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Phytochemical and biological overview of genus "Bignonia" (1969-2018)

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Abstract

Bignonia L. is the fifth largest genus in the tribe Bignonieae, with 31 lianas species. Bignonia plants are widely used in traditional medicine as skin ailments like fungal infections, postpartum haemorrhage, malaria, diabetes and pneumonia. Many literature reported that Bignonia species contained different classes of active constituents as phenylethanoids, phenolics, lignans, flavonoids, coumarins and xanthones. Additionally, they demonstrated a wide range of biological activities as cytotoxic, wound healing, antidiabetic, sleep induction, gastroprotection, anti-obesity and insecticidal activities. This review revealed that only 15 species have been reported in the literature. Moreover, Bignonia plants need further studies as they are considered a good source for bioactive natural products.

Key words

Bignonia, Bignoniaceae, Phytochemical, Biological activities, review

1. Introduction

Bignoniaceae is a flowering plants family, comprising of about 110 genera and 650 species, and commonly known as the Trumpet Creeper family [1, 2]. Bignoniaceae plants have various bioactive secondary metabolites with diverse pharmacological activities. They are widely used in traditional medicinal systems of a number of countries for the treatment of ailments like cancer, snake bite, skin disorders, gastrointestinal disorders, respiratory tract disorders, hepatic disorders, epilepsy, cholera, pain, urinary problems, malaria, heart problems and sexually transmitted diseases [1]. Bignonia L. is the fifth largest genus in the tribe Bignonieae (Bignoniaceae), with 31 lianas species distributed from Argentina to USA [3, 4]. Many species are reported to have different classes of bioactive secondary metabolites including; phenylethanoids, phenolics, lignans, flavonoids, coumarins and xanthones [5-7]. Bignonia genus has different species with various synonyms. The most popular species are listed in (**Table 1**) with their synonyms. Most Bignonia species are used in folk medicine for treating a wide range of ailments as *B. africana* fruit is used to treat skin ailments like fungal infections, boils, psoriasis, eczema, dysentery, anthelmintic (ringworm and tapeworm), postpartum haemorrhage, malaria, diabetes and pneumonia, while its bark is used to treat venereal diseases and the root is applied to treat ulcer [8, 9]. *B. unguis-cati* is used traditionally to treat a snake bite, dysentery, inflammation, rheumatism, venereal disease and as a quinine substitute for malaria [10-12].

2. Methodology

We performed a systematic search on genus "Bignonia" and reported and reported synonyms of different species as keywords for the search on different databases such as Science direct, DNP, SciFinder, Google Scholar and Scopus. The main search words were "Bignonia" or "biological activity" or "bioactive compounds" or "phytochemical compounds" or "diseases".

3. Chemical composition

Bignonia genus contained various classes of secondary metabolites, noticed from the isolated groups of compounds including; flavonoids, iridoids and quinones, which were the most abundant among Bignonia species. Besides, phenolic acid derivatives, phenylethanoids, lignans, coumarins and sterols. A comprehensive list of the previously isolated compounds from Bignonia species is presented in **(Table 2 and Figure 1)**.

3.1. Flavonoids

Flavonoids are polyphenolic compounds that possess different health benefits due to their antioxidant potential [13]. Flavonoids are the most abundant in different Bignonia plants as *B. brachypoda*, *B. ungis-cati* and *B. callistigoides* [6, 14, 15],….etc.

3.2. Iridoids

They are the second abundant class of secondary metabolites isolated from Bignonia plants, with different biological activities. In which, verminoside **(136)**, specioside **(137)** and minecoside **(138)** were reported in *B. africana* bark and have antiamoebic activity [16].

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Table 1: A list of plants belongs to genus "Bignonia" with their synonyms.

Bignonia species	Synonym (s)
B. digitalis Vell.	*Zeyheria digitalis* (Vell.) Hoehne
B. binata Thunb.	*Clytostoma binatum* Thunb. Sandwith
B. callistigoides Cham.	*Clytostoma callistigoides* (Cham.) Baill.
B. capensis Thunb	*Tecomaria capensis* (Thunb.)
B. adenophylla Wall. & G. Don	*Heterophragma adenophyllum* (Wall. & G. Don)
B. africana Lam.	*Kigelia africana* (Lam.) or *Kigelia pinnata* (Jacq.)
B. unguis-cati L.	*Macfadyena unguis-cati* (L.) A.H.Gentry
B. hymenaea DC.	Pachyptera hymenaea DC (Mansao hymenaea)
B. brachypoda DC.	*Arrabidaea brachypoda* Bureau
B. cuprea Cham.	*Arrabidaea chica* f. *cuprea* (Cham.) Sandwith
B. samydoides Cham	*Arrabidaea samydoides* (Cham.) Sandwith
B. triplinervia Mart. ex DC.	*Arrabidaea triplinervia* (Mart. ex DC.) Baill.
B. patellifera Schltdl.	*Arrabidaea patellifera* (Schltdl.) Sandwith
B. crucigera L.	*Pithecoctenium crucigerum* (L.) A.H.Gentry
B. elegans Vell.	*Pseudocalymma elegans* (Vell.)
B. stans L.	*Tecoma stans* (L.) Kunth
B. aesculifolia Kunth	*Godmania aesculifolia* Standl

Table 2: A list of previously reported compounds from genus "Bignonia" (with different synonyms as shown in Table 1).

Classification	No.	Item	Part used	Source	Ref.
I-Phenylethanoids					
	1	Decaffeoyl acteoside	Aerial part	*B. unguis-cati*	[14]
	2	Verbascoside	Leaf	*B. stans*	[19]
			Stem	*B. crucigera*	[5]
	3	Isoverbascoside	Stem	*B. crucigera*	[5]
	4	Forsythoside B			
	5	Jionoside D			
	6	Leucosceptoside B			
II-Phenolic compounds					
	7	4-Dihydroxyphenyl)ethyl 2-*O*-[5-*O*-(4-hydroxy-3,5-dimethoxybenzoyl)-β-D-apiofuranosyl]- β-D-glucopyranoside	Root	*B. brachypoda*	[6]
	8	3,4-Dihydroxyphenyl)ethyl 2-*O*-[5-*O*-(3,4-dihydroxybenzoyl)-β-D-apiofuranosyl]-β-D-glucopyranoside			
	9	*p*-Coumaric acid	Stem bark	*B. africana*	[18]
	10	Caffeic acid			
	11	Ferulic acid	Stem and fruit	*B. africana*	[20]
	12	Vanillic acid	Stem wood	*B. digitalis*	[21]
	13	Veratric acid			
	14	Atranorin	Stem bark	*B. africana*	[22]
	15	Chlorogenic acid	Leaf	*B. stans*	[19]
			Leaf	*B. unguis-cati*	[23]
	16	Isochlorogenic acid	Leaf	*B. unguis-cati*	[23]
	17	Nonacosanoic acid, 2-(4-hydroxyphenyl)ethyl ester	Stem barks	*B. africana*	[18]
	18	Zeyherol	Stem wood	*B. digitalis*	[21]
III-Lignans					
	19	(+)-Lyoniresinol 3-α-*O*-β-D-glucopyranoside	Aerial part	*B. unguis-cati*	[14]
IV-Flavonoids					
	20	Brachydin A	Root	*B. brachypoda*	[6, 24]
	21	Brachydin B			
	22	Brachydin C			
	23	Brachydin D	Root	*B. brachypoda*	[6]
	24	Brachydin E			
	25	Brachydin F			
	26	Brachydin G			
	27	Brachydin H			
	28	Brachydin I			
	29	Brachydin J			
	30	Cirsimarin	Aerial part	*B. unguis-cati*	[14]
	31	4'-Hydroxywogonin	Leaf	*B. callistigoides*	[15]

Table 2: A list of previously reported compounds from genus "Bignonia" (with different synonyms as shown in Table 1) (cont.).

