A Quarter Century of Pharmacognostic Research on Panamanian Flora: A Review*

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- Panamanian plants
- ethnomedicine
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Abstract

Panama is a unique terrestrial bridge of extreme biological importance. It is one of the "hot spots" and occupies the fourth place among the 25 most plant-rich countries in the world, with 13.4% endemic species. Panamanian plants have been screened for a wide range of biological activities: as cytotoxic, brine shrimp-toxic, antiplasmodial, antimicrobial, antiviral, antioxidant, immunosuppressive, and antihypertensive agents. This review concentrates on ethnopharmacological uses of medicinal plants employed by three Amerindian groups of Panama and on selected plants with novel structures and/or interesting bioactive compounds. During the last quarter century, a total of approximately 390 compounds from 86 plants have been isolated, of which 160 are new to the literature. Most of the work reported here has been the result of many international collaborative efforts with scientists worldwide. From the results presented, it is immediately obvious that the Panamanian flora is still an untapped source of new bioactive compounds.

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Introduction

Medicinal plants remain an endless source of new drugs, new drug leads, and new chemical entities (NCEs) [1]. In developing countries, medicinal plants have been the most accessible source of medicaments and in rural areas, traditional medicine is part of the first line of treatment for common pathologies [2]. The geographical characteristics of the Isthmus of Panama are responsible for its highly diverse flora and fauna. This diversity promotes the use of plants in traditional medicine by the Amerindian groups and the rural population, which have limited access to modern drugs.

Panama is a unique terrestrial bridge of great biological importance. Panamanian flora is one of the richest in the world with an estimate of 9893 different species of vascular plants, of which 1327 (13.4%) are endemic [3]. There is a large number of nonvascular species but they have not been investigated fully. Panama has over 687 species of ferns and about 1000 species of orchids, of which 50% are endemic. Epiphytes, lianas, and climbers are a major component of the Panamanian tropical forest. Mosses abound in moist cloud forests as well as other parts of the country. Panama is considered one of the botanical "hot spot" countries and occupies the fourth place in the world in number of vascular species [4]. The number of species per 10 000 km^2 ranks even much higher than in bigger countries like India, China, and the United States [5].

Evidence of the biomedical potential of herbal drugs used in Panamanian traditional medicine is continually being reported. Panamanian plants have been evaluated for their biological activities on a diverse range of disease targets. They have been studied *inter alia* as cytotoxic to cancer cell lines, antimalarial, antileishmanial, antimicrobial, antiviral, larvicidal, antioxidant, immunosupressive, acetylcholinesterase inhibitors, and antihypertensive agents [6–10].

Research on the highly diverse Panamanian flora proposes new economical and medicinal ventures attractive to the pharmaceutical industry. In the National Science Strategic Plan 2010–2014, a very high priority has been assigned to the study and utilization of Panamanian biodiversity as a source

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of molecules for the agrochemical, pharmaceutical, food, and cosmetic industries [11].

This paper summarizes and updates two earlier reviews [6,7] on the current available knowledge on Panamanian medicinal plants and the numerous investigations carried out during the last quarter century on their biomedical potential, resulting in identification of compounds with new chemical structures and possible new therapeutic and/or other applications.

Ethnomedical Surveys and Traditional Medicine

Systematic studies on Panamanian flora were initially based on selecting plants for phytochemical and pharmacological studies based on ethnopharmacological uses. In Panama, the Amerindian groups and the rural population have depended on plant preparations to treat a range of ailments, and quite remarkably with a great degree of success [12]. Panama is home to five Amerindian groups: Ngöbe-Buglé, Kuna, Emberá-Wounan, Naso or Teribe, and Bri-Bri, representing 9.6% of the total population [13]. These ethnopharmacological surveys collected a large amount of data from three major groups in Panama namely the Kunas, the Ngöbe-Buglé, and the Teribes.

Among the indigenous groups of Latin America, the Kunas have been able to preserve their cultural and political autonomy by means of a robust social organization. In spite of the Panamanian government support in health care, this ethnic group relies on the use of medicinal plants to treat a variety of illnesses and to perform religious rituals. The most common health problems in this community are malnutrition, tuberculosis, pneumonia, malign tumors in conditions like albinism, and intestinal problems. From the 90 species of plants employed in their medicine and rituals (**Table 1**), 49 plants were used topically to treat skin and eyes infections and as wound healing, 24 were used internally to treat fever, pain, cold, and general weakness, and 17 plants were used in both routes. Interestingly, 19% of the plants used in Kuna's traditional medicine were related to childbirth [14].

The Ngöbe-Buglé is the largest indigenous group in Panama (65% of the total indigenous population) [13]. During different field trips in the homeland of the Ngöbe-Buglé since the late eighties, a total of 104 medicinal plants have been collected and identified (**Table 1**) [15,16].

The Teribes represent the third most important group of Amerindians in the country. The use of medicinal plants is very common in this group, and the passing of this knowledge is the responsibility of the elders. The most common applications for medicinal plants were in the treatment of colds, headache, body aches, vertigo, cramps, diarrhea, furunculosis, leishmaniasis, and snakebites. From this study, 108 plants were identified (**Table 1**) [17].

Access Rights and Legal Framework

Panama values international cooperation and is aware of the need of increased international funding and specific initiatives to support research into priority areas to investigate the potential of unexplored Panamanian biodiversity.

As signatory to the Convention of the Biological Diversity (CBD), Panama encourages the objectives of the Convention: conservation of biological diversity, sustainable use of its components, and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources [18], and it is aware that intellectual property rights "may have an influence on the implementation" of the CBD and that it is compulsory for states to cooperate in order to ensure that intellectual property rights are "supportive of and do not run counter to" the objectives of the CBD [19].

Panama has put in place legislation through the Executive Decree 257 of 17 October 2006 and regulations of Article 71 of the General Law of Environment. Recently the Executive Decree No. 25 dated 29 of April 2009 has updated the legislation and now governs the regulations concerning access to the genetic resources of Panama. For this purpose a special unit, "Unidad Nacional de Recursos Genéticos" (UNARGEN), under the supervision of the National Environmental Authority has been created [20]. According to these regulations, collection and export permits issued by UNARGEN are required for research within the country and for sending samples out of Panama. Clear distinction is made between fundamental research and bioprospection studies. Material transfer agreements have to be signed by the collaborative scientists. Provisions are set forth for indigenous rights, equitable sharing of profits, and sovereignty rights of Panama on plant material and for conservation of biodiversity. This facilitates the exchange of samples and international collaboration while at the same time complying with the CBD.

Screenings of Panamanian Plants

It has been estimated that from a total of 300 000 identified plant species worldwide, only 6% of this total has been pharmacologically studied and only 15% phytochemically [21].

Four approaches were used to screen Panamanian plants for further phytochemical research. Plant selection was based on chemotaxonomy, ethnopharmacological information, and random selection of plants within an area of 0.1 ha biodiversity plots in national parks and ecologically-based bioprospection.

Selected Panamanian plant extracts were subjected to a range of biological screens. They were tested for toxicity, in particular against *Artemia salina* [22] and cancer cell lines [23], as antimicrobial [24], antifungal [25], molluscicidal [6], and DNA intercalation [26] agents, as inhibitors of protease and reverse transcriptase [27], for antiplasmodial [28], anti-inflammatory [29,30], antihyperglycemic [31], and anti-HSV1 [27] activities, for toxicity against *Aedes aegypti* [31], and as inhibitors of receptor-binding assays on endothelin ET_A, angiotensin AT_1, and neuropeptide Y Y_1 receptors [10].

Isolation of Compounds from Panamanian Plants

Table 2 summarizes the chemical composition and corresponding biological activities of selected Panamanian plants.

Phytochemical research on candidate plants chosen after biological and chemical screening has led to the isolation of numerous new compounds, many of which have a wide array of valuable biological activities. This review has concentrated on selected plants with novel structures and/or interesting bioactive compounds. **Table 2** summarizes in alphabetical order of the families and plants, novel and known compounds isolated, and the biological activity attributed to one or more of the compounds. This table was constructed from original publications of our group and other Panamanian scientists. The most important plant families which yielded active compounds were Clusaceae, Boragina-

Table 1 Medicinal plant inventory of Kuna, Ngöbe-Buglé, and Teribe Indians.

