

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

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Key words

- bioassays
- Panamanian plants
- ethnomedicine
- novel compounds

Abstract

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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

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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 km² 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, immunosuppressive, 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

received March 25, 2011

revised May 5, 2011

accepted May 10, 2011

Bibliography

DOI <http://dx.doi.org/10.1055/s-0030-1271187>
Published online June 14, 2011
Planta Med 2011; 77: 1189–1202 © Georg Thieme Verlag KG Stuttgart · New York · ISSN 0032-0943

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* Invited review – *Planta Medica* special supplement; editor, Prof. Dr. H. Kolodziej.

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 intel-

lectual 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 AT₁, and neuropeptide Y Y₁ 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 | <i>Aphelandra hartwegiana</i> Nees | Constipation (F; I; K), antiemetic (WP; D; NB) |
| | <i>Aphelandra aurantiaca</i> (Scheidw.) | Before childbirth (WP; I; NB) |
| | <i>Aphelandra sinclairiana</i> Nees | Antiemetic in pregnancy (St; D; NB) |
| | <i>Aphelandra tonduzii</i> Leonard. | Fever, skin rash, mumps, erysipelas (WP; D; NB) |
| | <i>Blechum costaricense</i> Oerst. | Vertigo (L; D; TB) |
| | <i>Blechum panamense</i> Lindau | Vertigo (St, L; D; TB) |
| | <i>Blechum pyramidatum</i> (Lam.) Urb. | Antiemetic (WP; D; NB), amebiasis (L; D; TB) |
| | <i>Justicia</i> sp. | Internal fever (WP; I; K) |
| | <i>Justicia ephemera</i> Leonard | Convulsions (WP; ID; K) |
| | <i>Justicia oerstedii</i> Leonard. | Diarrhea (St, R; D; TB) |
| | <i>Justicia pectoralis</i> Jacq. | Pain, hepatic disorders (St; I; NB) |
| | <i>Sanchezia pennellii</i> Leonard | “Enlargement of the mind” (F; I; K) |
| | <i>Odontonema tubiforme</i> (Bertol.) Kuntze | Anti-inflammatory (L; D; NB), induce child birth (St, L; D; TB) |
| | <i>Ruellia biolleyi</i> Lindau. | Dizziness, edema, fever (St; D; NB), appetite stimulant (St, L; D; TB) |
| | <i>Ruellia cf. metallica</i> Leonard | Body ache, fever (St; D; TB) |
| | <i>Ruellia praeclara</i> Standl. | Edema (St; D; NB) |
| Amaranthaceae | <i>Amaranthus</i> sp. | Antiemetic, hematuria (L, F; I; K) |
| | <i>Pleuropetalum sprucei</i> (Hook. f.) Standl. | Nose bleeding, post-measles weakness (St; D; TB) |
| Amaryllidaceae | <i>Crinum darienensis</i> Woodson | Fever (WP; I; K) |
| Annonaceae | <i>Annona reticulata</i> L. | Inflammation, fractures (L; C; TB) |
| | <i>Cymbopetalum costaricense</i> (J. D. Sm.) R. E. Fries. | Snakebite (B; I; NB) |
| | <i>Xylopia frutescens</i> Aubl. | Anthelmintic, antipyretic (L; NS; NB) |
| Apocynaceae | <i>Odontadenia puncticulosa</i> (L. Rich.) Pulle. | Rubella (WP; I; NB) |
| | <i>Peltastes colombianus</i> Woods. | Diarrhea (St; I; NB) |
| | <i>Rhabdadenia biflora</i> (Jacq.) Muell.-Arg. | Eye infections (F; I; K) |
| | <i>Stemmadenia grandiflora</i> (Jacq.) Miers | Renal disorders (St; I; NB) |
| Araceae | <i>Anthurium</i> sp. | To reduce size of the uterus during pregnancy (F; I; K), antiarrhoeic (R; D; NB) |
| | <i>Anthurium pentaphyllum</i> (Aubl.) G. Don. | Skin infections, pain reliever, inflammation of muscles and joints (WP; D; K) |
| | <i>Dieffenbachia aurantiaca</i> Engl. | Pain reliever, skin infections (WP; D; K) |
| | <i>Dracontium costaricense</i> Engler. | Snakebite (L; D; NB) |
| | <i>Dracontium dressleri</i> Croat. | To facilitate childbirth (F; IK; K), muscle aches, snakebite (L, R; NS; K) |
| | <i>Dracontium spruceanum</i> (Schott) G. H. Zhu | Snakebite (Rz, St, T; D; TB), skin ulcers (T; D; TB) |
| | <i>Homalomena wendlandii</i> Schott | Snakebite (St; D; TB) |
| | <i>Montrichardia arborescens</i> (L.) Schott. | Skin infections (L; D; K) |
| | <i>Philodendron</i> sp. | To increase vitality in children (WP; I; K), wound healing (S; DA; K), skin rash, fever (WP; D; NB) |
| | <i>Philodendron radiatum</i> Schott | Pain, snakebite (R; C; TB) |
| | <i>Spathiphyllum friedrichsthali</i> Schott. | To avoid enlargement of the uterus during pregnancy, to facilitate childbirth (F; I; K) |
| | <i>Spathiphyllum quindiuense</i> Engl. | To bathe sick children (WP; I; K) |
| | <i>Xanthosoma</i> sp. | Strong muscular and bone aches, inflammation (In; D; K) |
| | <i>Xanthosoma helleborifolium</i> (Jacq.) Shott. | To facilitate childbirth (T; IK; K) |
| | <i>Xanthosoma mexicanum</i> Liebm. | To facilitate childbirth, snakebite (F; I; K) |
| | Aristolochiaceae | <i>Aristolochia aff. grandiflora</i> Sw. |
| <i>Aristolochia chapmaniana</i> Stand. | | Snakebite, shortness of breath (WP; I; NB) |
| <i>Aristolochia constricta</i> Griseb. | | Snakebite (WP; I; NB), (St; D; TB); leishmaniasis (L; C; TB) |
| <i>Aristolochia pilosa</i> H. B. K. | | Snakebite (WP; I; NB) |
| <i>Aristolochia sylvicola</i> Stand. | | Snakebite (St; D; NB) |
| <i>Aristolochia tonduzii</i> O. C. Schmidt | | Pain, inflammation (St; D; TB) |
| Asclepiadaceae | <i>Sarcostemma clausum</i> (Jacq.) Roem. et Schult. | Shortness of breath (St; I; NB) |
| Aspleniaceae | <i>Asplenium serratum</i> L. | Burns (Sc; C; TB) |
| Asteraceae | <i>Bidens reptans</i> (L.) G. Don. | Sore eyes (St; D; NB) |
| | <i>Hebeclinium macrophyllum</i> (L.) DC. | Insect bites (L; D; TB) |
| | <i>Neurolaena lobata</i> (L.) R. Br. | Skin infections (WP; D; K), (L; D; TB); fever (St; I; NB) |
| | <i>Sinclairia polyantha</i> (Klatt) Rydb. | Cough (St; D; TB) |
| | <i>Sphagneticola trilobata</i> (L.) Pruski | Cough, flu (L; D; TB) |
| | <i>Rolandra fruticosa</i> (L.) Kuntze | Muscle aches (WP; D; K) |
| | <i>Vernonia</i> sp | To facilitate expulsion of the placenta (In; I; K) |
| | <i>Wedelia trilobata</i> (L.) Hitchc. | Skin diseases (WP; D; K) |
| Begoniaceae | <i>Begonia glabra</i> Aubl. | Furuncles (WP; fresh; NB) |
| | <i>Begonia hirsuta</i> Aubl. | Renal disorders (WP; D; NB) |
| | <i>Begonia multinervia</i> Liebm. | Fever (Pt; J; TB) |
| | <i>Begonia semiovata</i> Liebm. | Women's ailments (WP; D; NB), chicken pox (St; D; TB) |
| Bignoniaceae | <i>Arrabidaea verrucosa</i> (Standl.) A. Gentry | Fever, weakness, muscle aches (WP; I; K) |
| | <i>Callichlamys latifolia</i> (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) |
|------------------|--|--|
| | <i>Crescentia cujete</i> L. | Purgative (F; D; TB) |
| | <i>Mansoa standleyi</i> (SteYerm.) A. H. Gentry | Aggressive dementia (VI; D; TB) |
| | <i>Stizophyllum riparium</i> (HBK.) Sandw. | Anuria (WP; D; K), urinary infections (St; D; TB) |
| Blechnaceae | <i>Salpichlaena volubilis</i> (Kaulf.) J. Sm. | Toothache (VI; D; TB) |
| Boraginaceae | <i>Cordia alliodora</i> (Ruiz & Pav.) Oken | Fever (L; D; TB) |
| | <i>Cordia spinescens</i> L. | Wound healing (St; DA; NB) |
| | <i>Tournefortia bicolor</i> Sw. | Fever (St, L; D; TB) |
| | <i>Tournefortia cuspidata</i> Kunth | Fever (St; D; TB) |
| Burseraceae | <i>Bursera simaruba</i> (L.) Sarg. | Urinary infections, bruises, contraconceptive (St; D; TB) |
| | <i>Trattinnickia aspera</i> (Standley) Swart | Depurative hypertension (St; D; TB), leishmaniasis (Rs; DA; TB) |