Classification	No.	Item	Part used	Source	Ref.
	32	Acacetin	Leaf	*B. callistigoides*	[15]
			Leaf	*B. chica*	[25]
	33	Galangustin	Leaf	*B. callistigoides*	[15]
	34	7,8-Dimethoxyflavone	Leaf	*B. aesculifolia*	[26]
	35	5,6,7,8-Tetramethoxyflavone			
	36	Alnetin	Leaf	*B. aesculifolia*	[27]
	37	Gardenin B			
	38	Chrysin 7-methyl ether			
	39	3',4'-Dihydroxy-5,6,7-trimethoxyflavone	Leaf	*B. brachypoda*	[28]
	40	Cirsiliol			
	41	Cirsimaritin	Aerial part	*B. unguis-cati*	[14]
			Leaf	*B. brachypoda*	[28]
	42	Hispidulin	Leaf	*B. brachypoda*	[28]
	43	Chrysin	Leaf	*B. samydoides*	[29]
	44	Carajuflavone	leaf	*B. chica*	[30]
	45	Luteolin	Leaf	*B. stans*	[19]
			leaf	*B. chica*	[30]
	46	Sorbarin	Leaf	*B. elegans*	[31, 32]
	47	Triumboidin	Leaf	*B. elegans*	[32]
	48	Apigenin	Leaf	*B. stans*	[19]
	49	Chrysoeriol			
	50	Corymboside	Leaf	*B. unguis-cati*	[23]
	51	Vicenin-2	Leaf	*B. unguis-cati*	[12, 23]
	52	6-Methoxy acacetin 7-*O*-glucoside	Aerial part	*B. unguis-cati*	[12]
	53	8-Methoxy acacetin 7-*O*- glucoside			
	54	Acacetin 7-*O*-glucosyl-8-C-rhamnosyl-3-*O*-α-arabinofuranoside			
	55	4'-*O*-Methyl scutellarin 6-*O*-apiosyl galactoside			
	56	4'-Methyl-6-methoxy kaempferol 7-*O*-8-C diglucoside			
	57	6-Methoxy Apigenin 7-*O*- glucoside			
	58	Quercitrin	Aerial part	*B. unguis-cati*	[12]
			Leaf	*B. unguis-cati*	[23]
	59	Luteolin 7,4'-dimethyl ether	Leaf	*B. aesculifolia*	[27]
	60	Alpinetine	Leaf	*B. triplinervia*	[33]
	61	Carajurin	Leaf	*B. chica*	[25]
	62	6,7,4'-Trihydroxy-5-methoxy-flavylium			
	63	6,7,3',4'-Tetrahydroxy-5-methoxy-flavylium			
	64	6,7,3'-Trihydroxy-5,4'-dimethoxy-flavylium			
V-Coumarins					
	65	6-Methoxymellein	Root and bark	*B. africana*	[34]
	66	Kigelin			
	67	6-Demethylkigelin			
VI-Sterols					
	68	β-Sitosterol	Heartwood	*B. adenophylla*	[35]
			Stem bark	*B. africana*	[18]
			Leaf	*B. samydoides*	[29]
			Root and bark	*B. africana*	[34]
			Leaf	*B. unguis-cati*	[23]
			Aerial part	*B. unguis-cati*	[36]
	69	β-Sitosterol 3-*O*-β-D-glucopyranoside	Leaf	*B. unguis-cati*	[23]
	70	Stigmasterol	Root and bark	*B. africana*	[34]
			Leaf	*B. samydoides*	[29]
VII-Triterpenes					
	71	3β-estearioxy-olean-12-ene	Root	*B. brachypoda*	[37]
	72	Oleanolic acid	Stem bark	*B. africana*	[18]
			Leaf	*B. triplinervia*	[33]
			Leaf	*B. chica*	[25]
	73	Pomolic acid	Stem bark	*B. africana*	[18]
			Leaf	*B. triplinervia*	[33]
	74	2β,3β,19α-Trihydroxy-urs-12-en-28-oic acid	Stem bark	*B. africana*	[18, 22]
	75	β-Friedelinol			
	76	β-Amyrin	Heartwood	*B. adenophylla*	[35]
			Stem bark	*B. unguis-cati*	[36]
	77	3β,16α-Dihydroxy-urs-12-ene	Leaf	*B. samydoides*	[29]
	78	Erythrodiol			
	79	Ursolic acid	Aerial part	*B. unguis-cati*	[14]
			Leaf	*B. triplinervia*	[33]
			Leaf	*B. samydoides*	[29]

Table 2: A list of previously reported compounds from genus "Bignonia" (with different synonyms as shown in Table 1) (cont.).

Classification	No.	Item	Part used	Source	Ref.
	80	Uvaol	Leaf	*B. samydoides*	[29]
	81	Lupeol	Leaf	*B. samydoides*	[29]
			Leaf	*B. unguis-cati*	[23]
	82	Quinovic acid	Aerial part	*B. unguis-cati*	[36]
VIII-Diterpenes					
	83	Phytol	Leaf	*B. africana*	[38]
	84	3-Hydro-4,8-phytene			
IX-Unsaturated fatty acids					
	85	(9*Z*,12*Z*)-Methyl octadeca-9,12-dienoate	Leaf	*B. africana*	[38]
	86	Linoleic acid	Leaf	*B. callistigoides*	[39]
	87	Linolenic acid			
X-Saturated fatty acids					
	88	Stearic acid	Leaf	*B. callistigoides*	[39]
	89	Palmitic acid			
XI-Xanthones					
	90	Mangiferin	Leaf	*B. patellifera*	[7]
	91	3'-*O*-*p*-Hydroxybenzoylmangiferin			
	92	3'-*O*-Trans-coumaroylmangiferin			
	93	6'-*O*-Trans-coumaroylmangiferin			
	94	3'-*O*-Trans-cinnamoylmangiferin			
	95	3'-*O*-Trans-caffeoylmangiferin			
	96	3'-*O*-Benzoylmangiferin			
XII-Quinones					
	97	Lapachol	Stem wood	*B. adenophylla*	[17]
			Stem bark	*B. africana*	[18]
			Roots	*B. aesculifolia*	[40]
			Whole plant	*B. unguis-cati*	[23]
			Stem and fruit	*B. africana*	[20]
			Aerial part	*B. unguis-cati*	[36]
			Stem wood	*B. digitalis*	[21]
			roots and bark	*B. africana*	[34]
	98	Peshawaraquinone	Stem heart wood	*B. adenophylla*	[17]
	99	Methyl-1,2-dihydroxy-2-(3-methylbut-2-en-1-yl)-3-oxo-2,3-dihydro-1H-indene-1-carboxylate			
	100	*α*-Lapachone			
	101	Dehydro *α*-lapachone	Stem bark	*B. africana*	[18]
			Stem and fruit	*B. africana*	[20]
	102	3,4-Dihydroxy-2-(3-met-hylbut-2-en-1-yl)-3,4-dihydronaphthalen-1(2H)-one	Root	*B. aesculifolia*	[40]
	103	*β*-Lapachone	Heartwood	*B. adenophylla*	[35]
	104	Dilapachone			
	105	Adenophyllone			
	106	Tecomaquinone I			
	107	Dehydro iso *α*-lapachone			
	108	Tectol			
	109	2-Acetylfuro-1,4-naphthoquinone	Stem bark	*B. africana*	[18]
	110	Kigelinol	Stem bark	*B. africana*	[18]
			Root and stem bark		[41]
	111	Isokigelinol	Root and stem bark	*B. africana*	[41]
	112	Isopinnatal	Root and stem bark	*B. africana*	[41]
			Root and fruit	*B. africana*	[20]
	113	Norviburtina	Root bark	*B. africana*	[42]
	114	2-(1-Hydroxyethyl)-naphtho[2,3-b]furan-4,9-quinone	Root and stem bark	*B. africana*	[41]
	115	Kigelinone	Root and fruit	*B. africana*	[20]
	116	Kojic acid	Stem bark	*B. africana*	[18]
XIII- Limonoids					
	117	1-*O*-Deacetyl-2*α*-methoxykhayanolide	Whole plant	*B. africana*	[43]
	118	Deacetylkhayanolide E			
	119	1-*O*-Deacetyl-2-*α*-hydroxykhayanolide E			
	120	Kigelianolide			
	121	Khayanolide B			
XIV- Iridoids					
	122	Theviridoside	Stem	*B. crucigera*	[5]
	123	6'-*O*-Cyclopropanoyl theviridoside			
	124	10-*O*-*p*-Hydroxybenzoyl theviridoside			