Family	Specie	Application (plant part; preparation; Amerindian group)
Acanthaceae	*Aphelandra hartwegiana* Nees	Constipation (F; I; K), antiemetic (WP; D; NB)
	Aphelandra aurantiaca (Scheidw.)	Before childbirth (WP; I; NB)
	Aphelandra sinclairiana Nees	Antiemetic in pregnancy (St; D; NB)
	Aphelandra tonduzii Leonard.	Fever, skin rash, mumps, erysipelas (WP; D; NB)
	Blechum costaricense Oerst.	Vertigo (L; D; TB)
	Blechum panamense Lindau	Vertigo (St, L; D; TB)
	Blechum pyramidatum (Lam.) Urb.	Antiemetic (WP; D; NB), amebiasis (L; D; TB)
	Justicia sp.	Internal fever (WP; I; K)
	Justicia ephemera Leonard	Convulsions (WP; ID; K)
	Justicia oerstedii Leonard.	Diarrhea (St, R; D; TB)
	Justicia pectoralis Jacq.	Pain, hepatic disorders (St; I; NB)
	Sanchezia pennellii Leonard	"Enlargement of the mind" (F; I; K)
	Odontonema tubiforme (Bertol.) Kuntze	Anti-inflammatory (L; D; NB), induce child birth (St, L; D; TB)
	Ruellia biolleyi Lindau.	Dizziness, edema, fever (St; D; NB), appetite stimulant (St, L; D; TB)
	Ruellia cf. metallica Leonard	Body ache, fever (St; D; TB)
	Ruellia praeclara Standl.	Edema (St; D; NB)
Amaranthaceae	*Amaranthus sp.*	Antiemetic, hematuria (L, F; I; K)
	Pleuropetalum sprucei (Hook. f.) Standl.	Nose bleeding, post-measles weakness (St; D; TB)
Amaryllidaceae	*Crinum darienensis* Woodson	Fever (WP; I; K)
Annonaceae	*Annona reticulata* L.	Inflammation, fractures (L; C; TB)
	Cymbopetalum costarricense (J. D. Sm.) R. E. Fries.	Snakebite (B; I; NB)
	Xylopia frutescens Aubl.	Anthelmintic, antipyretic (L; NS; NB)
Apocynaceae	*Odontadenia puncticulosa* (L. Rich.) Pulle.	Rubella (WP; I; NB)
	Peltastes colombianus Woods.	Diarrhea (St; I; NB)
	Rhabdadenia biflora (Jacq.) Muell.-Arg.	Eye infections (F; I; K)
	Stemmadenia grandiflora (Jacq.) Miers	Renal disorders (St; I; NB)
Araceae	*Anthurium sp.*	To reduce size of the uterus during pregnancy (F; I; K), antidiarrhoeic (R; D; NB)
	Anthurium pentaphyllum (Aubl.) G. Don.	Skin infections, pain reliever, inflammation of muscles and joints (WP; D; K)
	Dieffenbachia aurantiaca Engl.	Pain reliever, skin infections (WP; D; K)
	Dracontium costaricense Engler.	Snakebite (L; D; NB)
	Dracontium dressleri Croat.	To facilitate childbirth (F; IK; K), muscle aches, snakebite (L, R; NS; K)
	Dracontium spruceanum (Schott) G. H. Zhu	Snakebite (Rz, St, T; D; TB), skin ulcers (T; D; TB)
	Homalomena wendlandii Schott	Snakebite (St; D; TB)
	Montrichardia arborescens (L.) Schott.	Skin infections (L; D; K)
	Philodendron sp.	To increase vitality in children (WP; I; K), wound healing (S; DA; K), skin rash, fever (WP; D; NB)
	Philodendron radiatum Schott	Pain, snakebite (R; C; TB)
	Spathiphyllum friedrichsthalii Schott.	To avoid enlargement of the uterus during pregnancy, to facilitate childbirth (F; I; K)
	Spathiphyllum quindiuense Engl.	To bathe sick children (WP; I; K)
	Xanthosoma sp.	Strong muscular and bone aches, inflammation (In; D; K)
	Xanthosoma helleborifolium (Jacq.) Shott.	To facilitate childbirth (T; IK; K)
	Xanthosoma mexicanum Liebm.	To facilitate childbirth, snakebite (F; I; K)
Aristolochiaceae	*Aristolochia aff. grandiflora* Sw.	Snakebite (L; D; TB)
	Aristolochia chapmaniana Stand.	Snakebite, shortness of breath (WP; I; NB)
	Aristolochia constricta Griseb.	Snakebite (WP; I; NB), (St; D; TB); leishmaniasis (L; C; TB)
	Aristolochia pilosa H. B. K.	Snakebite (WP; I; NB)
	Aristolochia sylvicola Stand.	Snakebite (St; D; NB)
	Aristolochia tonduzii O. C. Schmidt	Pain, inflammation (St; D; TB)
Asclepiadaceae	*Sarcostemma clausum* (Jacq.) Roem. et Schult.	Shortness of breath (St; I; NB)
Aspleniaceae	*Asplenium serratum* L.	Burns (Sc; C; TB)
Asteraceae	*Bidens reptans* (L.) G. Don.	Sore eyes (St; D; NB)
	Hebeclinium macrophyllum (L.) DC.	Insect bites (L; D; TB)
	Neurolaena lobata (L.) R. Br.	Skin infections (WP; D; K), (L;D;TB); fever (St; I; NB)
	Sinclairia polyantha (Klatt) Rydb.	Cough (St; D; TB)
	Sphagneticola trilobata (L.) Pruski	Cough, flu (L; D; TB)
	Rolandra fruticosa (L.) Kuntze	Muscle aches (WP; D; K)
	Vernonia sp	To facilitate expulsion of the placenta (In; I; K)
	Wedelia trilobata (L.) Hitchc.	Skin diseases (WP; D; K)
Begoniaceae	*Begonia glabra* Aubl.	Furuncles (WP; fresh; NB)
	Begonia hirsuta Aubl.	Renal disorders (WP; D; NB)
	Begonia multinervia Liebm.	Fever (Pt; Jc; TB)
	Begonia semiovata Liebm.	Women's ailments (WP; D; NB), chicken pox (St; D; TB)
Bignoniaceae	*Arrabidaea verrucosa* (Standl.) A. Gentry	Fever, weakness, muscle aches (WP; I; K)
	Callichlamys latifolia (L. C. Rich) K. Schum.	Body aches, loss of appetite (St; NS; NB)

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Table 1 Medicinal plant inventory of Kuna, Ngöbe-Buglé, and Teribe Indians. *(continued)*