| Cactaceae | <i>Epiphyllum phyllanthus</i> (L.) Haw. | Body aches (R; I; NB) |
| | <i>Pereskia bleo</i> (HBK.) DC | Muscle aches (L; D; K) |
| | <i>Pereskia bleo</i> (HBK.) DC | Stomachache (In; IK; K) |
| Campanulaceae | <i>Centropogon coccineus</i> (Hook.) Regel ex B. D. Jacks. | Arthritis (St; D; TB) |
| Capparaceae | <i>Cleome serrata</i> Jacq. | Topical warm bath (WP; D; K) |
| | <i>Cleome serrata</i> Jacq. | Snakebite (L; IK; K) |
| Caricaceae | <i>Carica papaya</i> L. | To improve blood circulation, to induce diuresis, to treat furuncles (F, L; IK; K) |
| Caryophyllaceae | <i>Drymaria cordata</i> (L.) Willd. ex Schult. | Headache, stomachache (St, L; D; TB), fever (WP; D; TB) |
| | <i>Stellaria ovata</i> Willd. ex Schltldl. | Worms (WP; D; TB) |
| Chenopodiaceae | <i>Chenopodium ambrosioides</i> L. | Stomachache (L; D; TB), to expel worms (L; Jc; TB) |
| Clusiaceae | <i>Symphonia globulifera</i> L. f. | Bloody vomiting (St; I; NB), body pain (L; C; TB) |
| Cochlospermaceae | <i>Cochlospermum vitifolium</i> (Willd.) Spr. | To improve blood circulation (Sd; I; K) |
| Commelinaceae | <i>Cochliostema odoratissimum</i> Lem. | To regulate menstruation (L; D; NB) |
| | <i>Commelina diffusa</i> Burm. f. | Common cold (WP; I; K) |
| | <i>Dichorisandra hexandra</i> (Aubl.) Standl. | Snakebite (T; D; NB), internal and body pain (T; D; TB) |
| | <i>Tradescantia zanoniana</i> (L.) Sw. | Hemorrhage (S; DA; TB) |
| | <i>Tripogandra serrulata</i> (Vahl) Handlos | Inflammation, fractures (WP; D; TB) |
| Convolvulaceae | <i>Ipomoea alba</i> L. | Snakebite (L; C; TB), inflammation in snakebite (WP; D; TB) |
| | <i>Ipomoea indica</i> (Burm. f.) Merr. | Laxative (L; D; NB) |
| Cucurbitaceae | <i>Cucurbita pepo</i> L. | As bath, to accelerate children's growth (WP; I; K) |
| | <i>Gurania makoyana</i> (Lem.) Cogn. | Leishmaniasis (St, L; D; TB), inflammation, liquid retention (L; D; TB) |
| | <i>Momordica charantia</i> L. | Bile, to facilitate child birth, fever, hypertension (WP; D; TB) |
| | <i>Psiguria warscewiczii</i> (Hook. f.) Wunderlin. | Shortness of breath (St; D; NB) |
| Cyatheaceae | <i>Cyathea petiolata</i> (Hook.) Tryon | Ceremony to bathe sick children (WP; I; K) |
| Cycadaceae | <i>Zamia pseudoparasitica</i> Yates | Emetic (T; D; K), muscle aches (St; DA; K) |
| | <i>Zamia sp.</i> | Colic, constipation (St; D; NB) |
| Cyclanthaceae | <i>Carludovica palmata</i> R. et P. | To prevent complications during childbirth (In; I; K) |
| | <i>Cyclanthus bipartitus</i> Poit. | To avoid enlargement of uterus (F; IK; K) |
| | <i>Dicranopygium crinitum</i> Harl. | To bathe sick children (WP; I; K) |
| Cyperaceae | <i>Cyperus luzulae</i> (L.) Retz. | Eye infections, to avoid complications during childbirth (WP; I; K) |
| Dilleniaceae | <i>Davill kunthii</i> St. Hil. | Colic in children (Br, F; I; K) |
| | <i>Tetracera volubilis</i> L. | Body aches (St, L; D; TB) |
| Euphorbiaceae | <i>Acalypha hispida</i> Burm. f. | To facilitate childbirth (F; IK; K) |
| | <i>Chamaesyce hirta</i> (L.) Millsp. | Acne (L; ID; K) |
| | <i>Croton fragans</i> HBK. | Common cold (L, F; ID; K) |
| | <i>Croton lobatus</i> L. | Skin diseases (WP; I; K) |
| | <i>Jatropha sp.</i> | Emetic (Sd; I; K) |
| | <i>Manhiot esculenta</i> Crantz. | Acne (L; ID; K) |
| | <i>Phyllanthus urinaria</i> L. | Diarrhea (St; D; TB) |
| Fabaceae | <i>Bauhinia guianensis</i> Aubl. | Diarrhea, bed wetting (St, L; D; TB) |
| | <i>Bauhinia reflexa</i> Schery | Headache (St, L; D; TB) |
| | <i>Calliandra stipulacea</i> Benth | Fever (WP; I; K) |
| | <i>Desmodium ascendens</i> (Sw.) DC. | Conjunctivitis (WP; C; TB) |
| | <i>Desmodium axillare</i> (Sw.) DC. | Postpartum aid to expel placenta (St; D; NB) |
| | <i>Machaerium sp.</i> | Antitussive (WP; D; NB), aphthous ulcers of the mouth (S; NS; NB) |
| | <i>Mimosa pudica</i> L. | Arthritis (St; I; NB) |
| | <i>Prioria copaifera</i> Griseb. | Tonic, energizer (F; I; K) |
| | <i>Senna fruticosa</i> (Mill.) H. S. Irwin & Barneby | Body aches (St, L; D; TB) |
| | <i>Senna reticulata</i> (Willd.) Irwin & Barneby. | Emetic (R; D; NB) |
| Flacourtiaceae | <i>Lindackeria laurina</i> C. Presl. | Pneumonia (St; D; NB) |
| | <i>Xylosma sp.</i> | Spider bites (St, R; I; NB) |
| Gentianaceae | <i>Schultesia lisianthoides</i> (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 | <i>Besleria laxiflora</i> Benth. | Fever (L; D; TB) |
| | <i>Besleria solanoides</i> Kunth | Fever (St; D; TB) |
| | <i>Chrysothemis friedrichsthaliana</i> (Hanst.) H. E. | Muscle aches, inflammation of the joints (WP; I; K) |
| | <i>Chrysothemis pulcella</i> (Donn ex Sims) Decne. | To facilitate childbirth (F; I; K) |
| | <i>Columnnea nicaraguensis</i> Oerst. | Chest pain (St; I; NB), fever, fatigue (St, L; D; TB) |
| | <i>Columnnea sanguinolenta</i> (Oerst.) Hanst. | Dysmenorrhea (St, L; D; TB) |
| | <i>Columnnea tulae</i> Urb. var. <i>tomentulosa</i> (C. V. Morton) B. D. Morley | Fever (St; D; TB), measles (St, L; D; TB), chicken pox (WP; Jc; TB) |
| | <i>Diastema scabrum</i> (Poepp.) Benth. ex. Walp. | Fever, measles (St; D; TB), vertigo (WP; D; TB) |
| | <i>Drymonia macrophylla</i> (Oerst.) H. E. Moore | Fever (St; D; TB) |
| | <i>Drymonia multiflora</i> (Oerst. ex Hanst.) Wiehler | Inflammation, breast pain, painful breathing (WP; D; TB) |
| | <i>Drymonia serrulata</i> (Jacq.) Mart. | Fever, headaches (St; D; NB), (St; Jc; TB) |
| | <i>Drymonia warscewicziana</i> Hanst. | Difficulty in breathing (St; D; TB) |
| | <i>Gasteranthus acropodus</i> (Donn. Sm.) Wiehler | Fever (WP; D; TB) |
| | <i>Gasteranthus imbricans</i> (Donn. Sm.) Wiehler | Fever (St; D; TB) |
| | <i>Reldia veraguensis</i> Wiehl. | Antiemetic (St; I; NB) |
| Gramineae | <i>Coix lacryma-jobi</i> L. | Common cold (R, F; D; K) |
| | <i>Oplismenus burmanni</i> (Retz.) Beauv. | Shortness of breath (WP; I; NB) |
| Hamaedoraceae | <i>Xyphidium caeruleum</i> Aubl. | Antiemetic (St; I; NB), skin disorders (L; I; NB), to facilitate childbirth (St; I; TB) |
| Lamiaceae | <i>Hyptis</i> sp. | Excipient (WP; NS; K) |
| | <i>Hyptis capitata</i> Jacq. | Snakebite (L; IK; K) |
| | <i>Ocimum campechianum</i> Mill. | Excipient (WP; NS; K) |
| | <i>Ocimum canum</i> Sims. | Excipient, "enlargement of the mind" (L, F; I; K) |
| Lecythidaceae | <i>Gustavia superba</i> (HBK.) Berg. | Mental disorders (F; IK; K) |
| Loganiaceae | <i>Spigelia anhelmia</i> L. | Skin and eye infections (WP; D; K) |
| | <i>Spigelia humboldtiana</i> Cham & Schlecht. | Anthelmintic (WP; D; NB), pain and inflammation (St; D; TB), headache (WP; D; TB) |
| | <i>Strychnos</i> sp. | Bee bites (St; D; NB) |
| Lomariopsidaceae | <i>Elaphoglossum herminieri</i> (Bory ex F'ee) T. Moore | Burns (F; C; TB) |
| Lythraceae | <i>Cuphea epilobifolia</i> Koehne | Rheumatism (St, L; D; TB) |
| Malpighiaceae | <i>Banisteriopsis muricata</i> (Cav.) Cuatr. | Headache, fever (St; I; NB) |
| | <i>Heteropteris obovata</i> (Small) Cuatr. et Croat. | Fever, headaches and diarrhea (St; D; NB) |
| Malvaceae | <i>Hibiscus rosa-sinensis</i> L. | To control size of uterus, "mental saturation" (F; I; K) |
| | <i>Hibiscus schizopetalus</i> (Mast.) Hook. f. | To facilitate childbirth (F; I; K) |
| | <i>Malvaviscus arboreus</i> Cav. | Difficult childbirths (Br; D; NB) |