Table 2: A list of previously reported compounds from genus "Bignonia" (with different synonyms as shown in Table 1) (cont.).

Classification	No.	Item	Part used	Source	Ref.
	125	10-*O*-Vanilloyltheviridosid			
	126	7-Hydroxyviteoid II	Fruit	*B. africana*	[44]
	127	7-Hydroxy eucommic acid			
	128	7-Hydroxy-10-deoxyeucommic acid			
	129	10-Deoxyeucommiol			
	130	Jiofuran			
	131	Jioglutolide			
	132	1-Dehydroxy-3,4-dihydroaucubigenin			
	133	Des-*p*-hydroxy benzoyl kisasagenol B			
	134	Ajugol			
	135	6-Trans-caffeoyl ajugol			
	136	Verminoside	Bark and fruit	*B. africana*	[16, 44]
	137	Specicoside	Stem bark	*B. africana*	[16, 22]
	138	Minecoside	Bark	*B. africana*	[45]
	139	Lamiide	Leaf	*B. elegans*	[31, 46]
	140	Pseudocalymmoside	Whole plant	*B. elegans*	[46]
	141	Durantosid II			
	142	Eleganoside A	Leaf	*B. elegans*	[32]
	143	Eleganoside B			
	144	Eleganoside C			
	145	Stansioside	Leaf	*B. stans*	[47]
	146	Plantarenaloside			
	147	5-Deoxystansioside			
XV- Alkaloids and nitrogenous compounds					
	148	4-Hydroxytecomanine	Fruit	*B. stans*	[48]
	149	Tecomanine (Tecomine)	Leaf	*B. stans*	[49, 50]
	150	5*β*-Hydroxyskitanthine	Fruit	*B. stans*	[48]
			Leaf	*B. stans*	[50]
	151	4-Noractinidin	Leaf	*B. stans*	[49, 50]
	152	Boschniakine			
	153	Tecostanine	Leaf	*B. stans*	[50]
	154	Allantoin	Leaf	*B. unguis-cati*	[23]
			Leaf	*B. elegans*	[31]
	155	Pheophorbide a	Leaf	*B. chica*	[51]
	156	Indole	Leaf	*B. stans*	[52]
	157	Tryptophan			
	158	Tryptamine			
	159	Skatole			
XVI- Dipeptides					
	160	N(N'-Benzoyl-S*-phenylalaninyl)-S*-phenylalaninol benzoate	Root	*B. digitalis*	[53]

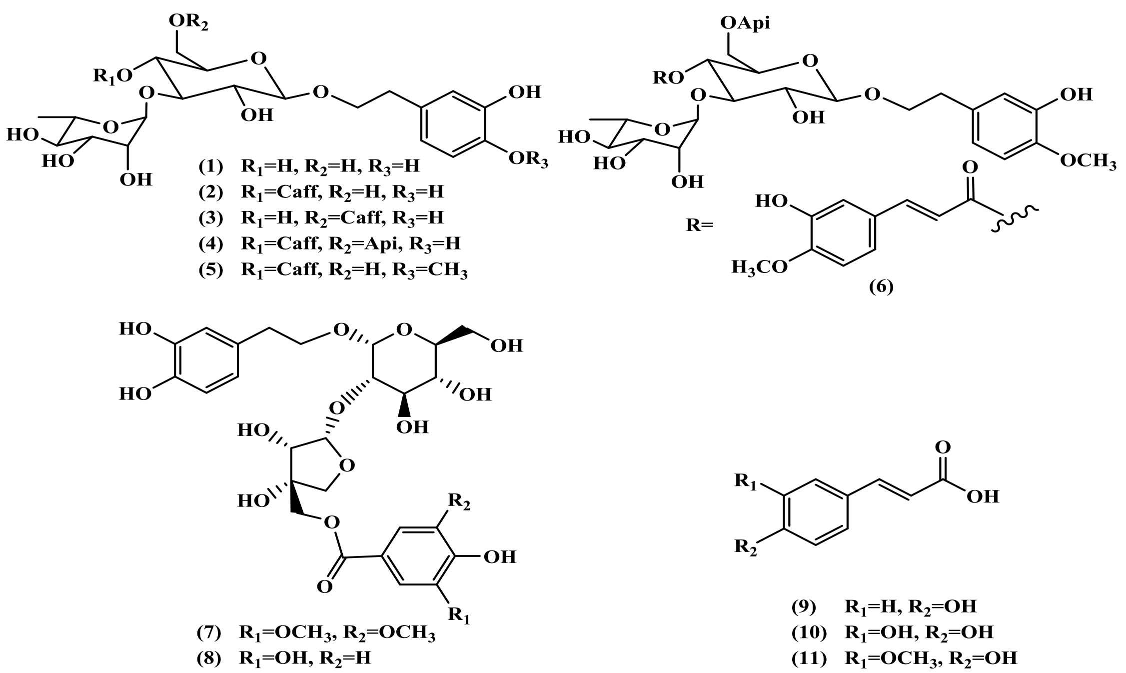
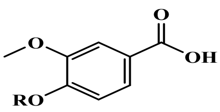
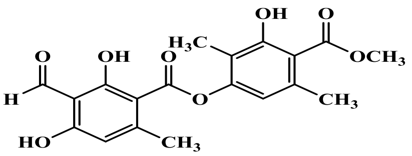


Figure 1: Compounds isolated from genus "Bignonia".