Family	Specie	Application (plant part; preparation; Amerindian group)
	Crescentia cujete L.	Purgative (F; D; TB)
	Mansoa standleyi (Steyerm.) A. H. Gentry	Aggressive dementia (VI; D; TB)
	Stizophyllum riparium (HBK.) Sandw.	Anuria (WP; D; K), urinary infections (St; D; TB)
Blechnaceae	*Salpichlaena volubilis* (Kaulf.) J. Sm.	Toothache (VI; D; TB)
Boraginaceae	*Cordia alliodora* (Ruiz & Pav.) Oken	Fever (L; D; TB)
	Cordia spinescens L.	Wound healing (St; DA; NB)
	Tournefortia bicolor Sw.	Fever (St, L; D; TB)
	Tournefortia cuspidata Kunth	Fever (St; D; TB)
Burseraceae	*Bursera simaruba* (L.) Sarg.	Urinary infections, bruises, contraconceptive (St; D; TB)
	Trattinnickia aspera (Standley) Swart	Depurative hypertension (St; D; TB), leishmaniasis (Rs; DA; TB)
Cactaceae	*Epiphyllum phyllanthus* (L.) Haw.	Body aches (R; I; NB)
	Pereskia bleo (HBK.) DC	Muscle aches (L; D; K)
	Pereskia bleo (HBK.) DC	Stomachache (In; IK; K)
Campanulaceae	*Centropogon coccineus* (Hook.) Regel ex B. D. Jacks.	Arthritis (St; D; TB)
Capparaceae	*Cleome serrata* Jacq.	Topical warm bath (WP; D; K)
	Cleome serrata Jacq.	Snakebite (L; IK; K)
Caricaceae	*Carica papaya* L.	To improve blood circulation, to induce diuresis, to treat furuncles (F, L; IK; K)
Caryophyllaceae	*Drymaria cordata* (L.) Willd. ex Schult.	Headache, stomachache (St, L; D; TB), fever (WP; D; TB)
	Stellaria ovata Willd. ex Schltdl.	Worms (WP; D; TB)
Chenopodiaceae	*Chenopodium ambrosioides* L.	Stomachache (L; D; TB), to expel worms (L; Jc; TB)
Clusiaceae	*Symphonia globulifera* L. f.	Bloody vomiting (St; I; NB), body pain (L; C; TB)
Cochlospermaceae	*Cochlospermum vitifolium* (Willd.) Spr.	To improve blood circulation (Sd; I; K)
Commelinaceae	*Cochliostema odoratissimum* Lem.	To regulate menstruation (L; D; NB)
	Commelina diffusa Burm. f.	Common cold (WP; I; K)
	Dichorisandra hexandra (Aubl.) Standl.	Snakebite (T; D; NB), internal and body pain (T; D; TB)
	Tradescantia zanonia (L.) Sw.	Hemorrhage (S; DA; TB)
	Tripogandra serrulata (Vahl) Handlos	Inflammation, fractures (WP; D; TB)
Convolvulaceae	*Ipomoea alba* L.	Snakebite (L; C; TB), inflammation in snakebite (WP; D; TB)
	Ipomoea indica (Burm. f.) Merr.	Laxative (L; D; NB)
Cucurbitaceae	*Cucurbita pepo* L.	As bath, to accelerate children's growth (WP; I; K)
	Gurania makoyana (Lem.) Cogn.	Leishmaniasis (St, L; D; TB), inflammation, liquid retention (L; D; TB)
	Momordica charantia L.	Bile, to facilitate child birth, fever, hypertension (WP; D; TB)
	Psiguria warscewiczii (Hook. f.) Wunderlin.	Shortness of breath (St; D; NB)
Cyatheaceae	*Cyathea petiolata* (Hook.) Tryon	Ceremony to bathe sick children (WP; I; K)
Cycadaceae	*Zamia pseudoparasitica* Yates	Emetic (T; D; K), muscle aches (St; DA; K)
	Zamia sp.	Colic, constipation (St; D; NB)
Cyclanthaceae	*Carludovica palmata* R. et P.	To prevent complications during childbirth (In; I; K)
	Cyclanthus bipartitus Poit.	To avoid enlargement of uterus (F; IK; K)
	Dicranopygium crinitum Harl.	To bathe sick children (WP; I; K)
Cyperaceae	*Cyperus luzulae* (L.) Retz.	Eye infections, to avoid complications during childbirth (WP; I; K)
Dilleniaceae	*Davill kunthii* St. Hil.	Colic in children (Br, F; I; K)
	Tetracera volubilis L.	Body aches (St, L; D; TB)
Euphorbiaceae	*Acalypha hispida* Burm. f.	To facilitate childbirth (F; IK; K)
	Chamaesyce hirta (L.) Millsp.	Acne (L; ID; K)
	Croton fragans HBK.	Common cold (L, F; ID; K)
	Croton lobatus L.	Skin diseases (WP; I; K)
	Jatropha sp.	Emetic (Sd; I; K)
	Manhiot esculenta Crantz.	Acne (L; ID; K)
	Phyllanthus urinaria L.	Diarrhea (St; D; TB)
Fabaceae	*Bauhinia guianensis* Aubl.	Diarrhea, bed wetting (St, L; D; TB)
	Bauhinia reflexa Schery	Headache (St, L; D: TB)
	Calliandra stipulacea Benth	Fever (WP; I; K)
	Desmodium adscendens (Sw.) DC.	Conjunctivitis (WP; C; TB)
	Desmodium axillare (Sw.) DC.	Postpartum aid to expel placenta (St; D; NB)
	Machaerium sp.	Antitussive (WP; D; NB), aphthous ulcers of the mouth (S; NS; NB)
	Mimosa pudica L.	Arthritis (St; I; NB)
	Prioria copaifera Griseb.	Tonic, energizer (F; I; K)
	Senna fruticosa (Mill.) H. S. Irwin & Barneby	Body aches (St, L; D; TB)
	Senna reticulate (Willd.) Irwin & Barneby.	Emetic (R; D; NB)
Flacourtiaceae	*Lindackeria laurina* C. Presl.	Pneumonia (St; D; NB)
	Xylosma sp.	Spider bites (St, R; I; NB)
Gentianaceae	*Schultesia lisianthoides* (Griseb.) Benth. & Hook	Pneumonia (St; I; NB)

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Table 1 Medicinal plant inventory of Kuna, Ngöbe-Buglé, and Teribe Indians. *(continued)*

Family	Specie	Application (plant part; preparation; Amerindian group)
Gesneriaceae	*Besleria laxiflora* Benth.	Fever (L; D; TB)
	Besleria solanoides Kunth	Fever (St; D; TB)
	Chrysothemis friedrichsthaliana (Hanst.) H. E.	Muscle aches, inflammation of the joints (WP; I; K)
	Chrysothemis pulcella (Donn ex Sims) Decne.	To facilitate childbirth (F; I; K)
	Columnea nicaraguensis Oerst.	Chest pain (St; I; NB), fever, fatigue (St, L; D; TB)
	Columnea sanguinolenta (Oerst.) Hanst.	Dysmenorrhea (St, L; D; TB)
	Columnea tulae Urb. var. *tomentulosa* (C. V. Morton) B. D. Morley	Fever (St; D; TB), measles (St, L; D; TB), chicken pox (WP; Jc; TB)
	Diastema scabrum (Poepp.) Benth. ex. Walp.	Fever, measles (St; D; TB), vertigo (WP; D; TB)
	Drymonia macrophylla (Oerst.) H. E. Moore	Fever (St; D; TB)
	Drymonia multiflora (Oerst. ex Hanst.) Wiehler	Inflammation, breast pain, painful breathing (WP; D; TB)
	Drymonia serrulata (Jacq.) Mart.	Fever, headaches (St; D; NB), (St; Jc; TB)
	Drymonia warscewicziana Hanst.	Difficulty in breathing (St; D; TB)
	Gasteranthus acropodus (Donn. Sm.) Wiehler	Fever (WP; D; TB)
	Gasteranthus imbricans (Donn. Sm.) Wiehler	Fever (St; D; TB)
	Reldia veraguensis Wiehl.	Antiemetic (St; I; NB)
Gramineae	*Coix lacryma-jobi* L.	Common cold (R, F; D; K)
	Oplismenus burmanni (Retz.) Beauv.	Shortness of breath (WP; I; NB)
Hamaedoraceae	*Xyphidium caeruleum* Aubl.	Antiemetic (St; I; NB), skin disorders (L; I; NB), to facilitate childbirth (St; I; TB)
Lamiaceae	*Hyptis sp.*	Excipient (WP; NS; K)
	Hyptis capitata Jacq.	Snakebite (L; IK; K)
	Ocimum campechianum Mill.	Excipient (WP; NS; K)
	Ocimum canum Sims.	Excipient, "enlargement of the mind" (L, F; I; K)
Lecythidaceae	*Gustavia superba* (HBK.) Berg.	Mental disorders (F; IK; K)
Loganiaceae	*Spigelia anthelmia* L.	Skin and eye infections (WP; D; K)
	Spigelia humboldtiana Cham & Schlecht.	Anthelmintic (WP; D; NB), pain and inflammation (St; D; TB), headache (WP; D; TB)
	Strychnos sp.	Bee bites (St; D; NB)
Lomariopsidaceae	*Elaphoglossum herminieri* (Bory ex F'ee) T. Moore	Burns (F; C; TB)
Lythraceae	*Cuphea epilobifolia* Koehne	Rheumatism (St, L; D; TB)
Malpighiaceae	*Banisteriopsis muricata* (Cav.) Cuatr.	Headache, fever (St; I; NB)
	Heteropteris obovata (Small) Cuatr. et Croat.	Fever, headaches and diarrhea (St; D; NB)
Malvaceae	*Hibiscus rosa-sinensis* L.	To control size of uterus, "mental saturation" (F; I; K)
	Hibiscus schizopetalus (Mast.) Hook. f.	To facilitate childbirth (F; I; K)
	Malvaviscus arboreus Cav.	Difficult childbirths (Br; D; NB)
	Pavonia fruticosa (Mill.) Fawc. et Rendl.	Fever, common cold (WP; D; K)
	Sida acuta Burm. f. var. acuta.	Tonic, antipyretic, alopecia in children (AP; D; K)
	Sida rhombifolia L.	Inflammation, fractures (WP; D; TB), difficult birth (L; D; TB), to facilitate childbirth (St; D; TB)
Marantaceae	*Calathea lutea* (Aubl.) G. Meyer	To increase learning capacity in children (F; I; K)
	Calathea warscewiczii (Mathieu) Koernicke.	Rubella (St; I; NB), snakebite (Rz, L; C; TB), painful wounds, inflammation (L; C; TB)
Marcgraviaceae	*Marcgravia nepenthoides* Seemann.	Tiredness (Br; I; NB)
	Souroubea sp.	Antidiarrhoeic (St; I; NB)
Melastomataceae	*Arthrostemma ciliatum* Ruiz & Pav.	Urinary infections (St, L; D; TB)
	Bellucia pentamera Naudin	Chicken pox, measles (St; D; TB)
	Blakea foliacea Gleason.	Diarrhea (St; D; NB)
	Ossaea quinquenervia (Mill.) Cogn.	Fever (St; D; TB)
	Triolena hirsuta (Benth.) Triana	Nose bleeding (St; D; TB)
Meliaceae	*Carapa guianensis* Aubl.	Furuncles, skin infections (S; C; TB)
	Cedrela odorata L.	Leishmaniasis (St; D; TB)
	Guarea multiflora A. Juss.	Hepatic disorders, emetic (St; I; NB)
Menispermaceae	*Cissampelos pareira* L.	As a drink when feeling sick on waking up (St; D; NB)
	Cissampelos tropaeofolia DC.	Snakebite (St; D; NB), diarrhea (St; D; TB)
Monimiaceae	*Siparuna sp.*	Fever (L; I; K)
Moraceae	*Cecropia peltata* L.	Headache, "mental saturation" (In; D; K)
	Dorstenia contrajerva L.	Snakebite, muscle aches (WP; D; K)
	Ficus insipid Willd.	Skin diseases (St; I; K)
Musaceae	*Heliconia hirsuta* L. F.	Antidiarrhoeic (R; I; NB)
	Heliconia mariae Hook. f.	To improve blood circulation (F; D; K)
	Heliconia platystachys Baker	To facilitate childbirth (F; I; K)
	Heliconia vaginalis Benth.	Drunk when fetus is found to be incorrectly positioned (WP; D; K)
	Musa sapientum L.	Urinary infection (Ht; D; TB)
Myrtaceae	*Psidium guajava* L.	Diarrhea (Br; D; TB)
Olaceae	*Heisteria macrophylla* Oerst.	Abdominal cramps (St; I; NB)
Orchidaceae	*Dichaea muricata* (SW.) Lindl.	Anthelmintic (WP; I; NB)