| | <i>Pavonia fruticosa</i> (Mill.) Fawc. et Rendl. | Fever, common cold (WP; D; K) |
| | <i>Sida acuta</i> Burm. f. var. <i>acuta</i> . | Tonic, antipyretic, alopecia in children (AP; D; K) |
| | <i>Sida rhombifolia</i> L. | Inflammation, fractures (WP; D; TB), difficult birth (L; D; TB), to facilitate childbirth (St; D; TB) |
| Marantaceae | <i>Calathea lutea</i> (Aubl.) G. Meyer | To increase learning capacity in children (F; I; K) |
| | <i>Calathea warscewiczii</i> (Mathieu) Koernicke. | Rubella (St; I; NB), snakebite (Rz, L; C; TB), painful wounds, inflammation (L; C; TB) |
| Marcgraviaceae | <i>Marcgravia nepenthoides</i> Seemann. | Tiredness (Br; I; NB) |
| | <i>Souroubea</i> sp. | Antidiarrhoeic (St; I; NB) |
| Melastomataceae | <i>Arthrostemma ciliatum</i> Ruiz & Pav. | Urinary infections (St, L; D; TB) |
| | <i>Bellucia pentamera</i> Naudin | Chicken pox, measles (St; D; TB) |
| | <i>Blakea foliacea</i> Gleason. | Diarrhea (St; D; NB) |
| | <i>Ossaea quinquenervia</i> (Mill.) Cogn. | Fever (St; D; TB) |
| | <i>Triolena hirsuta</i> (Benth.) Triana | Nose bleeding (St; D; TB) |
| Meliaceae | <i>Carapa guianensis</i> Aubl. | Furuncles, skin infections (S; C; TB) |
| | <i>Cedrela odorata</i> L. | Leishmaniasis (St; D; TB) |
| | <i>Guarea multiflora</i> A. Juss. | Hepatic disorders, emetic (St; I; NB) |
| Menispermaceae | <i>Cissampelos pareira</i> L. | As a drink when feeling sick on waking up (St; D; NB) |
| | <i>Cissampelos tropaeofolia</i> DC. | Snakebite (St; D; NB), diarrhea (St; D; TB) |
| Monimiaceae | <i>Siparuna</i> sp. | Fever (L; I; K) |
| Moraceae | <i>Cecropia peltata</i> L. | Headache, "mental saturation" (In; D; K) |
| | <i>Dorstenia contrajerva</i> L. | Snakebite, muscle aches (WP; D; K) |
| | <i>Ficus insipida</i> Willd. | Skin diseases (St; I; K) |
| Musaceae | <i>Heliconia hirsuta</i> L. F. | Antidiarrhoeic (R; I; NB) |
| | <i>Heliconia mariae</i> Hook. f. | To improve blood circulation (F; D; K) |
| | <i>Heliconia platystachys</i> Baker | To facilitate childbirth (F; I; K) |
| | <i>Heliconia vaginalis</i> Benth. | Drunk when fetus is found to be incorrectly positioned (WP; D; K) |
| | <i>Musa sapientum</i> L. | Urinary infection (Ht; D; TB) |
| Myrtaceae | <i>Psidium guajava</i> L. | Diarrhea (Br; D; TB) |
| Olaceae | <i>Heisteria macrophylla</i> Oerst. | Abdominal cramps (St; I; NB) |
| Orchidaceae | <i>Dichaea muricata</i> (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) |
|------------------|--|--|
| | <i>Epidendrum difforme</i> Jacq. | Rubella (L; I; NB) |
| | <i>Maxillaria</i> sp. | Fatigue, exhaustion (L; I; NB) |
| | <i>Octomeria</i> sp. | Antiemetic (NS; I; NB) |
| Palmae | <i>Bactris</i> sp. | Difficulties in breathing (St; D; NB) |
| | <i>Cocos nucifera</i> L. | Intense back pain (R; D; TB) |
| Passifloraceae | <i>Passiflora costaricensis</i> Killip | Chest pain (L; D; TB), body aches (St; D; TB); pain, snakebite (St, L; D; TB) |
| | <i>Passiflora pediculata</i> Mast. | Snakebite (St; D; NB) |
| | <i>Passiflora quadrangularis</i> L. | Anti-inflammatory (St; D; NB) |
| | <i>Passiflora sexflora</i> Juss. | Snakebite (WP; D; NB) |
| | <i>Passiflora vitifolia</i> HBK. | "Mental saturation" (F; I; K), snakebite (St; I; NB) |
| Phytolaccaceae | <i>Rivina humilis</i> L. | Cold (St, L; D; TB) |
| | <i>Petiveria alliacea</i> L. | Ritual ceremonies (St, L; D; NB) |
| Piperaceae | <i>Peperomia</i> aff. <i>ebingeri</i> Yunck. | Measles (WP; I; TB) |
| | <i>Peperomia pellucida</i> (L.) Kunth | Foot inflammation (WP; D; TB) |
| | <i>Peperomia rotundifolia</i> (L.) H. B. K. | Rash (L; D; NB) |
| | <i>Piper auritum</i> HBK. | Common cold (In; I; K) |
| | <i>Piper erubescens</i> Trel. | Headache (L; D; TB) |
| | <i>Piper hispidum</i> Sw. | Eyes infection, muscle aches (L; D; K), fever (St; D; TB), to expel worms (St; C; TB) |
| | <i>Piper multiplinervium</i> C. DC. | Body- and stomachaches (L; I; K) |
| | <i>Piper peltatum</i> L. | Infected wound (L; D; TB) |
| | <i>Piper tuberculatum</i> Jacq. | Liver pains (In, L; IK, D; K) |
| Polygalaceae | <i>Polygala panamensis</i> Chodat. | Sore eyes (WP; D; NB) |
| | <i>Polygala paniculata</i> L. | Fever (WP; D; TB) |
| | <i>Securidaca diversifolia</i> (L.) S. F. Blake | Toothache (L; D; TB) |
| Polypodiaceae | <i>Niphidium crassifolium</i> (L.) Lellinger | Fever (L; D; NB) |
| | <i>Polypodium</i> sp. | Difficulties in breathing (T; NS; NB) |
| Rhizophoraceae | <i>Rhizophora mangle</i> L. | Healing of bone fracture (R; I; K) |
| Rubiaceae | <i>Borreria laevis</i> (Lam.) Griseb. | Muscle and bone aches, inflammation, skin diseases, acne (WP; D; K) |
| | <i>Cephaelis elata</i> Sw. | Dizziness, hallucination, dementia (St; D; NB) |
| | <i>Cephaelis tomentosa</i> (Aubl.) Vahl. | Dizziness, hallucination, rubella (St, R; D; NB) |
| | <i>Chione panamensis</i> Steyermark. | Ritual ceremonies (R; I; NB) |
| | <i>Coffea arabica</i> L. | Fever (L; I; K) |
| | <i>Faramea eurycarpa</i> Don. Sm. | Pruritic (St; D; NB) |
| | <i>Genipa americana</i> L. | Drunk by mother to regulate growth of fetus (L; I; K), to treat weakness in girls (F; NS; K) |
| | <i>Hamelia patens</i> var. <i>glabra</i> Oerst. | Snakebite, postpartum aid to relieve pain (St; I; NB) |
| | <i>Hoffmannia vesiculifera</i> Standl. | Headache, body aches (St, R; D; NB), to induce and facilitate childbirth (St; D; TB) |
| | <i>Manettia reclinata</i> L. Mant. | Renal analgesic (St; D; NB), fever (St; D; TB) |
| | <i>Notopleura anomothyrsa</i> (K. Schum. & Donn. Sm.) C. M. Taylor | Fever (St; D; TB), stomachache (St, L; D; TB) |
| | <i>Palicourea guianensis</i> Aubl. | Mental disorders (F; I; K) |
| | <i>Pentagonia pinnatifida</i> Seem. | Fever (R; I; K), to facilitate childbirth and menstruation (F; IK; K) |
| | <i>Psychotria emetica</i> L. f. | Chicken pox, fever (R; D; TB) |
| | <i>Psychotria psychotriifolia</i> (Seem.) Standl. | Fever (St; D; TB) |
| | <i>Psychotria uliginosa</i> Sw. | Stomachache, fever (L; I; NB) |
| | <i>Sabicea villosa</i> R. et S. | Rheumatism (St; I; NB) |
| Rutaceae | <i>Citrus limon</i> (L.) Burm. f. | Common cold, cough, breathing difficulties (P; NS; K) |
| Sapindaceae | <i>Sapindus saponaria</i> L. | Skin diseases, colds (F; I; K) |
| | <i>Serjania rhombea</i> Radlk. | Dizziness (St; I; NB) |
| Scrophulariaceae | <i>Alectra aspera</i> (Cham. et Schlecht.) L. O. Williams. | Difficulties in breathing (St; I; NB) |
| | <i>Scoparia dulcis</i> L. | Fever (St; D; TB), chicken pox (L; D; TB) |
| | <i>Russelia sarmentosa</i> Jacq. | Snakebite (WP; D; NB) |
| Selaginellaceae | <i>Selaginella</i> sp. | Fever, weakness, muscle aches and eye infection (L; IK; K) |
| Simaroubaceae | <i>Picramnia allenii</i> D. M. Porter. | Shortness of breath (St; D; NB) |
| | <i>Simaba cedron</i> Planch. | Fever, malaria, snakebites (F; I; NB) |
| Smilacaceae | <i>Smilax chiriquensis</i> C. V. Morton | Weakness, malnutrition (Rz; D; TB) |
| Solanaceae | <i>Capsicum annuum</i> L. var. <i>aviculare</i> (Dierb.) D'Arcy et Eshb. | Serious ailments (F, L; IK, ID; K) |
| | <i>Cestrum nocturnum</i> L. | Fever (L; D; TB) |
| | <i>Cuatresia exiguiflora</i> (D'Arcy) Hunz. | Postpartum birth (St; D; TB) |
| | <i>Cyphomandra hartwegii</i> (Miers) Dun. | Snakebite (St; I; NB) |
| | <i>Lycianthes amatitlanensis</i> (J. M. Coult. & Donn. Sm.) Bitter | Headache (St, L; NS; TB) |