(12) R=H
(13) R=CH_3



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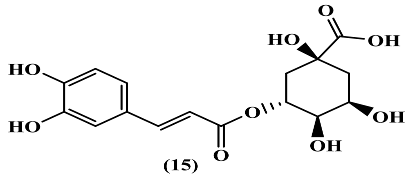

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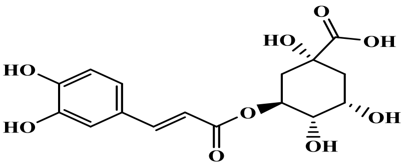

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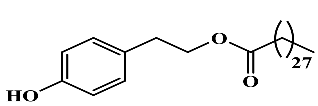

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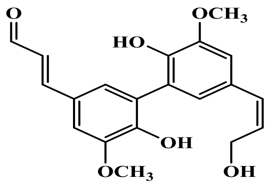
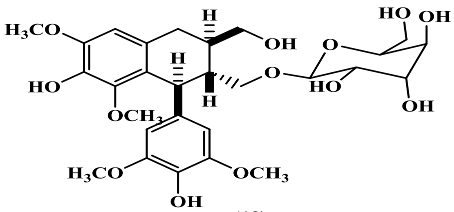
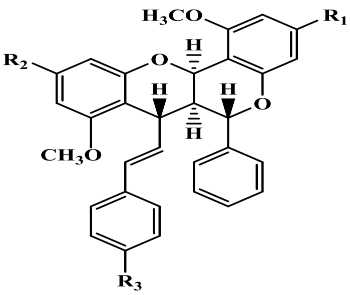


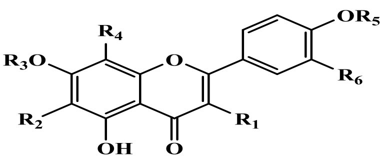
(18)



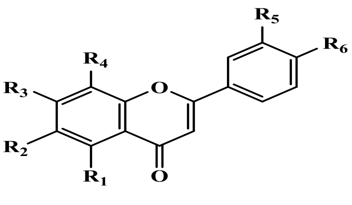
(19)



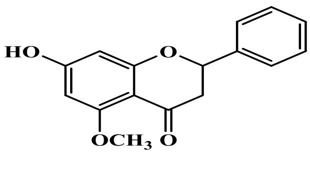
(20) R_1=OH, R_2=OH, R_3=OH
(21) R_1=OH, R_2=OH, R_3=OCH_3
(22) R_1=OH, R_2=OH, R_3=H
(23) R_1=GlucA, R_2=GlucA, R_3=OH
(24) R_1=GlucA, R_2=GlucA, R_3=H
(25) R_1=GlucA, R_2=GlucA, R_3=OCH_3
(26) R_1=GlucA, R_2=OH, R_3=OH
(27) R_1=OH, R_2=GlucA, R_3=OH
(28) R_1=OH, R_2=GlucA, R_3=OCH_3
(29) R_1=OH, R_2=GlucA, R_3=H



(48) R_1=H, R_2=H, R_3=H, R_4=H, R_5=H, R_6=H
(49) R_1=H, R_2=H, R_3=H, R_4=H, R_5=H, R_6=OCH_3
(50) R_1=H, R_2=C-Arab, R_3=H, R_4=C-Gala, R_5=H, R_6=H
(51) R_1=H, R_2=C-Glc, R_3=H, R_4=C-Glc, R_5=H, R_6=H
(52) R_1=H, R_2=OCH_3, R_3=Glc, R_4=H, R_5=CH_3, R_6=H
(53) R_1=H, R_2=H, R_3=Glc, R_4=OCH_3, R_5=CH_3, R_6=H
(54) R_1=OAra, R_2=H, R_3=Glc, R_4=C-Rha, R_5=CH_3, R_6=H
(55) R_1=H, R_2=OGal-Api, R_3=H, R_4=H, R_5=CH_3, R_6=H
(56) R_1=OH, R_2=OCH_3, R_3=Glc, R_4=C-Glc, R_5=CH_3, R_6=H
(57) R_1=H, R_2=OCH_3, R_3=Glc, R_4=H, R_5=H, R_6=H
(58) R_1=ORha, R_2=H, R_3=H, R_4=H, R_5=H, R_6=OH
(59) R_1=H, R_2=H, R_3=CH_3, R_4=H, R_5=CH_3, R_6=OH



(30) R_1=OH, R_2=OCH_3, R_3=OCH_3, R_4=H, R_5=H, R_6=OGlc
(31) R_1=OH, R_2=H, R_3=OH, R_4=OCH_3, R_5=H, R_6=OH
(32) R_1=OH, R_2=H, R_3=OH, R_4=H, R_5=H, R_6=OCH_3
(33) R_1=OH, R_2=H, R_3=OH, R_4=OCH_3, R_5=H, R_6=OCH_3
(34) R_1=H, R_2=H, R_3=OCH_3, R_4=OCH_3, R_5=H, R_6=H
(35) R_1=OCH_3, R_2=OCH_3, R_3=OCH_3, R_4=OCH_3, R_5=H, R_6=H
(36) R_1=OH, R_2=OCH_3, R_3=OCH_3, R_4=OCH_3, R_5=H, R_6=H
(37) R_1=OH, R_2=OCH_3, R_3=OCH_3, R_4=OCH_3, R_5=H, R_6=OCH_3
(38) R_1=OH, R_2=H, R_3=OCH_3, R_4=H, R_5=H, R_6=H
(39) R_1=OCH_3, R_2=OCH_3, R_3=OCH_3, R_4=H, R_5=OH, R_6=OH
(40) R_1=OH, R_2=OCH_3, R_3=OCH_3, R_4=H, R_5=OH, R_6=OH
(41) R_1=OH, R_2=OCH_3, R_3=OCH_3, R_4=H, R_5=H, R_6=OH
(42) R_1=OH, R_2=OCH_3, R_3=OH, R_4=H, R_5=H, R_6=OH
(43) R_1=OH, R_2=H, R_3=OH, R_4=H, R_5=H, R_6=H
(44) R_1=OCH_3, R_2=OH, R_3=OH, R_4=H, R_5=OH, R_6=OH
(45) R_1=OH, R_2=H, R_3=OH, R_4=H, R_5=OH, R_6=OH
(46) R_1=OH, R_2=OH, R_3=ORha, R_4=H, R_5=H, R_6=OH
(47) R_1=OH, R_2=OXyl, R_3=ORha, R_4=H, R_5=H, R_6=OH



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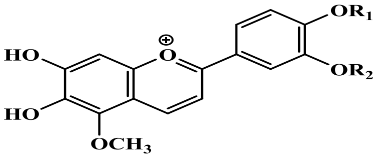
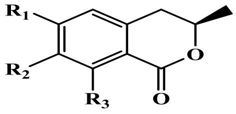
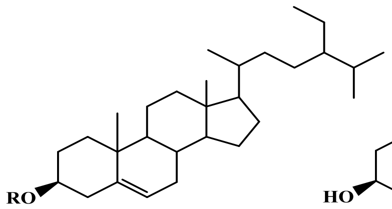


(61) R_1=CH_3, R_2=H
(62) R_1=H, R_2=H
(63) R_1=H, R_2=OH
(64) R_1=CH_3, R_2=OH

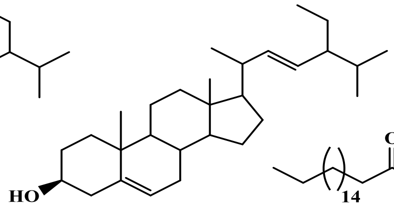


(65) R_1=OCH_3, R_2=H, R_3=OH
(66) R_1=OCH_3, R_2=OCH_3, R_3=OH
(67) R_1=OH, R_2=OCH_3, R_3=OH

Figure 1: Compounds isolated from genus "Bignonia" (cont.).