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Table 1 Medicinal plant inventory of Kuna, Ngöbe-Buglé, and Teribe Indians. *(continued)*

Family	Specie	Application (plant part; preparation; Amerindian group)
	Epidendrum difforme Jacq.	Rubella (L; I; NB)
	Maxillaria sp.	Fatigue, exhaustion (L; I; NB)
	Octomeria sp.	Antiemetic (NS; I; NB)
Palmae	*Bactris sp.*	Difficulties in breathing (St; D; NB)
	Cocos nucifera L.	Intense back pain (R; D; TB)
Passifloraceae	*Passiflora costaricencis* Killip	Chest pain (L; D; TB), body aches (St; D; TB); pain, snakebite (St, L; D; TB)
	Passiflora pediculata Mast.	Snakebite (St; D; NB)
	Passiflora quadrangularis L.	Anti-inflammatory (St; D; NB)
	Passiflora sexflora Juss.	Snakebite (WP; D; NB)
	Passiflora vitifolia HBK.	"Mental saturation" (F; I; K), snakebite (St; I; NB)
Phytolaccaceae	*Rivina humilis* L.	Cold (St, L; D; TB)
	Petiveria alliacea L.	Ritual ceremonies (St, L; D; NB)
Piperaceae	*Peperomia aff. ebingeri* Yunck.	Measles (WP; I; TB)
	Peperomia pellucida (L.) Kunth	Foot inflammation (WP; D; TB)
	Peperomia rotundifolia (L.) H. B. K.	Rash (L; D; NB)
	Piper auritum HBK.	Common cold (In; I; K)
	Piper erubescentispicum Trel.	Headache (L; D; TB)
	Piper hispidum Sw.	Eyes infection, muscle aches (L; D; K), fever (St; D; TB), to expel worms (St; C; TB)
	Piper multiplinervium C. DC.	Body- and stomachaches (L; I; K)
	Piper peltatum L.	Infected wound (L; D; TB)
	Piper tuberculatum Jacq.	Liver pains (In, L; IK, D; K)
Polygalaceae	*Polygala panamensis* Chodat.	Sore eyes (WP; D; NB)
	Polygala paniculata L.	Fever (WP; D; TB)
	Securidaca diversifolia (L.) S. F. Blake	Toothache (L; D; TB)
Polypodiaceae	*Niphidium crassifolium* (L.) Lellinger	Fever (L; D; NB)
	Polypodium sp.	Difficulties in breathing (T; NS; NB)
Rhizophoraceae	*Rhizophora mangle* L.	Healing of bone fracture (R; I; K)
Rubiaceae	*Borreria laevis* (Lam.) Griseb.	Muscle and bone aches, inflammation, skin diseases, acne (WP; D; K)
	Cephaelis elata Sw.	Dizziness, hallucination, dementia (St; D; NB)
	Cephaelis tomentosa (Aubl.) Vahl.	Dizziness, hallucination, rubella (St, R; D; NB)
	Chione panamensis Steyermark.	Ritual ceremonies (R; I; NB)
	Coffea arabica L.	Fever (L; I; K)
	Faramea eurycarpa Don. Sm.	Pruritous (St; D; NB)
	Genipa americana L.	Drunk by mother to regulate growth of fetus (L; I; K), to treat weakness in girls (F; NS; K)
	Hamelia patens var. *glabra.* Oerst.	Snakebite, postpartum aid to relieve pain (St; I; NB)
	Hoffmannia vesiculifera Standl.	Headache, body aches (St, R; D; NB), to induce and facilitate childbirth (St; D; TB)
	Manettia reclinata L. Mant.	Renal analgesic (St; D; NB), fever (St; D; TB)
	Notopleura anomothyrsa (K. Schum. & Donn. Sm.) C. M. Taylor	Fever (St; D; TB), stomachache (St, L; D; TB)
	Palicourea guianensis Aubl.	Mental disorders (F; I; K)
	Pentagonia pinnatifida Seem.	Fever (R; I; K), to facilitate childbirth and menstruation (F; IK; K)
	Psychotria emetica L. f.	Chicken pox, fever (R; D; TB)
	Psychotria psychotriifolia (Seem.) Standl.	Fever (St; D; TB)
	Psychotria uliginosa Sw.	Stomachache, fever (L; I; NB)
	Sabicea villosa R. et S.	Rheumatism (St; I; NB)
Rutaceae	*Citrus limon* (L.) Burm. f.	Common cold, cough, breathing difficulties (P; NS; K)
Sapindaceae	*Sapindus saponaria* L.	Skin diseases, colds (F; I; K)
	Serjania rhombea Radlk.	Dizziness (St; I; NB)
Scrophulariaceae	*Alectra aspera* (Cham. et Schlecht.) L. O. Williams.	Difficulties in breathing (St; I; NB)
	Scoparia dulcis L.	Fever (St; D; TB), chicken pox (L; D; TB)
	Russelia sarmentosa Jacq.	Snakebite (WP; D; NB)
Selaginellaceae	*Selaginella sp.*	Fever, weakness, muscle aches and eye infection (L; IK; K)
Simaroubaceae	*Picramnia allenii* D. M. Porter.	Shortness of breath (St; D; NB)
	Simaba cedron Planch.	Fever, malaria, snakebites (F; I; NB)
Smilacaceae	*Smilax chiriquensis* C. V. Morton	Weakness, malnutrition (Rz; D; TB)
Solanaceae	*Capsicum annuum* L. var. *aviculare* (Dierb.) D'Arcy et Eshb.	Serious ailments (F, L; IK, ID; K)
	Cestrum nocturnum L.	Fever (L; D; TB)
	Cuatresia exiguiflora (D'Arcy) Hunz.	Postpartum birth (St; D; TB)
	Cyphomandra hartwegii (Miers) Dun.	Snakebite (St; I; NB)
	Lycianthes amatitlanensis (J. M. Coult. & Donn. Sm.) Bitter	Headache (St, L; NS; TB)