continued next page

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

| Family | Specie | Application (plant part; preparation; Amerindian group) |
|-----------------|---|--|
| | <i>Solanum lancaefolium</i> Jacq. | Muscle and stomachaches (WP; D; K); shortness of breath (R; D; NB) |
| | <i>Witheringia correana</i> D'Arcy | Fever (St; D; TB) |
| | <i>Witheringia solanacea</i> L'Her. | Anthelmintic (WP; I; NB) |
| Sterculiaceae | <i>Theobroma cacao</i> L. | To facilitate childbirth (St; IK; K), bleeding (F; C; TB) |
| | <i>Herrania purpurea</i> (Pittier) R. E. Schultes | To facilitate childbirth (AP; IK; K) |
| Tectariaceae | <i>Cyclopetis semicordata</i> (Sw.) J. Sm. | Burns (Sc; DA; TB) |
| Theophrastaceae | <i>Clavija costaricana</i> Pittier | To expel worms (St; D; TB) |
| | <i>Clavija</i> sp. | Women's ailment (L; I; NB) |
| Tiliaceae | <i>Heliocarpus americanus</i> L. | To facilitate child birth (St; I; TB) |
| Urticaceae | <i>Pilea imparifolia</i> Wedd. | Diarrhea (St; D; NB) |
| | <i>Pilea microphylla</i> (L.) Liebm. | Chicken pox (St, L; D; TB), warts (WP; C; TB), measles (WP; D; TB) |
| | <i>Urera caracasana</i> (Jacq.) Griseb | Foot pain (L; DA; TB) |
| | <i>Urera laciniata</i> (Goud.) Wedd. | Body aches (L; NS; K) |
| Verbenaceae | <i>Lantana hispida</i> Kunth | Placenta retention (Fl; I; K) |
| | <i>Lantana trifolia</i> L. | Fever (St, L; D; TB) |
| | <i>Stachytarpheta jamaicensis</i> (L.) Vahl | Neck pain, muscle pain (L; D; TB) |
| Vittariaceae | <i>Vittaria lineate</i> (L.) Sw. | Headaches (L; D; NB) |
| Zamiaceae | <i>Zamia skinneri</i> Warsz. ex A. Dietr. | Wound healing (Rz; D; TB) |
| Zingiberaceae | <i>Costus ruber</i> Griseb | To calm pain after childbirth (St; I; NB) |
| | <i>Costus villosissimus</i> Jacq. | To calm pain after childbirth (St; I; NB) |
| | <i>Dimerocostus strobilaceus</i> Kuntze | To improve blood circulation (Fl, L; I; K) |
| | <i>Zingiber officinale</i> 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; VI: vines; Ht: heart; I: infusion; D: decoction; C: cataplasm; IK: *Ina kuamakalet*; ID: *Ina dibalet*; Jc: juice; Rs: resin; DA: direct application; NS: not specified; K: Kuna Indians; NB: Ngöbe-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* Schltld. & Cham, *Piper dilatatum* Rich., *Lonchocarpus chiricanus* Pittier, *Erythrina berteroa* 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*, *Arabidaea patellifera* (Schltld.) 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 lisanthioside from *Lisianthus jefensis* with antimicrobial activity, larvicidal purpureacin from *Annona purpurea* against *Aedes aegypti*, antifungal xanthenes from *Marila laxiflora*, antifungal and larvicidal naphthoquinones and naphthoxirene from *Cordia linnaei*, and antifungal benzoic acid derivatives from *Piper dilatatum* 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, xanthenes, 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 | <i>Hymenocallis littoralis</i> (Jacq.) Salisb. = <i>Pancratium littorale</i> Jacq. | | 7,4'-dihydroxy-8-methylflavan (1) | DPPH: (1) | [32] |
| Anacardiaceae | <i>Mosquitoxylon jamaicense</i> Krug & Urb. | | phloridzin (2), 4-hydroxy benzene-propanal (3), trilobatin (4), quercetin-3-O-β-D-galactoside (5) | AP: Pf (2) | [33] |
| Annonaceae | <i>Annona purpurea</i> 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] |
| | <i>Duguetia panamensis</i> Standl. | | 2,4,5-trimethoxystyrene (12) | TBS: (12) | [35] |
| | <i>Guatteria amplifolia</i> Triana and Planch | | xylopine (13), nornuciferine (14), lysicamine (15), laudanosine (16) | L: Lm, Lp (13, 14) | [36] |
| | <i>Guatteria dumentorum</i> R. E. Fr. | (+)-isodomesticine (17), (+)-norisodomesticine (18), (+)-nantenine (19), (+)-neolitsine (20), (+)-lirioferine (21), (+)-N-methyl-laurotetanine (22), (+)-norlirioferine (23), (+)-isoboldine (24), (+)-reticuline (25) | cryptodorine (26), nornantenine (27) | L: Lm, Lp (26, 27); Lm (17–20) | [36, 37] |
| Apocynaceae | <i>Stemmadenia robinsonii</i> 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), hydroxyindoleninecoronaridine (39), hydroxyindoleninevoacangine (40), heyneanine (41), voacristine (42), 19-oxo-coronaridine (43), 13-hydroxycoronaridine (44) | AB: Bs (42, 44) TBS: (36) | [38, 39] |
| Asteraceae | <i>Baccharis pedunculata</i> (Mill.) Cabrera | | lachnophyllum lactone (45), uloptero 3-methylether flavones (46), uloptero (47) | AF: Cc (46, 47), Ca (45, 46), Ef (45, 47), Mg (45) Toxic to human keratinocytes: (45) | [40] |
| Bignoniaceae | <i>Arrabidaea patellifera</i> (Schltdl.) Sandwith | (3'-O-p-hydroxybenzoyl-mangiferin (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] |
| | <i>Jacaranda caucana</i> Pittier | 6'-O-(cis-1,4-dihydroxycyclohexanacetyl) acteoside (56), 6'-O-(1-hydroxy-4-oxo-cyclohexanacetyl) acteoside (57), 4-O-rhamnosyl-7S, 8R-7,8'-erythro-sisymbriofolin (58) | protocatechuic acid (59), acteoside (60), jionoside D (61), isoacteoside (62), martynoside (63) | DPPH, ALP: (56–63) | [42] |
| Boraginaceae | <i>Cordia alliodora</i> Ruiz & Pavon | 1-(3'-methoxypropanoyl)-2,4,5-trimethoxybenzene (64), 2-(2Z)-(3-hydroxy-3,7-dimethylocta-2, 6-dienyl)-1,4-benzenediol (65) | | AF: Cc (64, 65) LC: Aa (64) | [43] |
| | <i>Cordia linnaei</i> Stearn | cordiaquinona E (66), cordiaquinona F (67), cordiaquinona G (68), cordiaquinona H (69) | cordiaquinona B (70), naftoxireno (71) | AF: Cc, Ca (66–70) | [44] |
| | <i>Cordia spinescens</i> 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 | <i>Marila laxiflora</i> 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] |
| | <i>Marila pluricostata</i> Standl. & L. O. Williams | 5-hydroxy-8,8-dimethyl-4-phenyl-9,10-dihydro-8 <i>H</i> -pyrano-[2,3- <i>f</i>]chromen-2-one (82), 5-hydroxy-8,8-dimethyl-4-phenyl-6-propionyl-9,10-dihydro-8 <i>H</i> -pyrano-[2,3- <i>f</i>]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), cyclo-mammeisin (96), disparinol A (97), MAB 3 (98), and mesuol cyclo F (99), squalene (100), friedelin (101), 4- <i>epi</i> -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), <i>epi</i> -betulinic acid (108), betulinic acid (109), β -sistosterol (110), stigmasterol (111), 3- <i>O</i> - β -glucopyranosyl-sistosterol (112) | AC: MCF-7, H-460, SF-268 (82–87, 91–112) | [48, 49] |
| Clusiaceae | <i>Tovomita longifolia</i> (Rich.) Hochr. | (<i>E</i>)-3-(2-hydroxy-7-methyl-3-methyleneoct-6-enyl)-2,4,6-trihydroxybenzophenone (113), (<i>E</i>)-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 <i>H</i> -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] |
| | <i>Vismia macrophylla</i> Kunth | ferruginin C (119) | ferruginins A (120) and B (121), vismin (122), harunganin (123) | AC: MCF-7, H-460, SF-268 (119–123) | [51] |
| | <i>Vismia baccifera</i> (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 | <i>Bonamia trichantha</i> Hallier f. | trichanthins A (129), B (130), C (131), and D (132) | | AC: MCF-7, H-460, SF-268 (129, 130, 132) | [52] |
| Elaeocarpaceae | <i>Sloanea zuliaensis</i> Pittier | 2-deoxycucurbitacin-D (133) | cucurbitacin D (134), 25-acetylcucurbitacin F (135) | AC: MCF-7, H-460, SF-268 (133–135) | [53] |
| Euphorbiaceae | <i>Chamaesyce hyssopifolia</i> (L.) Small | | quercetin (136), quercetin 3- <i>O</i> - α -L-arabinopyranoside (137), quercetin 3- <i>O</i> - β -D-xylopyranoside (138), quercetin 3- <i>O</i> - β -D-glucopyranoside (139), quercetin 3- <i>O</i> - β -D-galactopyranoside (140), apigenin 7- <i>O</i> - β -D-glucopyranoside (141), kaempferol 3- <i>O</i> - β -D-glucopyranoside (142), gallic acid (143), gallic acid methyl ester (144), corilagin (145), 1,3,4,6-tetra- <i>O</i> -galloyl- β -D-glucopyranose (146) | HIV-1 RT: (136–138) | [45, 46] |
| Fabaceae | <i>Andira inermis</i> (W. Wright) Kunth. ex DC. | | formononetin (147), calicosin (148), prunetin (149), biocanin (150), genistein (151), pratensein (152) | AP: Pf (148, 151) | [54] |

