with important ethnobotanical uses. Greater effort should be made to study the pharmacological activity of these species that share medicinal uses throughout their geographic ranges, as well as those closely related species as determined through molecular phylogenetics research. It remains valuable to continue to gather ethnobotanical data in the field as well as study the effects of wild harvesting on natural populations and the options for cultivation of those species that are highly used and/or rare in occurrence. More investigation on the distribution patterns, population density and regeneration of these species could help with planning and establishing harvest regulations that assure a sustainable supply of plant materials.

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