(68) R=H
(69) R=Glc



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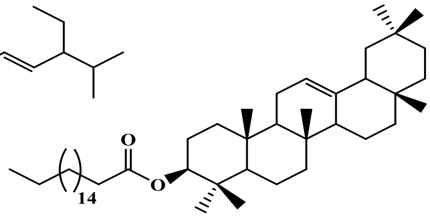

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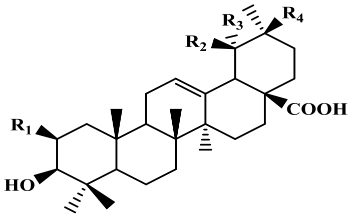
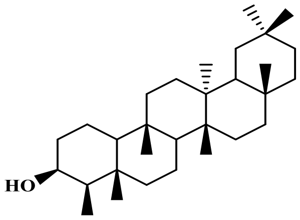


(72) R_1=H, R_2=H, R_3=H, R_4=CH_3
(73) R_1=H, R_2=CH_3, R_3=OH, R_4=H
(74) R_1=OH, R_2=CH_3, R_3=OH, R_4=H



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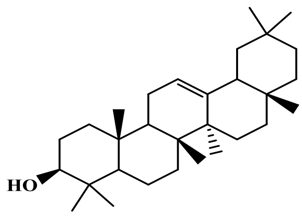

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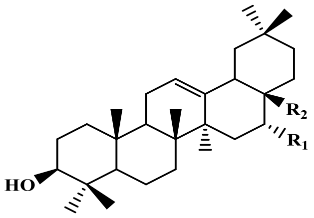
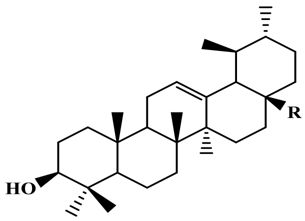
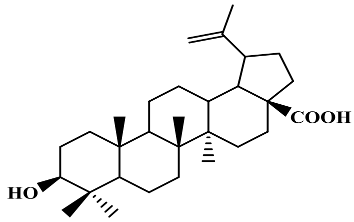


(77) R_1=OH, R_2=CH_3
(78) R_1=H, R_2=CH_2OH



(79) R=COOH
(80) R=CH_2OH



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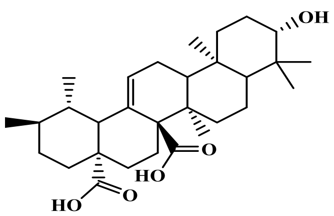

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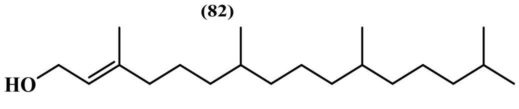

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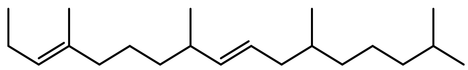

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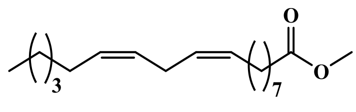

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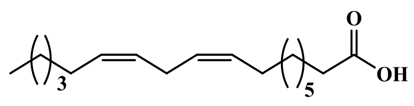

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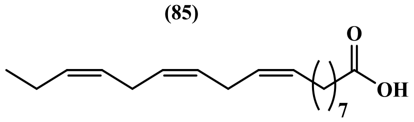

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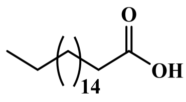

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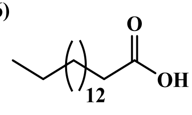

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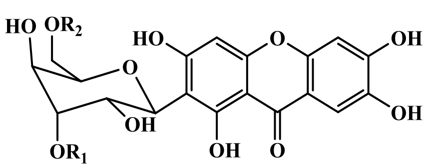

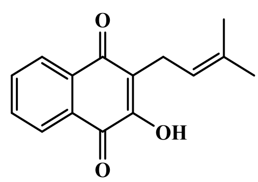

(97)

Figure 1: Compounds isolated from genus "Bignonia" (cont.).

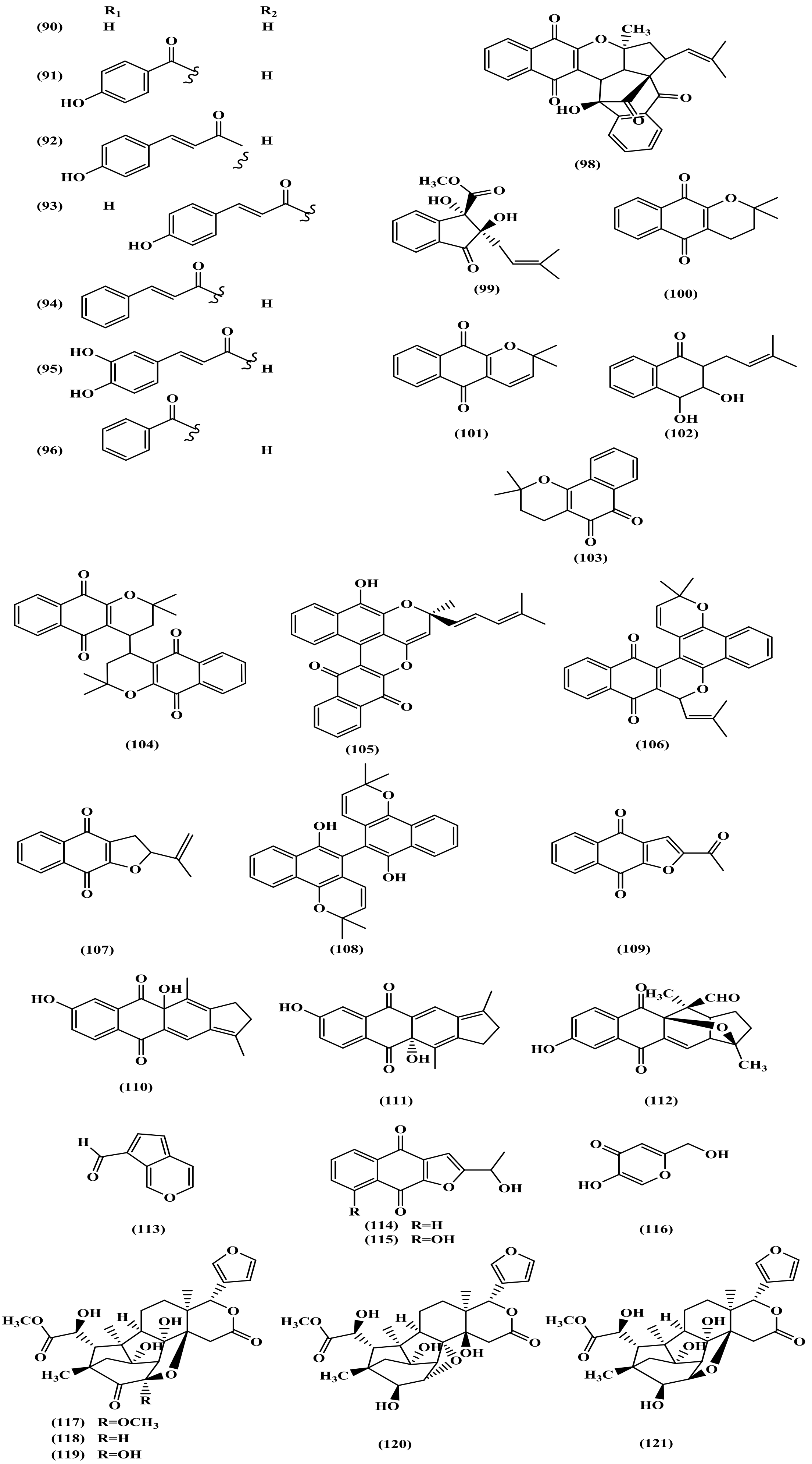

Figure 1: Compounds isolated from genus "Bignonia" (cont.).