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

| Family | Species | New compounds | Known compounds | Biological activity | Ref.] |
|-----------------|--|---|--|--|----------|
| | <i>Erythrina berteroa</i> Urb. | 5,7-dihydroxy-3-[5-hydroxy-4-methoxy-3-(3-methyl-2-butenyl)phenyl]-2,3-dihydro-4 <i>H</i> -1-benzopyran-4-one (153), sigmoidin B (154) | | AF: Cc (153, 154) | [55, 56] |
| | <i>Lonchocarpus chiricanus</i> Pittier | chiricanines A–E (155–159) | longistylin C (160) and D (161), 3,5-dimethoxystilbene (162) | AF: Cc (155), LC: Aa (162) | [57] |
| | <i>Myrospermum frutescens</i> 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] |
| | <i>Swartzia simplex</i> (Sw.) Spreng. | β -D-glucopyranosyl[β -D-glucuronopyranosyl (1 \rightarrow 3)]-3 β -hydroxyolean-12-en-23-al-28-oate (169), β -D-glucopyranosyl[β -D-xylopyranosyl-(1 \rightarrow 2) (α -L-rhamnopyranosyl (1 \rightarrow 3)- β -D-glucopyranosyl (1 \rightarrow 3)]-3 β -hydroxyolean-12-en-28-oate (170), β -D-glucopyranosyl[β -D-glucuronopyranosyl (1 \rightarrow 4)]-[β -D-glucopyranosyl-(1 \rightarrow 3)]-3 β -hydroxyolean-12-en-28-oate (171) | [α -L-rhamnopyranosyl-(1 \rightarrow 3)- β -D-glucopyranosyl-(1 \rightarrow 3)]-3 β -hydroxyolean-12-en-28-oic acid (172); β -D-glucopyranosyl[β -D-glucuronopyranosyl (1 \rightarrow 3)]-3 β -hydroxyolean-12-en-28-oate (173), β -D-glucopyranosyl [α -L-rhamnopyranosyl (1 \rightarrow 3)- β -D-glucopyranosyl (1 \rightarrow 3)]-3 β -hydroxyolean-12-en-28-oate (174), β -D-glucopyranosyl [β -D-glucopyranosyl (1 \rightarrow 3)]-3 β -hydroxyolean-12-en-23-oic-28-oate (175) | MC: Bg (171, 172) | [59] |
| Gentianaceae | <i>Lisianthus seemanii</i> (Griseb) O. Kuntze | seemannoside A (176) | lisianthioside (177), seemannoside B (178), (4 <i>Z</i> ,4 <i>aR</i> [*] ,12 <i>Z</i> ,12 <i>aR</i> [*])-4,12-Diethylidene-4,4 <i>a</i> ,5,6,12,12 <i>a</i> ,13,14-octahydro-3 <i>H</i> ,8 <i>H</i> ,11 <i>H</i> ,16 <i>H</i> ,dipyrano[3,4-c:3',4'-i] [1,7]dioxacyclododecin-3,8,11,16-tetrone (179) | AF: Cc (179) | [60] |
| Lamiaceae | <i>Cornutia grandifolia</i> var. <i>intermedia</i> | cornutine C–L (180–189) | | AP: Pf (180, 181) | [61] |
| Lauraceae | <i>Nectandra lineata</i> (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 | <i>Adenaria floribunda</i> Kunth. | adenafloin A–D (192–195) | | AC: MCF-7, H-460, SF-268 (192) | [63] |
| Malpighaceae | <i>Hiraea reclinata</i> Jacq. | | kaempferol 3-O-(6''-galloyl)- β -D-galactopyranoside (196), hyperin 6''-gallate (197), 1,3,4,5-tetra-galloylquinic acid (198), vitexin 2''-rhamnoside (199), isovitexin 2''-rhamnoside (200), orientin 2''-rhamnoside (201), isoorientin 2''-rhamnoside (202) | HIV-P: (198) | [64] |
| Malvaceae | <i>Apeiba tiburou</i> Aubl. | | rosmarinic acid (203) | IC: (203) | [65] |
| | <i>Guazuma ulmifolia</i> Lam. | | (-)-epicatechin (204), procianidina B2 (205), procianidina B5 (206), procianidina C1 (207) | BI-AT ₁ : (207 and more complex polymers) | [66] |
| Melastomataceae | <i>Clidemia sericea</i> D. Don | 2'',6''-O-digalloylvitexin (208) | isovitexin (209), 2''-O-galloylvitexin (210), rutin (211), vitexin (212) | AP: Pf (208, 210) | [33] |