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Table 1 Medicinal plant inventory of Kuna, Ngöbe-Buglé, and Teribe Indians. *(continued)*

Family	Specie	Application (plant part; preparation; Amerindian group)
	Solanum lancaeifolium Jacq.	Muscle and stomachaches (WP; D; K); shortness of breath (R; D; NB)
	Witheringia correana D'Arcy	Fever (St; D; TB)
	Witheringia solanacea L'Her.	Anthelmintic (WP; I; NB)
Sterculiaceae	*Theobroma cacao* L.	To facilitate childbirth (St; IK; K), bleeding (F; C; TB)
	Herrania purpurea (Pittier) R. E. Schultes	To facilitate childbirth (AP; IK; K)
Tectariaceae	*Cyclopeltis semicordata* (Sw.) J. Sm.	Burns (Sc; DA; TB)
Theophrastaceae	*Clavija costaricana* Pittier	To expel worms (St; D; TB)
	Clavzja sp.	Women's ailment (L; I; NB)
Tiliaceae	*Heliocarpus americanus* L.	To facilitate child birth (St; I; TB)
Urticaceae	*Pilea imparifolia* Wedd.	Diarrhea (St; D; NB)
	Pilea microphylla (L.) Liebm.	Chicken pox (St, L; D; TB), warts (WP; C; TB), measles (WP; D; TB)
	Urera caracasana (Jacq.) Griseb	Foot pain (L; DA; TB)
	Urera laciniata (Goud.) Wedd.	Body aches (L; NS; K)
Verbenaceae	*Lantana hispida* Kunth	Placenta retention (Fl; I; K)
	Lantana trifolia L.	Fever (St, L; D; TB)
	Stachytarpheta jamaicensis (L.) Vahl	Neck pain, muscle pain (L; D; TB)
Vittariaceae	*Vittaria lineate* (L.) Sw.	Headaches (L; D; NB)
Zamiaceae	*Zamia skinneri* Warsz. ex A. Dietr.	Wound healing (Rz; D; TB)
Zingiberaceae	*Costus ruber* Griseb	To calm pain after childbirth (St; I; NB)
	Costus villosissimus Jacq.	To calm pain after childbirth (St; I; NB)
	Dimerocostus strobilaceus Kuntze	To improve blood circulation (Fl, L; I; K)
	Zingiber officinale Roscoe	Pneumonia, toothache (Rz; D; TB)

Fl: flower; L: leave; AP: aerial parts; St: stem; WP: whole plant; F: fruit; P: peel; R: root; Rz: rhizomes; In: Inflorescence; Pt: petioles; Br: branch; S: sap; Sd: seed; T: tuber; Sc: scales; Vl; vines; Ht: heart; I: infusion; D: decoction; C: cataplasm; IK: *Ina kuamakalet*; ID: *Ina dibialet*; Jc: juice; Rs: resin; DA: direct application; NS: not specified; K: Kuna Indians; NB: Ngäbe-Buglé; TB: Teribes [14–17]

ceae, Rubiaceae, Fabaceae, Piperaceae, and Simaroubaceae, which are some of the major plant families in Panama. A total of 160 new compounds belonging to a wide variety of chemical structures: acetogenins, flavonoids, alkaloids, coumarins, terpenoids, quinones, benzophenones, iridoids, and quassinoids were isolated from Panamanian plants. Noteworthy are the new compounds isolated from plants such as *Marila pluricostata* Standl. & L. O. Williams, *Tovomita longifolia* (Rich.) Hochr., *Vismia macrophylla* Kunth., *Bonamia trichantha* Hallier f., *Sloanea zuliaensis* Pittier, *Adenaria floribunda* Kunth., *Triplaris cumingiana* Fisch. & C. A. Mey. ex Mey., which exhibited cytotoxicity to specific cancer cell lines; and from *Monnina sylvatica* Schltdl. & Cham, *Piper dilatatum* Rich., *Lonchocarpus chiricanus* Pittier, *Erythrina berteroana* Urb., and *Cordia linnaei* Stearn, which exhibited antifungal activity. Additionally, new compounds isolated from *Siparuna thecaphora* (Poepp. & Endl.) A. DC., *Calycolpus warzewiczianus O. Berg, Clidemia sericea* D. Don, *Cornutia grandifolia var. intermedia, Arrabidaea patellifera* (Schltdl.) Sandwith were identified as antiplasmodials; and chemical evaluation of *Guatteria dumentorum* R. E. Fr. revealed new compounds toxic to *Leishmania mexicana*. Moreover, novel dimeric secoiridoid lisianthioside from *Lisianthus jefensis* with antimicrobial activity, larvicidal purpureacin from *Annona purpurea* against *Aedes aegypti,* antifungal xanthones from *Marila laxiflora,* antifungal and larvicidal naphthoquinones and naphthoxirene from *Cordia linnaei*, and antifungal benzoic acid derivatives from *Piper dilatum* are also worth mentioning. Thus, these data show that extensive pharmacognostic research on Panamanian flora can increase the probabilities of discovering new lead compounds of therapeutic importance.

Conclusions

From the results presented, it is immediately obvious that the Panamanian flora is still an untapped valuable source of new bioactive natural products. Most of the work reported here has been the result of many collaborative efforts with scientists worldwide. During the last quarter century, a total of approximately 390 compounds from 86 plants have been isolated to date, of which 160 are new to the literature. These belong to very diverse compound classes: naphthoquinones, flavonoids, biphenyls, coumarins, acetogenins, xanthones, benzoic acid derivatives, monoterpenes, triterpenes, saponins, alkaloids, amides, procyanidins, quinones, amides, iridoids, tannins, dimeric secoiridoids, and quassinoids. Among the isolated compounds, 155 exhibited a range of biological activities. Ethnopharmacological information gathered and extensive screening of Panamanian flora have indicated that many species have interesting activities and that much remains to be done. The potential of discovering new lead compounds is clearly evident.

The richness of plant biodiversity, high percentage of endemic species and a good legal framework for accessing genetic resources make Panama a unique place for international collaboration. For example a European Union project within the Framework of Seventh Program called AGROCOS is currently being executed in Panama in collaboration with a consortium of industries and academic institutions in Europe, South Africa, and Panama with the aim to discover novel compounds for the agrochemical and cosmetic industries.

Supporting Information

Table 1S provides a summary of novel compounds from Panamanian flora, but not tested for biological activity.

Table 2 Chemistry and biological activity of selected Panamanian plants.