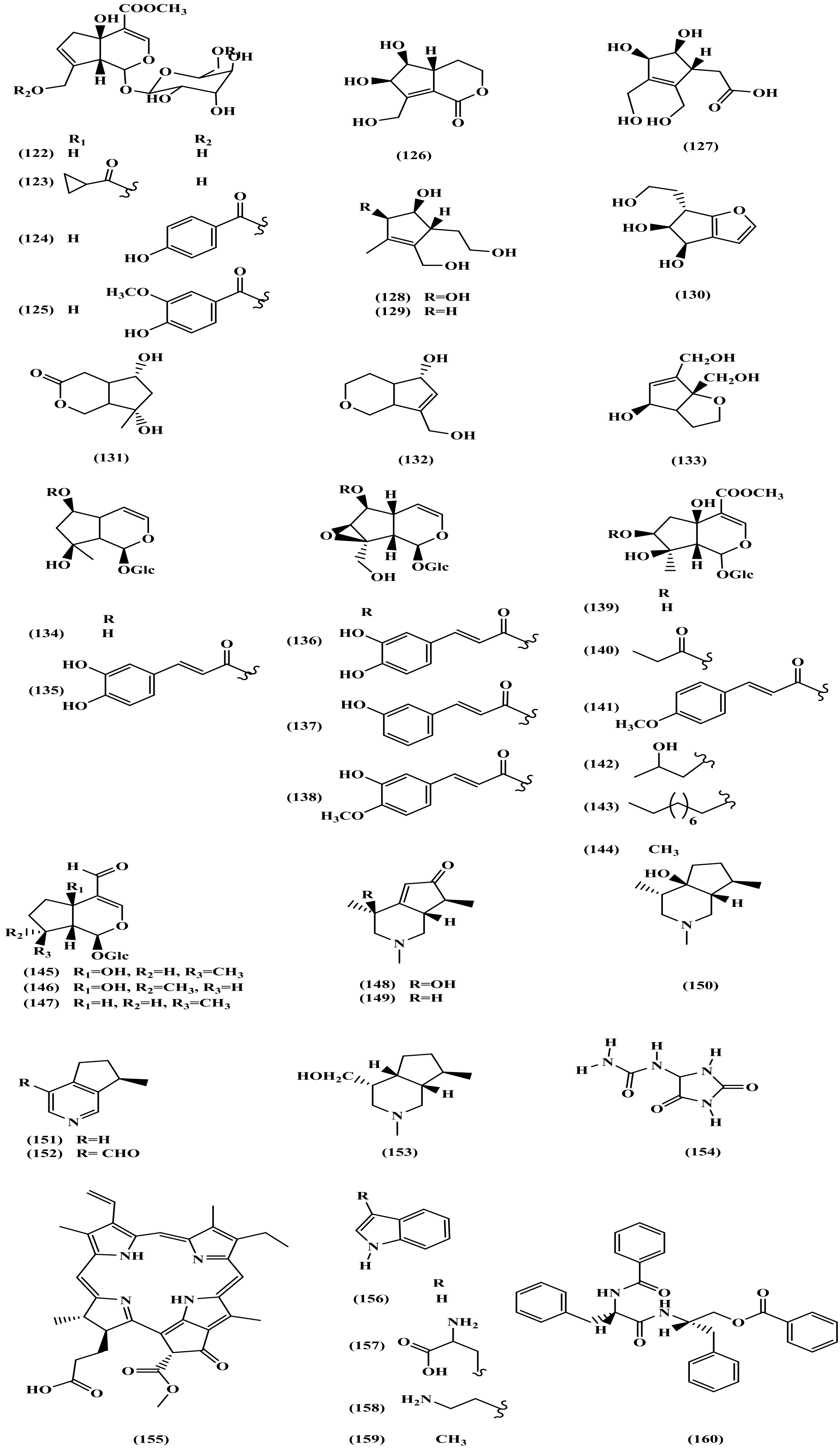

Figure 1: Compounds isolated from genus "Bignonia" (cont.).

3.3. Quinones

Quinones are widely distributed in Bignonia species, as lapachol, *α*-lapachone and dehydro *α*-lapachone in *B. africana* and *B. adenophylla* [17, 18].

4. Biological activities of genus "Bignonia"

Bignonia species exhibited various biological activities including; cytotoxic [54] antiprotozoal [51], analgesic [55], insect repellant [15], anti-inflammatory [37] and cholinergic activities [43] as demonstrated in **(Table 3)**.

Table 3: A list of different biological activities of genus "Bignonia" (with different synonyms as shown in Table 1).

Biological activity	Plant name /part used	Extract, fraction or compound	Method/ Result	Ref.
I- Anti-insect activity				
	B. callistigoides Leaf	Hydrolysed methanol extract 4'-Hydroxywogonin Acacetin Galangustin	They showed different settling inhibition activity against *Myzus persicae* and *Rhopalosiphum padi*, agricultural aphids, in which the hydrolyzed methanol extract was active only against *M. persicae*, while acacetin had activity only against *R. padi* (PI=0.3±0.1), Galangustin had activity against both aphids (PI=0.4±0.1) for *M. persicae* and 0.8±0.1 for *R. padi* and 4'-Hydroxywogonin had no any activity.	[15]
		Palmitic acid Stearic acid Linoleic acid Linolenic acid	Stearic acid, linoleic acid and linolenic acid inhibit *R. padi* settling, while palmitic acid was inactive.	[39]
	B. africana Bark	Aqueous extract	Its mollucidal effect was tested on Nile tilapia, *Oreochromis niloticus* (L.), using continuous aeration over a period of 96 h result in eventual fatigue and eventual death.	[56]
II- Steroidogenic enzymes effect				
	B. capensis	Ethanol extract	It showed rhythm in estrus cyclicity and ovarian weights similar to controls in letrozole-induced polycystic ovarian model.	[57]
III- Antimicrobial activity				
	B. adenophylla Leaf and seed	Aqueous and methanol extracts	They were tested using the disc diffusion method, in which the aqueous extract of the seeds showed maximum potency against *Staphylococcus aureus* and *Staphylococcus epidermidis*, while the methanol extract showed maximum activity against *Escherichia coli*, on the other hand, the methanol extract of the leaves showed the maximum activity against *S. aureus.*	[58]
	B. africana Stem bark	*p*-Coumaric acid Caffeic acid Kojic acid	They showed varied anti-candidal activity against four *Candida albicans* strains (ATCCL26, ATCC12C, ATCCP37039 and ATCCP37037) through agar diffusion method and microbroth dilution technique, in which kojic acid was the most potent.	[18]
	B. cuprea Leaf	Hydroethanol extract	It showed activity against *Helicobacter pylori* and moderate activity against *Enterococcus faecalis* in broth microdilution method.	[59]
	B. aesculifolia Root	Ethanol extract	It showed no antifungal activity against subcutaneous fungi, *Sporothrix schenkii* and *Fonsecaea pedrosoi* using 100 µg/ml.	[60]
	B. callistigoides Bark	Ethanol extract	It showed no antifungal activity against sc. fungi, *S. schenkii* and *F. pedrosoi* using 100 µg/ml.	[60]
	B. brachypoda Leaf	Cirsimaritin, Cirsiliol 3',4'-Dihydroxy-5,6,7-trimethoxyflavone Hispidulin	They showed antifungal activity against *Cladosporium sphaerospermum* spores by direct bioautography method on TLC plates, but hispidulin is the less active one.	[28]
	B. africana Root and fruit	Methanol extract	It showed antibacterial activity only against the Gram-positive organisms.	[20]
		Kigelinone Isopinnatal Dehydro-*α*-lapachone Caffeic acid *p*-Coumaric acid Ferulic acid	They showed various antibacterial and antifungal activities against different microorganisms, in which kigelinone was the most active one, followed with the caffeic acid.	
IV- Cholinergic activity				
	B. africana Whole plant	1-*O*-Deacetyl-2*α*-methoxy khayanolide Deacetylkhayanolide E 1-*O*-Deacetyl-2-*α*-hydroxy Khayanolide E Kigelianolide Khayanolide B	They had weak inhibition activities against acetylcholinesterase and butyrycholinesterase.	[43]