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

| Family | Species | New compounds | Known compounds | Biological activity | Ref. |
|--------------|---|--|---|--|----------|
| | <i>Henriettella fascicularis</i> (Sw.) C. Wright | 4',5,7-trihydroxy-6,8-dimethylisoflavone (213), ácido (2 <i>E</i> , 6 <i>S</i>)-6-[(1 <i>R</i> ,5 <i>Z</i> ,3 <i>aS</i> ,9 <i>R</i> ,10 <i>Z</i> ,12 <i>aR</i>)-1,2,3,3 <i>a</i> ,4,7,8,9,12,12 <i>a</i> -decahydro-9-hydroxy-3 <i>a</i> ,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 | <i>Calycolpus warzewiczianus</i> O. Berg | myricetin-3- <i>O</i> - α -L-3''-acetyl-arabinofuranoside (220), myricetin-3- <i>O</i> - α -L-3''-5''-diacetyl-arabinofuranoside (221), and 5-galloylquercetin-3- <i>O</i> - α -L-arabinofuranoside (222) | myricetin-3- <i>O</i> - α -L-arabinofuranoside (223), (-)-epicatechin (224) | AP: Pf (222) | [68] |
| Siparunaceae | <i>Siparuna thecaphora</i> (Poepp. & Endl.) A. DC. = <i>Siparuna andina</i> (Tul.) A. DC. | sipandinolide (225), (-)-cis-3-acetoxy-4',5,7-trihydroxyflavanone (226) | | AP: Pf (226) | [69] |
| | <i>Siparuna pauciflora</i> (Beurl.) A. DC. | sipaucin A (227), B (228), and C (229) | <i>nor</i> -boldine (230), boldine (231), laurotetanine (232), N-methyl-laurotetanine (233) | AP: Pf (230) | [70] |
| Papaveraceae | <i>Bocconia frutescens</i> 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 | <i>Piper darienense</i> C. DC. | | pipercollosine (246) | Local anesthetic (246) | [72] |
| | <i>Piper dilatatum</i> Rich. | taboganic acid (247) | methyl tabogonate (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] |
| | <i>Piper fimbriatum</i> C. DC. | 3,4,5'-trimethoxy-3',4'-methylenedioxy-7,9':7',9 diepoxy lignan (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] |
| | <i>Piper multiplinervium</i> C. DC. | 3-farnesyl-2-hydroxy benzoic acid (264) | | AB: Hp; Sa, Ec, Kp, Ms, Pa, Ca (264) | [77] |
| Polygalaceae | <i>Monnina sylvatica</i> Schlttdl. & Cham. | 3'-Hydroxy-5-methoxy-3,4-methylenedioxybiphenyl (265), 3'-hydroxy-5,5'-dimethoxy-3,4-methylenedioxybiphenyl (266), kaempferol 3- <i>O</i> - β -D-glucosyl-(1 \rightarrow 2)- <i>O</i> -[α -L-rhamnopyranosyl(1 \rightarrow 6)]- β -D-galactoside (267) | 1,5-dihydroxy-2,3-dimethoxyxanthone (268), kaempferol 3- <i>O</i> - α -L-rhamnopyranosyl-(1 \rightarrow 6)- β -D-galactoside (269), kaempferol 3- <i>O</i> - β -D-apio-D-furanosyl-(1 \rightarrow 2)- β -D-galactoside (270), kaempferol 3- <i>O</i> -[<i>O</i> - β -D-apio-D-furanosyl(1 \rightarrow 2)- <i>O</i> -[α -L-rhamnopyranosyl(1 \rightarrow 6)]- β -D-galactopyranoside (271) | AF: Cc (265 , 266), Sc (265 , 266), Af (265), Tm (265) TBS: (265 , 266) | [78, 79] |

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

| Family | Species | New compounds | Known compounds | Biological activity | Ref. |
|-----------------|--|---|---|--|------|
| Polygonaceae | <i>Triplaris cumingiana</i> 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-trihydroxybenzo- yl) glucopyranoside (272), 5,7-dihydroxy-2-(4-hy- droxyphenyl)-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-chro- men-2-yl)phenylarabino- furanoside (274) | quercetin 3-O-α-L-(5''-O-galloyl)ara- binofuranoside (275), quercetin 3- O-β-D-(6''-O-galloyl)glucopyrano- side (276) | AC: H-460 (272, 274, 275), MCF-7 (273–275), SF-268 (275) | [80] |
| Rubiaceae | <i>Coutarea hexandra</i> (Jacq.) K. Schum. | 5-O-β-D-glucopyranosyl-4- (4-hydroxyphenyl)-7-me- thoxy-2H-chromen-2-one (277) | coumarin, 5-O-β-D-galactopyrano- syl-4-(4-hydroxyphenyl)-7-me- thoxy-2H-chromen-2-one (278), 23,24-dihydrocucurbitacin F (279), 23,24-dihydro-25-acetylcucurbita- cin F (280) and 2-O-β-D-glucopyra- nosyl-23,24-dihydrocucurbitacin F (281) | AC: MCF-7, H-460, SF-268 (279, 281) | [81] |
| | <i>Pogonopus speciosus</i> (Jacq.) K. Schum. | 1'',2'',3'',4''-tetrahydrotru- bulosine (282) | tubulosine (283), psychotrine (284) | AC: (283) | [82] |
| | <i>Notopleura camponutans</i> (Dwyer & M. V. Hayden) C. M. Taylor = <i>Notopleura cam- ponutans</i> (Dwyer & M. V. Hayden) C. M. Taylor | 1-hydroxybenzoisochro- manquinone (284) | benz[g]isoquinoline-5,10-dione (285) | TBS, KB: (284, 285) AP: Pf (284, 285) | [83] |
| Selaginellaceae | <i>Selaginella willdenowii</i> (Desv. Ex Poir) Baker | 2'',3''-dihydroisocrypto- merin (286) | 4',7''-di-O-methylamentoflavone (287), isocryptomerin (288), bilo- betin (289), 7''-O-methylrobusta- flavone (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 | <i>Simarouba amara</i> Aubl. | | ailanthinone (293), 2-acetylglau- carubinone (294), holacanthone (295), glaucarubinone (296) | AP: Pf, Pb (295) | [85] |
| Solanaceae | <i>Witheringia solanace</i> L'Her. | | physalins B (297), F (298), and D (299), | NF-kB: (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 AT₁ 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 pneumoniae*; Ms: *Mycobacterium smegmatis*; Pa: *Pseudomonas aeruginosa*; Ca: *Candida albicans*; Ef: *Epidermophyton floccosum*; Sc: *Saccharomyces cerevisiae*; Af: *Aspergillus fumigatus*; Tm: *Trichophyton mentagrophytes*; Mg: *Microsporium 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-kB: NF-kB inhibition; IC: inhibition of complement

Acknowledgements

Thanks are due to the Organization of American States, National Secretariat for Science, Technology and Innovation of Panama, Interamerican Development Bank, European Union, Iberoamerican Program for Science and Technology for Development (CYTED), Alexander von Humboldt Stiftung, Fundación Natura, International Cooperative Biodiversity Groups (NIH, AID) for support. Thanks are also due to Kurt Hostettmann, Arnold Vlietinck, Luc Pieters, Patrick Vanderheyden, Georges Vauquelin, Arturo San Feliciano, Phyllis Coley, Finn Sandberg, Jose Luis López, Eckert Eich,

Kristina Jenet-Siems, Hans Achenbach, Pablo Solís, Dionisio Olmedo, Angela Calderon, Masao Hattori, Late Antonio González, Hans Becker, Erik Spörle, and Mireya Correa for collaborating. We are grateful to Alex Espinosa for revising the botanical names of the plants and the National Environment Authority of Panama for collection and export permits.

Conflict of Interest

The authors have no conflict of interest to report.