Family	Species	New compounds	Known compounds	Biological activity	Ref.
Amaryllidaceae	*Hymenocallis littoralis* (Jacq.) Salisb. = *Pancratium littorale* Jacq.		7,4′-dihydroxy-8-methylflavan (**1**)	**DPPH:** (**1**)	[32]
Anacardiaceae	*Mosquitoxylon jamaicense* Krug & Urb.		phloridzin (**2**), 4-hydroxy benzenepropanal (**3**), trilobatin (**4**), quercetine-3-*O*-β-D-galactoside (**5**)	**AP:** *Pf* (**2**)	[33]
Annonaceae	*Annona purpurea* Moc. & Sessé ex Dunal	purpureacin 1 (**6**), purpureacin 2 (**7**)	rolliniastatin 1 (**8**), bullatacin (**9**), cherimolin (**10**), sylvaticin (**11**)	**AB:** *Bs* (**6**); **AF:** *Ca* (**6**, **7**, **9**–**11**)	[34]
	Duguetia panamensis Standl.		2,4,5-trimethoxystyrene (**12**)	**TBS:** (**12**)	[35]
	Guatteria amplifolia Triana and Planch		xylopine (**13**), nornuciferine (**14**), lysicamine (**15**), laudanoscine (**16**)	**L:** *Lm*, *Lp* (**13**, **14**)	[36]
	Guatteria dumentorum R. E. Fr.	(+)-isodomesticine (**17**), (+)-norisodomesticine (**18**), (+)-nantenine (**19**), (+)-neolitsine (**20**), (+)-lirioferine (**21**), (+)-N-methyllaurotetanine (**22**), (+)-norlirioferine (**23**), (+)-isoboldine (**24**), (+)-reticuline (**25**)	cryptodorine (**26**), nornantenine (**27**)	**L:** *Lm*, *Lp* (**26**, **27**); *Lm* (**17**–**20**)	[36, 37]
Apocynaceae	*Stemmadenia robinsonii* Woodson	(−)-lyoniresinol 3α-*O*-β-D-glucopyranoside (**28**), (+)-5′-methoxyisolariciresinol 3α-*O*-β-D-glucopyranoside (**29**), (−)-5′-methoxyisolariciresinol 3α-*O*-β-D-glucopyranoside (**30**), (−)-isolariciresinol 3α-*O*-β-D-glucopyranoside (**31**), 16-epi-panarine (**32**)	(+)-lyoniresinol 3α-*O*-β-D-glucopyranoside (**33**), (+)-isolariciresinol 3α-*O*-β-D-glucopyranoside (**34**), coronaridine (**35**), voacangine (**36**), ibogamine (**37**), hydroxyindolenine-ibogamine (**38**), hydroxy-indoleninecoronaridine (**39**), hydroxyindoleninevoacangine (**40**), heyneanie (**41**), voacristine (**42**), 19-oxo-coronaridine (**43**), 13-hydroxycoronaridine (**44**)	**AB:** *Bs* (**42**, **44**) **TBS:** (36)	[38, 39]
Asteraceae	*Baccharis pedunculata* (Mill.) Cabrera		lachnophyllum lactone (**45**), ulopterol 3-methylether flavones (**46**), ulopterol (**47**)	**AF:** *Cc* (**46**, **47**), *Ca* (**45**, **46**), *Ef* (**45**, **47**), *Mg* (**45**) Toxic to human keratinocytes: (**45**)	[40]
Bignoniaceae	*Arrabidaea patellifera* (Schltdl.) Sandwith	(3′-*O*-*p*-hydroxybenzoylmangiferin (**48**), 3′-*O*-*trans*-coumaroylmangiferin (**49**), 6′-*O*-*trans*-coumaroylmangiferin (**50**), 3′-*O*-*trans*-cinnamoylmangiferin (**51**), 3′-*O*-*trans*-caffeoylmangiferin (**52**), 3′-*O*-benzoylmangiferin (**53**)	mangiferin (**54**), isomangiferin (**55**)	**AP:** *Pf* (**48**–**54**); **DPPH, ALP:** (**48**–**54**)	[41]
	Jacaranda caucana Pittier	6′-*O*-(*cis*-1,4-dihydroxycyclohexanacetyl) acteoside (**56**), 6′-*O*-(1-hydroxy-4-oxo-cyclohexanacetyl) acteoside (**57**), 4-*O*-rhamnosyl-7*S*, 8*R*-7,8′-*erythro*-sisymbrifolin (**58**)	protocatechuic acid (**59**), acteoside (**60**), jionoside D (**61**), isoacteoside (**62**), martynoside (**63**)	**DPPH, ALP:** (**56**–**63**)	[42]
Boraginaceae	*Cordia alliodora* Ruiz & Pavon	1-(3′-methoxypropanoyl)-2,4,5-trimethoxybenzene (**64**), 2-(2*Z*)-(3-hydroxy-3,7-dimethylocta-2, 6-dienyl)-1,4-benzenediol (**65**)		**AF:** *Cc* (**64**, **65**) **LC:** *Aa* (**64**)	[43]
	Cordia linnaei Stearn	cordiaquinona E (**66**), cordiaquinona F (**67**), cordiaquinona G (**68**), cordiaquinona H (**69**)	cordiaquinona B (**70**), naftoxireno (**71**)	**AF:** *Cc*, *Ca* (**66**–**70**)	[44]
	Cordia spinescens L.		magnesium lithospermate (**72**), calcium rosmarinate (**73**), magnesium rosmarinate (**74**)	**HIV-1 RT:** (72–74)	[45, 46]

continued next page

Table 2 Chemistry and biological activity of selected Panamanian plants. *(continued)*

Family	Species	New compounds	Known compounds	Biological activity	Ref
Calophyllaceae	*Marila laxiflora* Rusby		5-hydroxy-1-methoxyxanthone (**75**), 1,5-dihydroxyxanthone (**76**), 1,6-dihydroxy-5-methoxyxanthone (**77**), betulinic acid (**78**), rhamnetin (**79**), 2-(3,3-dimethylallyl)-1,3,5,6-tetrahydroxyxanthone (**80**), 3,4-dihydroxy-benzoic acid (**81**)	**AF:** *Cc* (**75**–**77**)	[47]
	Marila pluricostata Standl. & L. O. Williams	5-hydroxy-8,8-dimethyl-4-phenyl-9,10-dihydro-8*H*-pyrano-[2,3-*f*]chromen-2-one (**82**), 5-hydroxy-8,8-dimethyl-4-phenyl-6-propionyl-9,10-dihydro-8*H*-pyrano-[2,3-*f*]chromen-2-one (**83**), and 5,7-dihydroxy-8-(3-methylbut-2-enyl)-4-phenylchromen-2-one (**84**), pluricostatic acid (**85**)	mammeisin (**86**), isomammeisin (**87**), mammeigin (**88**), MAB 5 (**89**), mesuagin (**90**), isomesuol (**91**), MAB 1 (**92**), mesuol (**93**), mammea A/BB (**94**), isodispar B (**95**), cyclomammeisin (**96**), disparinol A (**97**), MAB 3 (**98**), and mesuol cyclo F (**99**), squalene (**100**), friedelin (**101**), 4-*epi*-friedelin (**102**), canophyllal (**103**), friedelinol (**104**), canophyllol (**105**), 3-oxo-friedelan-28 oic acid (**106**), D : A-friedo-3,4-seco-olean-3-oic acid (**107**), *epi*-betulinic acid (**108**), betulinic acid (**109**), *β*-sistosterol (**110**), stigmasterol (**111**), 3-*O*-*β*-glucopyranosyl-sistosterol (**112**)	**AC:** MCF-7, H-460, SF-268 (**82**–**87**, **91**–**112**)	[48, 49]
Clusiaceae	*Tovomita longifolia* (Rich.) Hochr.	(*E*)-3-(2-hydroxy-7-methyl-3-methyleneoct-6-enyl)-2,4,6-trihydroxybenzophenone (**113**), (*E*)-3-(6-hydroxy-3,7-dimethylocta-2,7-dienyl)-2,4,6-trihydroxybenzophenone (**114**), 8-benzoyl-2-(4-methylpenten-3-yl)chromane-3,5,7-triol (**115**), and 5-benzoyl-1,1,4a-trimethyl-2,3,4,4a,9,9a-hexahydro-1*H*-xanthene-6,8-diol (**116**)	4-geranyloxy-2,6-dihydroxybenzophenone (**117**) and 3-geranyl-2,4,6-trihydroxybenzophenone (**118**)	**AC:** MCF-7, H-460, SF-268 (**113**, **115**, **117**) **AB:** *Ms* (**115**–**118**), *Kp* (**115**, **116**), *Sg* (**116**), *Pa* (**116**), *Sa* (**117**)	[50]
	Vismia macrophylla Kunth	ferruginin C (**119**)	ferruginins A (**120**) and B (**121**), vismin (**122**), harunganin (**123**)	**AC:** MCF-7, H-460, SF-268 (**119**–**123**)	[51]
	Vismia baccifera (L.) Triana & Planch.		vismione B (**124**), deacetylvismione A (**125**) and H (**126**), bivismiaquinone (**127**), vismiaquinone (**128**)	**AC:** MCF-7, H-460, SF-268 (**124**–**126**)	[51]
Convolvulaceae	*Bonamia trichantha* Hallier f.	trichanthins A (**129**), B (**130**), C (**131**), and D (**132**)		**AC:** MCF-7, H-460, SF-268 (**129, 130, 132**)	[52]
Elaeocarpaceae	*Sloanea zuliaensis* Pittier	2-deoxycucurbitacin-D (**133**)	cucurbitacin D (**134**), 25-acetyl-cucurbitacin F (**135**)	**AC:** MCF-7, H-460, SF-268 (**133**–**135**)	[53]
Euphorbiaceae	*Chamaesyce hyssopifolia* (L.) Small		quercetin (**136**), quercetin 3-*O*-*α*-L-arabinopyranoside (**137**), quercetin 3-*O*-*β*-D-xylopyranoside (**138**), quercetin 3-*O*-*β*-D-glucopyranoside (**139**), quercetin 3-*O*-*β*-D-galactopyranoside (**140**), apigenin 7-*O*-*β*-D-glucopyranoside (**141**), kaempferol 3-*O*-*β*-D-glucopyranoside (**142**), gallic acid (**143**), gallic acid methyl ester (**144**), corilagin (**145**), 1,3,4,6-tetra-*O*-galloyl-*β*-D-glucopyranose (**146**)	HIV-1 RT: (**136**–**138**)	[45, 46]
Fabaceae	*Andira inermis* (W. Wright) Kunth. ex DC.		formononetin (**147**), calicosin (**148**), prunetin (**149**), biocanin (**150**), genistein (**151**), pratensein (**152**)	**AP:** *Pf* (**148**, **151**)	[54]

continued next page

Table 2 Chemistry and biological activity of selected Panamanian plants. *(continued)*