Table 3: A list of different biological activities of genus "Bignonia" (with different synonyms as shown in Table 1) (cont.).

Biological activity	Plant name /part used	Extract, fraction or compound	Method/ Result	Ref.
V- Antiprotozoal activity				
	B. cuprea Leaf	Petroleum ether fraction Hexane fraction Chloroform fraction EtOAc fraction Pheophorbide a	They showed various activities against *Trypanosoma cruzi* on different stages, but the chloroform fraction was the best one. While, pheophorbide a activity was tested in the presence and absence of light, in which its effect increased against the main infective forms of *Trypanosoma cruzi* (trypomastigotes and amastigotes) in the presence of light.	[51]
	B. brachypoda Root	Nonpolar fraction Brachydin A Brachydin B Brachydin C	The Nonpolar fraction was active against *T. cruzi*, while brachydin B, brachydin C showed selective inhibition activity, in which they inhibited the parasite invasion process and its intracellular development in host cells with similar potencies to benznidazole. Additionally, brachydin B decreased the blood parasitemia of *T. cruzi*-infected mice.	[24]
	B. africana Stem bark	Specicoside 2β,3β,19α-Trihydroxy urs-12-en-28-oic acid Atranorin *p*-Hydroxy cinnamic acid	The antiplasmodial activity was evaluated against the multidrug-resistant W2mef strain of *Plasmodium falciparum* by the parasite lactate dehydrogenase assay, in which specicoside, 2β,3β,19α-trihydroxyurs-12-en-28-oic acid and atranorin were significantly active.	[22]
	B. patellifera Leaf	Mangiferin 3'-*O*-*p*-Hydroxybenzoylmangiferin 3'-*O*-trans coumaroylmangiferin	They were active *in vitro* against the chloroquine-sensitive *P. falciparum* 3D7 clone.	[7]
	B. patellifera Leaf	Ethanol extract Ursolic acid Alpinetine Oleanolic acid	They showed trypanocidal activity against *T. cruzi*, in which ursolic acid was four times more active than oleanolic acid, while alpinetine was inactive.	[33]
	B. africana Bark	Verminoside Specioside Minecoside	Their antiamoebic were evaluated *in vitro* against *Entamoeba histolytica* HK-9 strain, in which verminoside was the most active one followed by specioside.	[16]
	B. africana Root and stem bark	2-(1- Hydroxyethyl) naphtho[2,3-*b*]furan-4,9-quinone Isopinnatal Kigelinol Isokigelinol	They showed different antitrypanosomal activity against *T. brucei brucei* and *T. brucei rhodesiense*, in which 2-(1-hydroxyethyl) naphtho[2,3-*b*]furan-4,9-quinone was the most potent.	[41]
	B. unguis-cati Whole plant	Ethanol extract Pet. ether extract EtOAc extract	They did not show antiprotozoal activity against *Leshmania* sp. or *T. cruzi*.	[61]
VI- Analgesic activity				
	B. brachypoda Root	Ethanol extract	It showed clear potency in formalin and acetic acid induced writhing tests activity.	[62]
	B. hymenaea Leaf	Aqueous extract	It showed significant activity in acetic acid-induced writhing, formalin (paw licking test) and tail flick testes with a possible involvement of central mechanism and adenosine system test in mice.	[55]
	B. africana Stem bark	Ethanol extract	It tested by using acetic acid induced mouse writhing, in which it decreased the number of writhes in a dose dependent manner while, in hot plate reaction time, it showed insignificant elongation of the reaction time.	[63]
VII- Anti-inflammatory activity				
	B. cuprea Leaf	Ethanol and aqueous extracts	They reduced the inflammation in murine sponge model by decreasing neutrophil accumulation and hemoglobin content in the sponge implants without altering the level of cytokines.	[64]
	B. brachypoda Root	3β-Estearioxy-olean-12-ene	It showed potent anti-inflammatory activity by using carrageenan-induced paw edema, formalin and hot plate tests.	[37]
	B. brachypoda Root	Ethanol extract	It showed marked anti-inflammatory activity against carrageenan-induced paw edema, peritonitis and fibrovascular tissue growth, which induced by subcutaneous cotton pellet implantation.	[62]
	B. unguis-cati Aerial part	Ethanol extract Chloroform extract	The ethanol extract was more potent extract than chloroform in reducing the carrageenan-induced paw edema.	[12]
	B. africana Stem bark	Ethanol extract	It showed a significant dose dependent carrageenan induced paw edema inhibition between the 2^{nd} and 5^{th} h.	[63]
	B. brachypoda Leaf	3',4'-Dihydroxy-5,6,7-trimethoxy flavone	It inhibited arachidonate 5-lipoxygenase enzyme.	[28]
	B. cuprea Leaf	Carajurin	It was studied by investigation the NF-kB and NF-AT assays, in which it inhibited NF-kB, but not NF-AT at 500 mM .	[25]
VIII- Antidiarrheal activity				
	B. africana Leaf	Aqueous extract	It was examined by using castor oil-induced animal model. It decreased the fecal output by reducing nicotine induced contractions.	[65]

Table 3: A list of different biological activities of genus "Bignonia" (with different synonyms as shown in Table 1) (cont.).