References

- Newman DJ, Cragg GM. Natural products as sources of new drugs over the last 25 years. *J Nat Prod* 2007; 70: 461–477
- Schuster BG. A new integrated program for natural product development and the value of an ethnomedical approach. *J Altern Complement Med* 2001; 7: 61–72
- Correa MD, Galdames C, Stapf MS. Catálogo de plantas vasculares de Panamá. Panama: Editora Novo Art, SA; 2004: 600
- Anonymous. New map of biodiversity hot spot aids targeting of conservation efforts. *Diversity* 1997; 13: 27–29
- Bartholt W, Lauer W, Placke A. Global distribution of species in vascular plants. In: von Troll CB, editor. *Erdkunde. Archiv für Wissenschaftliche Geographie*. Kelve: Boss Verlag; 1996: 317–327
- Gupta MP, Marston A, Hostettmann K. Bioactive compounds from Panamanian plants. In: Hostettmann K, Gupta MP, Marston A, editors. *Chemistry, biological and pharmacological properties of medicinal plants from the Americas*. The Netherlands: Harwood Academic Publishers; 1999: 143–159
- Gupta MP. Panamanian flora: source of bioactive compounds. In: Hostettmann K, Marston A, Maillard M, Hamburger M, editors. *Phytochemistry of plants used in traditional medicine*. Oxford: Oxford Science Publications, Clarendon Press; 1995: 359–398
- Calderón AI, Romero LI, Ortega-Barria E, Solís PN, Zacchino S, Gimenez A, Pinzón R, Cáceres A, Tamayo G, Guerra C, Espinosa A, Correa M, Gupta MP. Screening of Latin American plants for antiparasitic activities against malaria, Chagas disease, and leishmaniasis. *Pharm Biol* 2010; 48: 545–553
- Calderón AI, Cubilla M, Espinosa A, Gupta MP. Screening of plants of Amaryllidaceae and related families from Panama as sources of acetylcholinesterase inhibitors. *Pharm Biol* 2010; 48: 988–993
- Caballero-George C, Vanderheyden PM, Solís PN, Pieters L, Shahat AA, Gupta MP, Vauquelin G, Vlietinck AJ. Biological screening of selected medicinal Panamanian plants by radioligand-binding techniques. *Phytomedicine* 2001; 8: 59–70
- National Science Strategic Plan 2010–2014. Available at http://www.senacyt.gob.pa/doc/PENECYT_completo_Gabinete.pdf. Accessed March 18, 2011
- Gupta MP, Arias T, Correa M. Ethnopharmacognostic observations on Panamanian medicinal plants. Part I. *Quart J Crude Drug Res* 1979; 17: 115–130
- Población Indígena Panameña. Available at <http://panama.unfpa.org/poblacion-panama>. Accessed March 18, 2011
- Gupta MP, Correa MD, Solís PN, Jones A, Galdames C, Guionneau-Sinclair F. Medicinal plant inventory of Kuna Indians: Part I. *J Ethnopharmacol* 1993; 40: 77–109
- Joly LG, Guerra S, Septimo R, Solís PN, Correa M, Gupta MP, Levy S, Perera P, Sandberg F. Ethnobotanical inventory of medicinal plants used by the Guaymí Indians in Western Panama. Part II. *J Ethnopharmacol* 1990; 28: 191–206
- Joly LG, Guerra S, Septimo R, Solís PN, Correa M, Gupta MP, Levy S, Sandberg F. Ethnobotanical inventory of medicinal plants used by the Guaymí Indians in Western Panama. Part I. *J Ethnopharmacol* 1987; 20: 145–171
- Gupta MP, Solís PN, Calderón AI, Guionneau-Sinclair F, Correa M, Galdames C, Guerra C, Espinosa A, Alvenda GI, Robles G, Ocampo R. Medical ethnobotany of the Teribes of Bocas del Toro, Panama. *J Ethnopharmacol* 2005; 96: 389–401
- Convention on Biological Diversity. Available at <http://www.cbd.int/convention/text/>. Accessed March 23, 2011
- Integrating Intellectual Property Rights and Development of Policy. Commission on Intellectual Property Rights. Available at http://www.iprcommission.org/papers/pdfs/final_report/CIPRfullfinal.pdf. Accessed March 23, 2011
- Decreto Ejecutivo No. 257 de 17 Octubre de 2006, que reglamenta el artículo 71 de la ley 41 de 1 julio de 1998. General de Ambiente. Available at http://www.wipo.int/clea/docs_new/pdf/es/pa/pa025es.pdf. Accessed March 23, 2011
- Cragg GM, Newman DJ. Nature as source of medicines; novel drugs from nature; screening for antitumor activity. In: Mander L, Lui HW, editors. *Comprehensive natural products II chemistry and biology*, vol. 3. Oxford: Elsevier; 2010: 135–175
- Solís PN, Wright CW, Anderson MM, Gupta MP, Phillipson JD. A microwell cytotoxicity assay using *Artemia salina* (brine shrimp). *Planta Med* 1993; 59: 250–252
- Calderón AI, Terreaux C, Gupta MP, Hostettmann K. *In vitro* cytotoxicity of 11 Panamanian plants. *Fitoterapia* 2003; 74: 378–383
- Gupta MP, Solís PB, Miranda C, Montenegro O, Martínez R, Varela LA, Correa MA. Antimicrobial activity in medicinal plants of Panama. *Rev Med Panama* 1988; 13: 79–84
- Rahalison L, Hamburger M, Hostettmann K, Monod M, Frenk E, Gupta MP, Santana AI, Gonzalez AG. Screening of antifungal activity of Panamanian plants. *Int J Pharmacognosy* 1993; 31: 68–76
- Gupta MP, Monge A, Karikas GA, Lopez de Cerain A, Solís PN, de Leon E, Trujillo M, Suarez O, Wilson F, Montenegro G, Noriega Y, Santana AI, Correa M, Sanchez C. Screening of Panamanian medicinal plants for brine shrimp toxicity, crown gall tumor inhibition, cytotoxicity and DNA intercalation. *Int J Pharmacognosy* 1996; 34: 19–27
- Matsuse IT, Lim YA, Hattori M, Correa M, Gupta MP. A search for anti-viral properties in Panamanian medicinal plants. The effects on HIV and its essential enzymes. *J Ethnopharmacol* 1999; 64: 15–22
- Corbett Y, Herrera L, Gonzalez J, Cubilla L, Capson TL, Coley PD, Kursar TA, Romero LI, Ortega-Barria E. A novel DNA-based microfluorimetric method to evaluate antimalarial drug activity. *Am J Trop Med Hyg* 2004; 70: 119–124
- Segura L, Vila R, Gupta MP, Espósito-Avella M, Adzet T, Cañigueral S. Anti-inflammatory activity of *Anthurium cerrocampaense* croat in rats and mice. *J Ethnopharmacol* 1998; 61: 243–248
- Jacobo-Herrera NJ, Bremner P, Marquez N, Gupta MP, Gibbons S, Muñoz E, Heinrich M. Physalins from *Witheringia solanacea* as modulators of the NF-kappaB cascade. *J Nat Prod* 2006; 69: 328–331
- Gupta MP, Solís NG, Avella ME, Sanchez C. Hypoglycemic activity of *Neurolepta lobata* (L.) R. BR. *J Ethnopharmacol* 1984; 10: 323–327
- Ioset JR, Marston A, Gupta MP, Hostettmann K. A methylflavan with free radical scavenging properties from *Pancreatium littorale*. *Fitoterapia* 2001; 72: 35–39
- Montenegro H, González J, Ortega-Barria E, Cubilla-Rios L. Antiprotozoal activity of flavonoid glycosides isolated from *Clidemia sericea* and *Mosquitoxylon jamaicense*. *Pharm Biol* 2007; 45: 376–380
- Ceplenaev F, Ohtani K, Hamburger M, Gupta MP, Solís P, Hostettmann K. Novel acetogenins from the leaves of *Annona purpurea*. *Helv Chim Acta* 1993; 76: 1379–1387
- Wang ZW, Ma WW, McLaughlin JL. 2,4,5-trimethoxystyrene, a bioactive component of the bark of *Duguetia panamensis*. *J Nat Prod* 1988; 51: 382–384
- Montenegro H, Gutierrez M, Romero L, Ortega-Barria E, Capson T, Cubilla Rios L. Aporphine alkaloids from *Guatteria* spp. with leishmanicidal activity. *Planta Med* 2003; 69: 677–679
- Correa JE, Rios CH, del Rosario Castillo A, Romero LI, Ortega-Barria E, Coley PD, Kursar TA, Heller MV, Gerwick WH, Rios LC. Minor alkaloids from *Guatteria dumetorum* with antileishmanial activity. *Planta Med* 2006; 72: 270–272
- Achenbach H, Löwel M, Waibel R, Gupta M, Solís P. New Lignan Glucosides from *Stemmadenia minima*. *Planta Med* 1992; 58: 270–272
- Gupta MP, Alvarez D, Solís PN, Löwel M, Achenbach H. Phytochemical and biological study of *Stemmadenia minima*. *Planta Med* 1991; 57: 502–503
- Rahalison L, Benathan M, Monod M, Frenk E, Gupta MP, Solís PN, Fuzzati N, Hostettmann K. Antifungal principles of *Baccharis pedunculata*. *Planta Med* 1995; 61: 360–362
- Martin F, Hay AE, Cressend D, Reist M, Vivas L, Gupta MP, Carrupt PA, Hostettmann K. Antioxidant C-glucosylxanthones from the leaves of *Arrabidaea patellifera*. *J Nat Prod* 2008; 71: 1887–1890
- Martin F, Hay AE, Quinteros Condorety VR, Cressend D, Reist M, Gupta MP, Carrupt PA, Hostettmann K. Antioxidant phenylethanoid glycosides and a neolignan from *Jacaranda caucana*. *J Nat Prod* 2009; 72: 852–856
- Ioset JR, Marston A, Gupta MP, Hostettmann K. Antifungal and larvicidal compounds from the root bark of *Cordia alliodora*. *J Nat Prod* 2000; 63: 424–426
- Ioset JR, Marston A, Gupta MP, Hostettmann K. Antifungal and larvicidal meroterpenoid naphthoquinones and a naphthoxirene from the roots of *Cordia linnaei*. *Phytochemistry* 1998; 47: 729–734
- Lim Y, Kida H, Miyaji M, Kusumoto I, Miyashiro H, Hattori M, Shimotohno K, Gupta MP, Correa M. Inhibitory effect of some Panamanian plants on human immunodeficiency viral reverse transcriptase and protease. *J Tradit Med* 1997; 14: 54–58
- Matsuse IT, Lim YA, Hattori M, Correa M, Gupta MP. A search for anti-viral properties in Panamanian medicinal plants. The effects on HIV and its essential enzymes. *J Ethnopharmacol* 1999; 64: 15–22