Family	Species	New compounds	Known compounds	Biological activity	Ref.]
	Erythrina berteroana Urb.	5,7-dihydroxy-3-[5-hydroxy-4-methoxy-3-(3-methyl-2-butenyl)phenyl]-2,3-dihydro-4*H*-1-benzopyran-4-one (**153**), sigmoidin B (**154**)		**AF:** *Cc* (**153**, **154**)	[55, 56]
	Lonchocarpus chiricanus Pittier	chiricanines A–E (**155**–**159**)	longistylines C (**160**) and D (**161**), 3,5-dimethoxystilbene (**162**)	**AF:** *Cc* (**155**), **LC:** *Aa* (**162**)	[57]
	Myrospermum frutescens Jacq.	18-hydroxycassan-13,15-diene (**163**), 6 *β*,-18-dihydroxycassan-13,15-diene (**164**), 6 *β*-hydroxy-18-acetoxycassan-13,15-diene (**165**), 18-acetoxy-13,15-diene-19-cassanoic acid (**166**), and 6*β*,13 *β*-dihydroxy-18-acetoxycassan-14(**167**),15-diene (**168**)		**AT:** *Tc* (**163**–**168**)	[58]
	Swartzia simplex (Sw.) Spreng.	*β*-D-glucopyranosyl[*β*-D-glucuronopyranosyl (1 → 3)]-3-*β*-hydroxyolean-12-en-23-al-28-oate (**169**), *β*-D-glucopyranosyl[*β*-D-xylopyranosyl-(1 → 2) (*α*-L-rhamnopyranosyl (1 → 3)-*β*-D-glucuropyranosyl (1 → 3)]-3*β*-hydroxyolean-12-en-28-oate (**170**), *β*-D-glucopyranosyl[*β*-D-glucuronopyranosyl (1 → 4)]-[*β*-D-glucopyranosyl-(1 → 3)]-3*β*-hydroxyolean-12-en-28-oate (**171**)	[*α*-L- rhamnopyranosyl-(1 → 3)- *β*-D-glucopyranosyl-(1 → 3)]-3*β*-hydroxyolean-12-en-28-oic acid (**172**); *β*-D-glucopyranosyl[*β*-D-glucuronopyranosyl (1 → 3)]-3-*β*-hydroxyolean-12-en-28-oate (**173**), *β*-D-glucopyranosyl [*α*-L-rhamnopyranosyl (1 → 3)- *β*-D-glucuropyranosyl (1 → 3)]-3*β*-hydroxyolean-12-en-28-oate (**174**), *β*-D-glucopyranosyl [*β*-D-glucopyranosyl (1 → 3)] 3*β*-hydroxyolean-12-en-23-oic-28-oate (**175**)	**MC:** *Bg* (**171**, **172**)	[59]
Gentianaceae	*Lisianthius seemannii* (Griseb) O. Kuntze	seemannoside A (**176**)	lisianthioside (**177**), seemannoside B (**178**), (4*Z*,4a*R**,12*Z*,12a*R**)-4,12-Diethylidene-4,4a,5,6,12, l2a,13,14-octahiydro-3H, 8H, 11H, 16H, dipyrano[3,4-c:3′,4′-i] [1, 7]dioxacyclododecin-3,8,11,l6-tetrone (**179**)	**AF:** *Cc* (**179**)	[60]
Lamiaceae	*Cornutia grandifolia* var. *intermedia*	cornutine C–L (**180**–**189**)		**AP:** *Pf* (**180**, **181**)	[61]
Lauraceae	*Nectandra lineata* (Kunth.) Rohwer	3′-methoxy-3,4-methylenedioxy-4′,7-epoxy-9-nor-8,5′-neolignan-9′-acetoxy (**190**)	3′-methoxy-3,4-methylenedioxy-4′-7-epoxy-9-nor-8,5′-neolignan-7,8′-diene (**191**)	**AT:** *Tc* (**190**, **191**)	[62]
Lythraceae	*Adenaria floribunda* Kunth.	adenaflorin A–D (**192**–**195**)		**AC:** MCF-7, H-460, SF-268 (**192**)	[63]
Malpighaceae	*Hiraea reclinata* Jacq.		kaempferol 3-*O*-(6′′-galloyl)-*β*-D-galactopyranoside (**196**), hyperin 6′′-gallate (**197**), 1,3,4,5-tetragalloylquinic acid (**198**), vitexin 2′′-rhamnoside (**199**), isovitexin 2′′-rhamnoside (**200**), orientin 2′′-rhamnoside (**201**), isoorientin 2′′-rhamnoside (**202**)	**HIV-P:** (**198**)	[64]
Malvaceae	*Apeiba tibourbou* Aubl.		rosmarinic acid (**203**)	**IC:** (**203**)	[65]
	Guazuma ulmifolia Lam.		(−)-epicatechin (**204**), procianidina B2 (**205**), procianidina B5 (**206**), procianidina C1 (**207**)	BI-AT$_1$: (**207** and more complex polymers)	[66]
Melastomataceae	*Clidemia sericea* D. Don	2′′,6′′-*O*-digalloylvitexin (**208**)	isovitexin (**209**), 2′′-*O*-galloylvitexin (**210**), rutin (**211**), vitexin (**212**)	**AP:** *Pf* (**208**, **210**)	[33]

continued next page

Table 2 Chemistry and biological activity of selected Panamanian plants. *(continued)*