Biological activity	Plant name /part used	Extract, fraction or compound	Method/ Result	Ref.
IX- Cytotoxic activity				
	B. africana Seed	Seed oil	It inhibited significantly dose-dependently Caco-2 cell growth compared to HEK-293 cell growth.	[54]
	B. unguis-cati Aerial part	Ethanol extract	It was the most effective sample on lung cell line.	[12]
	B. africana Stem bark and fruit	DCM extracts Norviburtinal Isopinnatal *β*-Sitosterol	The extracts were tested *in vitro*, using sulphorhodamine B assay against cultured melanoma and other cancer cell lines, in which norviburtinal was found to be the most active compound with little selectivity, while isopinnatal also showed some cytotoxic activity.	[66]
	B. africana Stem bark and fruit	Aqueous extract Ethanol extract DCM extract Lapachol	They were investigated for their growth inhibitory effects against four melanoma cell lines and Caki-2 using two different assays. The DCM extract of the stem bark and lapachol had significant dose-dependent inhibitory activity, while the extract was less active after an hour exposure. The chemosensitivity of the melanoma cell lines to the stem bark was greater than that seen for the renal adenocarcinoma line. In which sensitivity to lapachol was similar amongst the five cell lines.	[67]
X- Sleep induction				
	B. africana Stem bark	Ethanol extract	It reduced the duration of sleeping time in dose-dependent manner in barbiturate-induced sleeping.	[68]
XI- Male fertility				
	B. africana Bark	Aqueous extract	It showed ability to reverse *Carica papaya* induced testicular damage, if administered within a certain window period such as: *If administrated within 4 weeks of treatment with *C. papaya* reversed the deleterious effects on semen parameters. *If given after 10 weeks, the damage remains unreversed.	[69]
XII- Anti-obesity				
	B. hymenaea Leaf	Aqueous extract	It reduced significantly the plasma LDL-cholesterol and triglycerides comparing to the atorvastatin in diet-induced hypercholesterolemia.	[70]
XIII- Heart protection				
	B. stans Flower	70% Ethanol extract	It prevented the reduction of the antioxidants and retarded elevation of cardiac damage markers in isoproterenol-induced myocardial infarction rats.	[71]
XIV- Hepatic and renal protection				
	B. hymenaea Leaf	Aqueous extract Ethanol extract	The aqueous extract caused an increase in Glucose, creatinine and albumin parameters. While, urea, aspartate aminotransferase and alanine aminotransferase values were decreased with (50 and 100 mg/kg) and increased with dose of 200 mg/kg. But, ethanol extract caused an increase in this parameter to the doses used. In addition to, their ability to cause leukopenia.	[72]
	B. stans Flower	EtOAc extract	It significantly protected rat kidneys in gentamicin-induced nephrotoxicity albino rats.	[73]
XV- Gastric protection				
	B. Brachypoda Root	Hydroethanol extract	It protected significantly the stomach against absolute ethanol, depletion of (glutathione and nitric oxide), non-steroidal anti-inflammatory drugs, pylorus ligation and acetic acid-induction gastric ulcer in rats.	[6]
XVI- Protection against light				
	B. cuprea Leaf	A crude extract Hexane fraction EtOAc fraction Chloroform fraction	The crude extract and chloroform fraction showed photochemoprotective activity in protecting L929 fibroblasts against both UVA and UVB-induced cell damage through scavenging mechanisms.	[74]
XVII- Antioxidant activity				
	B. cuprea Leaf	A crude extract Hexane fraction EtOAc fraction Chloroform fraction	The chloroform fraction showed the best antioxidant activity in DPPH and xanthine/luminol/xanthine oxidase system methods.	[74]
	B. unguis-cati Aerial part	Petroleum ether fraction Chloroform fraction EtOAc fraction *n*-Butanol fraction Aqueous fraction	The EtOAc and *n*-butanol fractions showed the potent activity on DPPH radical scavenging assay and ferric reducing power test.	[14]
	B. africana Leaf	Hexane fraction EtOAc fraction Methanol fraction	The methanol fraction exhibited the most potency in DPPH assay.	[38]
	B. patellifera Leaf	Methanol extract Mangiferin 3'-*O*-*p*-Hydroxy benzoylmangiferin	The tested compounds and the extract showed good activity against DPPH radical scavenging activity.	[7]

Table 3: A list of different biological activities of genus "Bignonia" (with different synonyms as shown in Table 1) (cont.).

Biological activity	Plant name /part used	Extract, fraction or compound	Method/ Result	Ref.
		3'-*O*-Trans-coumar-oylmangiferin 6'-*O*-Trans-coumar-oylmangiferin 3'-*O*-Trans-cinnamo-ylmangiferin 3'-*O*-Trans-caffeoylmangiferin 3'-*O*-Benzoyl mangiferin		
	B. cuprea Leaf	Methanol/0.3% citric acid extract	It exhibited moderate scavenging activity on DPPH assay.	[75]
	B. crucigera Stem	Methanol extract Verbascoside Isoverbascoside Forsythoside B Jionoside D Leucosceptoside B	The extract exhibited activity against DPPH by using rapid TLC tests. The isolated compounds showed potent radical-scavenging activity against DPPH.	[5]
	B. cuprea Leaf	Carajurin 6,7,4'-Trihydroxy-5-methoxy-flavylium 6,7,3',4'-Tetrahydroxy- 5-methoxy-flavylium 6,7,3'-Trihydroxy-5, 4'-dimethoxy flavylium	They exhibited no activity on DPPH TLC analysis.	[25]
XVIII- Wound healing activity				
	B. cuprea Whole plant	Lyophilized extract	It improved collagen organization and increased the quantity of dermatan sulfate on the 14th day of the tendon healing.	[76]
	B. cuprea Leaf	Methanol/0.3% citric acid extract	It exhibited efficient wound healing activity on both *in vivo* and *in vitro* using fibroblast growth and collagen production stimulation assays.	[75]
XIX- Anti-diabetic activity				
	B. stans Leaf	Hydroalcohol extract Flavone fractions Chrysoeriol Apigenin Luteolin Verbascoside	The mixtures of (chrysoeriol and apigenin) and (chrysoeriol and luteolin) showed significant lipase inhibitory activity *in vitro* by indirect spectrophotometric method type 2 diabetes mellitus.	[19]
	B. stans Leaf	Aqueous extract	It evaluated *in vitro* on the adipogenesis and 2-NBDglucose uptake in insulin-sensitive and insulin-resistant murine 3T3-F442A and human subcutaneous adipocytes. It stimulated 2-NBDG uptake in a concentration-dependent manner.	[77]
	B. stans Leaf	Aqueous extract	It displayed *in vitro* a dose-dependent inhibition of glucose release from starch.	[78]
	B. stans Leaf	Tecomine Boschniakine 5*β*-Hydroxyskitanthine Tecostanine	Tecomine only affected markedly on glucose uptake *in vitro* glucose uptake in white adipocytes, while none of them was active *in vivo* on albino mice, a genetic model of type II diabetes.	[50]

5. Conclusion

The literature survey of different Bignonia species revealed the presence 160 compounds of different classes of phytoconstituents as flavonoids (45 compound), iridoids (26) and quinones (20), which are the most abundant among the various species of Bignonia, followed by triterpenes (12), phenolic acid derivatives (12) and alkaloids (12). Besides, 5 limonoids, 7 xanthones and 6 phenylethanoids. Furthermore, 9 compounds belong to different classes of secondary metabolites e.g., coumarins (3), sterols (3) and unsaturated fatty acids (3). Finally, saturated fatty acids (2) and diterpenes (2). This review showed the diversity of biological activities exhibited by Bignonia plants as cytotoxic as *B. unguis-cati* and *B. africana*, antioxidant as *B. cuprea*, *B. patellifera*, *B. unguis-cati* and *B. africana*, antileishmanial as *B. unguis-cati*, antitrypanosomal as *B. cuprea*, *B. patellifera* and *B. brachyboda* and antimalarial as *B. africana* and *B. patellifera*. Besides, antimicrobial of the different species, analgesic as *B. hymenaea, B. brachyboda* and *B. africana.* In addition to the anti-inflammatory of *B. cuprea*, *B. brachyboda B. unguis-cati* and *B. africana*. Also, some plants of Bignonia exhibited wound healing potential, antidiabetic activity, sleep induction, gastroprotective and anti-obesity activities.

Based on, the present review Bignonia plants need further investigation to study their safety and confirm their application in folk medicine. Although, Bignonia genus comprises of 31 species, only 15 species reported in the literature, while the others uninvestigated neither phytochemically nor biologically. Moreover, Bignonia plants need further studies as they are considered a good source of bioactive natural products.

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