- 47 Ioset JR, Marston A, Gupta MP, Hostettmann K. Antifungal xanthenes from roots of *Marila laxiflora*. *Pharm Biol* 1998; 36: 103–106
- 48 López-Pérez JL, Olmedo D, del Olmo E, Vásquez Y, Solís PN, Gupta MP, San Feliciano A. Cytotoxic 4-phenylcoumarins from the leaves of *Marila pluricostata*. *J Nat Prod* 2005; 6: 369–373
- 49 Olmedo DA, López-Pérez JL, del Olmo E, Vásquez Y, San Feliciano A, Gupta MP. A new cytotoxic friedelane acid–pluricostatic acid–and other compounds from the leaves of *Marila pluricostata*. *Molecules* 2008; 13: 2915–2924
- 50 Pecchio M, Solís PN, López-Pérez JL, Vasquez Y, Rodríguez N, Olmedo D, Correa M, San Feliciano A, Gupta MP. Cytotoxic and antimicrobial benzophenones from the leaves of *Tovomita longifolia*. *J Nat Prod* 2006; 69: 410–413
- 51 Hussein AA, Bozzi B, Correa M, Capson TL, Kursar TA, Coley PD, Solís PN, Gupta MP. Bioactive constituents from three *Vismia* species. *J Nat Prod* 2003; 66: 858–860
- 52 Hussein AA, Olmedo DA, Vasquez Y, Coley PD, Solís PN, Gupta MP. New cytotoxic cinnamic acid derivatives from leaves of *Bonamia trichantha*. *Rev Latinoamer Quím* 2005; 32: 90–96
- 53 Rodríguez N, Vasquez Y, Hussein AA, Coley PD, Solís PN, Gupta MP. Cytotoxic cucurbitacin constituents from *Sloanea zuliaensis*. *J Nat Prod* 2003; 66: 1515–1516
- 54 Kraft C, Jenett-Siems K, Siems K, Gupta MP, Bienzle U, Eich E. Antiplasmodial activity of isoflavones from *Andira inermis*. *J Ethnopharmacol* 2000; 73: 131–135
- 55 Maillard M, Hamburger M, Gupta MP, Hostettmann K. An antifungal isoflavanone and a structure revision of a flavanone from *Erythrina berteroaana*. *Planta Med* 1989; 55: 281–282
- 56 Maillard M, Gupta MP, Hostettmann K. A new antifungal prenylated flavanone from *Erythrina berteroaana*. *Planta Med* 1987; 53: 563–564
- 57 Ioset JR, Marston A, Gupta MP, Hostettmann K. Five new prenylated stilbenes from the root bark of *Lonchocarpus chiricanus*. *J Nat Prod* 2001; 64: 710–715
- 58 Mendoza DT, Ureña González LD, Ortega-Barría E, Capson TL, Rios LC. Five new cassane diterpenes from *Myrospermum frutescens* with activity against *Trypanosoma cruzi*. *J Nat Prod* 2003; 66: 928–932
- 59 Borel C, Gupta MP, Hostettmann K. Molluscicidal saponins from *Swartzia simplex*. *Phytochemistry* 1987; 26: 2685–2689
- 60 Rodríguez S, Wolfender JL, Hostettmann K, Stoeckli-Evans H, Gupta MP. Monoterpene dimers from *Lisianthus seemannii*. *Helv Chim Acta* 1998; 81: 1393–1403
- 61 Jenett-Siems K, Köhler I, Kraft C, Siems K, Solís PN, Gupta MP, Bienzle U. Cornutins C–L, neo-clerodane-type diterpenoids from *Cornutia grandifolia* var. *intermedia*. *Phytochemistry* 2003; 64: 797–804
- 62 Chérigo L, Polanco V, Ortega-Barría E, Heller MV, Capson TL, Rios LC. Antitrypanosomal activity of a novel norlignan purified from *Nectandra lineata*. *Nat Prod Res* 2005; 19: 373–377
- 63 Hussein AA, Barberena I, Capson TL, Kursar TA, Coley PD, Solís PN, Gupta MP. New cytotoxic naphthopyrane derivatives from *Adenaria floribunda*. *J Nat Prod* 2004; 67: 451–453
- 64 Hussein AA, Gomez B, Ramos M, Heller M, Coley P, Solís PN, Gupta MP. Constituents of *Hiraea reclinata* and their anti-HIV activity. *Rev Latinoamer Quím* 2003; 31: 74–77
- 65 Lasure A, Van Poel B, Pieters L, Claeys M, Gupta M, Vanden Berghe D, Vlietinck AJ. Complement-inhibiting properties of *Apeiba tibourbou*. *Planta Med* 1994; 60: 276–277
- 66 Caballero-George C, Vanderheyden PM, De Bruyne T, Shahat AA, Van den Heuvel H, Solís PN, Gupta MP, Claeys M, Pieters L, Vauquelin G, Vlietinck AJ. *In vitro* inhibition of [³H]-angiotensin II binding on the human AT₁ receptor by proanthocyanidins from *Guazuma ulmifolia* bark. *Planta Med* 2002; 68: 1066–1071
- 67 Calderón AI, Terreaux C, Schenk K, Pattison P, Burdette JE, Pezzuto JM, Gupta MP, Hostettmann K. Isolation and structure elucidation of an isoflavone and a sesterterpenoic acid from *Henriettella fascicularis*. *J Nat Prod* 2002; 65: 1749–1753
- 68 Torres-Mendoza D, González J, Ortega-Barría E, Heller MV, Capson TL, McPhail K, Gerwick WH, Cubilla-Rios L. Weakly antimalarial flavonol arabinofuranosides from *Calycolpus warszewiczianus*. *J Nat Prod* 2006; 69: 826–828
- 69 Jenett-Siems K, Siems K, Jakupovic J, Solís PN, Gupta MP, Mockenhaupt FP, Bienzle U, Eich E. Sipandinolide: a butenolide including a novel type of carbon skeleton from *Siparuna andina*. *Planta Med* 2000; 66: 384–385
- 70 Jenett-Siems K, Kraft C, Siems K, Jakupovic J, Solís PN, Gupta MP, Bienzle U. Sipaucins A–C, sesquiterpenoids from *Siparuna pauciflora*. *Phytochemistry* 2003; 63: 377–381
- 71 Caballero-George C, Vanderheyden PM, Apers S, Van den Heuvel H, Solís PN, Gupta MP, Claeys M, Pieters L, Vauquelin G, Vlietinck AJ. Inhibitory activity on binding of specific ligands to the human angiotensin II AT (1) and endothelin 1 ET(A) receptors: bioactive benzo[c]phenanthridine alkaloids from the root of *Bocconia frutescens*. *Planta Med* 2002; 68: 770–775
- 72 Rodríguez N, Rodríguez M, Calderón A, San Feliciano A, Solís PN, Gupta MP. Anesthetic activity of pipercollosine isolated from *Piper darienense*. *Rev Latinoamer Quím* 2005; 33: 115–120
- 73 Terreaux C, Gupta MP, Hostettmann K. Antifungal benzoic acid derivatives from *Piper dilatatum*. *Phytochemistry* 1998; 49: 461–464
- 74 Solís PN, Olmedo D, Nakamura N, Calderón A, Hattori M, Gupta MP. A new larvicidal lignan from *Piper fimbriatum*. *Pharm Biol* 2005; 43: 378–381
- 75 De León EJ, Olmedo DA, Solís PN, Gupta MP, Terencio MC. Diayangambin exerts immunosuppressive and anti-inflammatory effects *in vitro* and *in vivo*. *Planta Med* 2002; 68: 1128–1131
- 76 Mundina M, Vila R, Tomi F, Gupta MP, Adzet T, Casanova J, Cañigual S. Leaf essential oils of three Panamanian *Piper* species. *Phytochemistry* 1998; 47: 1277–1282
- 77 Rüegg T, Calderón AI, Queiroz EF, Solís PN, Marston A, Rivas F, Ortega-Barría E, Hostettmann K, Gupta MP. 3-Farnesyl-2-hydroxybenzoic acid is a new anti-*Helicobacter pylori* compound from *Piper multiplinervium*. *J Ethnopharmacol* 2006; 103: 461–467
- 78 Bashir A, Hamburger M, Rahalison L, Monod M, Gupta MP, Solís P, Hostettmann K. Antifungal biphenyls from *Monnina sylvatica*. *Planta Med* 1991; 57: 192–193
- 79 Bashir A, Hamburger M, Gupta MP, Solís PN, Hostettmann K. Flavonol glycosides from *Monnina sylvatica*. *Phytochemistry* 1991; 30: 3781–3784
- 80 Hussein AA, Barberena I, Correa M, Coley PD, Solís PN, Gupta MP. Cytotoxic flavonol glycosides from *Triplaris cumingiana*. *J Nat Prod* 2005; 68: 231–233
- 81 Olmedo D, Rodríguez N, Vásquez Y, Solís PN, López-Pérez JL, Feliciano AS, Gupta MP. A new coumarin from the fruits of *Coutarea hexandra*. *Nat Prod Res* 2007; 21: 625–631
- 82 Ito A, Lee YH, Chai HB, Gupta MP, Farnsworth NR, Cordell GA, Pezzuto JM, Kinghorn AD. 1',2',3',4'-tetrahydrorotubulosine, a cytotoxic alkaloid from *Pogonopus speciosus*. *J Nat Prod* 1999; 62: 1346–1348
- 83 Solís PN, Lang'at C, Gupta MP, Kirby GC, Warhurst DC, Phillipson JD. Bioactive compounds from *Psychotria camponutans*. *Planta Med* 1995; 61: 62–65
- 84 Silva GL, Chai H, Gupta MP, Farnsworth NR, Cordell GA, Pezzuto JM, Beecher CW, Kinghorn AD. Cytotoxic biflavonoids from *Selaginella willdenowii*. *Phytochemistry* 1995; 40: 129–134
- 85 O'Neill MJ, Bray DH, Boardman P, Wright CW, Phillipson JD, Warhurst DC, Gupta MP, Corroya M, Solís P. Plants as sources of antimalarial drugs, Part 6: Activities of *Simarouba amara* fruits. *J Ethnopharmacol* 1988; 22: 183–190
- 86 Jacobo-Herrera NJ, Bremner P, Marquez N, Gupta MP, Gibbons S, Muñoz E, Heinrich M. Physalins from *Witheringia solanacea* as modulators of the NF-kappaB cascade. *J Nat Prod* 2006; 69: 328–331