Family	Species	New compounds	Known compounds	Biological activity	Ref.
	Henriettella fascicularis (Sw.) C. Wright	4′,5,7-trihydroxy-6,8-dimethylisoflavone (**213**), ácido (2*E*, 6*S*)-6-[(1*R*,5*Z*,3a*S*,9*R*,10*Z*,12a*R*)-1,2,3,3a,4,7,8,9,12,12a-decahydro-9-hydroxy-3a,6,10-trimethylcyclopentanocycloundecen-1-yl]-2-methylhept-2-enoic acid (**214**)	lichexanthone (**215**), (−)-pinoresinol (**216**), betulinic acid (**217**), palmitic acid (**218**), *β*-sitosterol (**219**)	**AE:** (**213**)	[67]
Myrtaceae	*Calycolpus warzewiczianus* O. Berg	myricetin-3-*O*-*α*-L-3′′-acetylarabinofuranoside (**220**), myricetin-3-*O*-*α*-L-3′′-5′′-diacetylarabinofuranoside (**221**), and 5-galloylquercetin-3-*O*-*α*-L-arabinofuranoside (**222**)	myricetin-3-*O*-*α*-L-arabinofuranoside (**223**), (−)-epicatechin (**224**)	**AP:** *Pf* (**222**)	[68]
Siparunaceae	*Siparuna thecaphora* (Poepp. & Endl.) A. DC. = *Siparuna andina* (Tul.) A. DC.	sipandinolide (**225**), (−)-cis-3-acetoxy-4′,5,7-trihydroxyflavanone (**226**)		**AP:** *Pf* (**226**)	[69]
	Siparuna pauciflora (Beurl.) A. DC.	sipaucin A (**227**), B (**228**), and C (**229**)	*nor*-boldine (**230**), boldine (**231**), laurotetanine (**232**), N-methyl-laurotetanine (**233**)	**AP:** *Pf* (**230**)	[70]
Papaveraceae	*Bocconia frutescens* L.		sanguinarine (**234**), chelirubine (**235**), chelerythrine (**236**), macarpine (**237**), chelidonin (**238**), berberine (**239**), allocryptopine (**240**), protopine (**241**), (−)-isocoripalmine (**242**), coptisine (**243**), aescoulerine (**244**), (−)-*cis*-N-methyl-canadine (**245**)	**BI-AT$_1$:** (**234**–**236**, **238**) **BI-ET$_A$:** (**236**)	[71]
Piperaceae	*Piper darienense* C. DC.		pipercallosine (**246**)	Local anesthetic (**246**)	[72]
	Piper dilatatum Rich.	taboganic acid (**247**)	methyl taboganate (**248**), 2,2-dimethyl-6-carboxychroman-4-one methyl ester (**249**), 2,2-dimethyl-3-hydroxy-6-carboxychromane methyl ester (**250**), methyl 3-(2′-hydroxy-3′-methyl-3′-butenyl)-4-hydroxy-benzoate (**251**), 2,2-dimethyl-6-carboxychromene methyl ester (**252**), flavokawin (**253**), alpinetin chalcone (**254**), 2′-hydroxy-3′,4′,6′-trimethoxy-chalcone (**255**)	**AF:** *Cc* (**247**–**250**)	[73]
	Piper fimbriulatum C. DC.	3,4,5′-trimethoxy-3′,4′-methylenedioxy-7,9′:7′,9 diepoxylignan (**256**)	7′-epi-sesartemin (**257**) and diayangambin (**258**), 5-hydroxy-7,4′-dimethoxyflavone (**259**), *β*-caryophyllene (**260**), germacrene (**261**), linalol (**262**), linalol acetate (**263**)	**LC:** *Aa* (**257**) **AP:** *Pf* (**257**) **AI, IS:** (**257**)	[74–76]
	Piper multiplinervium C. DC.	3-farnesyl-2-hydroxy benzoic acid (**264**)		**AB:** *Hp; Sa, Ec, Kp, Ms, Pa, Ca* (**264**)	[77]
Polygalaceae	*Monnina sylvatica* Schltdl. & Cham.	3′-Hydroxy-5-methoxy-3,4-methyilenedioxybiphenyl (**265**), 3′-hydroxy-5,5′-dimethoxy-3,4-methylenedioxybiphenyl (**266**), kaempferol 3-*O*-*β*-D-glucosyl-(1 → 2)-*O*-[*α*-L-rhamnosyl(1 → 6)]-*β*-D-galactoside (**267**)	1,5-dihydroxy-2,3-dimethoxyxanthone (**268**), kaempferol 3-*O*-*α*-L-rhamnopyranosyl -(1 → 6)-*β*-D-galactoranoside (**269**), kaempferol 3-*O*-*β*-D-apio-D-furanosyl -(1 → 2)-*β*-D-galactoranoside (**270**), kaempferol 3-*O*-[*O*-*β*-D-apio-D-furanosyl(1 → 2)-*O*-[*α*-L-rhamnopyranosyl(1 → 6)]-*β*-D-galactopyranoside (**271**)	**AF:** *Cc* (**265, 266**), *Sc* (**265, 266**), *Af* (**265**), *Tm* (**265**) **TBS:** (265, 266)	[78, 79]

continued next page

Table 2 Chemistry and biological activity of selected Panamanian plants. *(continued)*

Family	Species	New compounds	Known compounds	Biological activity	Ref.
Polygonaceae	*Triplaris cumingiana* Fisch. & C. A. Mey. ex Mey.	2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-4-oxo-4H-chromen-3-yl-4,6-bis-*O*-*β*-D-(3,4,5-trihydroxybenzoyl) glucopyranoside (**272**), 5,7-dihydroxy-2-(4-hydroxyphenyl)-4-oxo-4H-chromen-3-yl-5-*O*-*α*-L-(3,4,5-trihydroxybenzoyl) arabinofuranoside (**273**), 2-hydroxy-4-*O*-*α*-L-(3,5,7-trihydroxy-4-oxo-4H-chromen-2-yl)phenylarabinofuranoside (**274**)	quercetin 3-*O*-*α*-L-(5′′-*O*-galloyl)arabinofuranoside (**275**), quercetin 3-*O*-*β*-D-(6′′-*O*-galloyl)glucopyranoside (**276**)	**AC:** H-460 (**272**, **274**, **275**), MCF-7 (**273**–**275**), SF-268 (**275**)	[80]
Rubiaceae	*Coutarea hexandra* (Jacq.) K. Schum.	5-*O*-*β*-D-glucopyranosyl-4-(4-hydroxyphenyl)-7-methoxy-2H-chromen-2-one (**277**)	coumarin, 5-*O*-*β*-D-galactopyranosyl-4-(4-hydroxyphenyl)-7-methoxy-2H-chromen-2-one (**278**), 23,24-dihydrocucurbitacin F (**279**), 23,24-dihydro-25-acetylcucurbitacin F (**280**) and 2-*O*-*β*-D-glucopyranosyl-23,24-dihydrocucurbitacin F (**281**)	**AC:** MCF-7, H-460, SF-268 (**279**, **281**)	[81]
	Pogonopus speciosus (Jacq.) K. Schum.	1′,2′,3′,4′-tetradehydrotubulosine (**282**)	tubulosine (**283**), psychotrine (**284**)	**AC:** (283)	[82]
	Notopleura camponutans (Dwyer & M. V. Hayden) C. M. Taylor = *Notopleura camponutans* (Dwyer & M. V. Hayden) C. M. Taylor	1-hydroxybenzoisochromanquinone (**284**)	benz[g]isoquinoline-5,10-dione (**285**)	**TBS, KB:** (**284**, **285**) AP: *Pf* (**284**, **285**)	[83]
Selaginellaceae	*Selaginella willdenowii* (Desv. Ex Poir) Baker	2′′,3′′-dihydroisocryptomerin (**286**)	4′,7′′-di-*O*-methylamentoflavone (**287**), isocryptomerin (**288**), bilobetin (**289**), 7′′-*O*-methylrobustaflavone (**290**), amentoflavone (**291**), robustaflavone (**292**)	**AC:** BC1, U373 (**287**, **288**, **290**), HT-1080, Lu1, Col2, KB, LNCaP, ZR-75-1 (**288**, **290**), KB-V+ (**287**, **288**), KB-V- (**288**)	[84]
Simaroubaceae	*Simarouba amara* Aubl.		ailanthinone (**293**), 2-acetylglaucarubinone (**294**), holacanthone (**295**), glaucarubinone (**296**)	**AP:** *Pf*, *Pb* (**295**)	[85]
Solanaceae	*Witheringia solanace* L'Her.		physalins B (**297**), F (**298**), and D (**299**),	NF-*κ*B: (**297**, **298**)	[86]

DPPH: radical-scavenging activity of 1,1-diphenyl-2-picrylhydrazine; ALP: antioxidant activity in alkaline phosphatase test; HIV-1 RT: human immunodeficiency virus reverse transcriptase assay; HIV-P: cellular protection against HIV infection; AE: antiestrogenic activity; AB: antibacterial activity; AC: anticancer; AI: anti-inflammatory; AH: antihypertensive; IS: immunosuppressive; AF: antifungal activity; AP: antiplasmodial; AT: antitrypanosomal; L: leishmanicidal; LC: larvicidal; MC: molluscicidal; TBS: toxic to brine shrimp; BI-AT1: binding inhibition on angiotensin II AT_1 receptor; BI-ETA: binding inhibition on endothelin ET_A receptor; *Bs: Bacillus subtilis; Ms: Mycobacterium smegmatis; Hp: Helicobacter pylori; Sa: Staphylococcus aureus; Ec: Escherichia coli; Kp: Klebsiella pneumonia; Ms: Mycobacterium smegmatis; Pa: Pseudomonas aeruginosa; Ca: Candida albicans; Ef: Epidermophyton floccosum; Sc: Saccharomyces cerevisiae; Af: Aspergillus fumigatus; Tm: Trichophyton mentagrophytes; Mg: Microsporum gypseum; Sg: Salmonella gallinarum; Cc: Cladosporium cucumerinum; Pf: Plasmodium falciparum; Pb: Plasmodium berghei; Tc: Trypanosoma cruzi; Lm: Leishmania mexicana; Lp: Leishmania panamensis; Aa: Aedes aegypti; Bg: Biomphalaria glabrata;* MCF-7: breast human cancer; H-460: lung human cancer; SF-268: CNS human cancer; KB: oral epidermoid carcinoma; BC1: breast cancer; HT-1080: fibrosarcoma; Lu1: lung cancer; Col2: colon cancer; KB-V+: drug-resistant KB in presence of vinblastin; KB-V-: drug resistant KB in absence of vinblastin; LNCaP: hormone-dependent prostate cancer; ZR-75-1: hormone dependent breast cancer; U373: glioblastoma; NF-*κ*B: NF-*κ*B inhibition; IC: inhibition of complement

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Conflict of Interest

The authors have no conflict of interest to report.

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