Chapter 9

Plant-Based Ethnopharmacological Remedies for Hypertension in Suriname

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Additional information is available at the end of the chapter

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Abstract

Hypertension is the most important modifiable risk factor for cardiovascular, cerebrovascular, and renal diseases which are together among the most frequent causes of morbidity and mortality in the world. Despite the availability of a wide range of effective medicines, many individuals suffering from hypertension use plant-derived preparations for treating their disease. The choice for these alternatives is often associated with the closer relationship of such approaches to specific social, cultural, and religious perceptions about health and disease. However, in most cases, the scientific evidence for clinical efficacy of such medications is scant. The Republic of Suriname is a middle-income country in South America with a relatively high prevalence of hypertension and other cardiovascular diseases. This country harbors descendants of all continents, all of whom have preserved their cultural customs including their ethnopharmacological traditions. As a result, many Surinamese are inclined to treat their diseases including hypertension as they have done for centuries, that is, with plant-based preparations. This chapter has compiled the plants used for treating hypertension in Suriname; extensively evaluates 15 commonly used plants for potential efficacy on the basis of available phytochemical, mechanistic, preclinical, and clinical literature data; and closes with conclusions about their potential usefulness against the disease.

Keywords: hypertension, medicinal plants, Suriname, preclinical studies, clinical studies, phytochemical composition, mechanism of action

1. Introduction

Blood pressure is the force exerted by the heart and the arteries to maintain the flow of blood through the body in order to supply all cells with oxygen and nutrients and remove waste products. This normally occurs at average systolic and diastolic pressures of 120 and 80 mm Hg, respectively [1]. High blood pressure or arterial hypertension (or hypertension for short) is present when these values are persistently above 140 and 90 mm Hg, respectively [1]. This condition initially does not cause symptoms [1]. However, in the long-term, it is one of the most important predisposing factors for potentially fatal coronary artery disease, heart failure, stroke, peripheral vascular disease, vision loss, and chronic kidney disease [1].

Hypertension is classified as primary (or essential) hypertension and secondary hypertension [2]. Primary hypertension accounts for 90–95% of cases, typically begins in the fifth or sixth decade of life, and is associated with nonspecific lifestyle factors such as excess salt intake, obesity and a sedentary lifestyle, cigarette smoking, high alcohol intake, stress, and a family history suggesting the involvement of genetic factors in its etiology [3]. In the remaining 5–10% of cases categorized as secondary hypertension, the elevated blood pressure has an identifiable cause such as renal artery stenosis, chronic kidney disease, sleep apnoea, hyperthyroidism, pheochromocytoma, the use of oral contraceptives, or pregnancy [2].

In both situations, the elevated blood pressure is caused by an increase in the total peripheral resistance, that is, the total resistance to the flow of blood in the systemic circulation. The increased peripheral resistance is most often attributable to abnormalities in the sympathetic nervous system [4] and the renin-angiotensin-aldosterone system [5]. In the former case, the excessive release of adrenaline and noradrenaline leads to overstimulation of β_1- and α_1-adrenoreceptors, contraction of arterial smooth muscles, constriction of the arterioles, and an increased peripheral resistance [4]. In the latter case, excess secretion of renin by juxtaglomerular cells following stimulation of β_1-adrenergic receptors on their surface, along with glomerular underperfusion, leads to the reabsorption of salt and water and the release of renin, enlarging vascular volume and further increasing peripheral resistance [5]. Impairments in the functioning of vasorelaxing factors such as nitric oxide due to endothelial dysfunction as well as that of vasoactive substances such as endothelin, bradykinin, and atrial natriuretic peptide may further contribute to and/or maintain the hypertension [6].

Lifestyle modifications such as dietary changes can lower blood pressure and decrease the risk of health complications. Examples of such alterations are diets low in sodium, high in potassium, rich in vegetables, fruits, and low-fat dairy products (the so-called Dietary Approaches to Stop Hypertension (DASH) diet, as well as vegetarian diets [7]. Lifestyle modifications other than dietary changes shown to reduce hypertension are increased physical exercise, weight loss, and stress reduction [8]. The potential effectiveness of these modifications is similar to, and may even exceed the effects of a single medication [9]. Notably, several randomized controlled trials have demonstrated that even a slight blood pressure decrease of 10 mm Hg reduces the risk of death due to cardiovascular disease by 25% and the risk of stroke-related mortality by 40% [10].

If lifestyle changes are not sufficient to reduce the elevated blood pressure, antihypertensive medications are prescribed. Still, lifestyle changes are recommended in conjunction with medication [6, 11]. Among the commonly used antihypertensives are thiazide-diuretics such as chlorthalidone and hydrochlorothiazide, calcium channel blockers such as nifedipine and amlodipine, β-blockers such as atenolol and metoprolol, angiotensin-converting enzyme (ACE) inhibitors such as captopril and enalapril, and angiotensin receptor blockers such as losartan and candesartan [6, 11]. These medications may be used either alone or at certain combinations [6, 11]. β-blockers are widely used as a first-line treatment for hypertension, but their efficacy may be inferior to those of other antihypertensive drugs [12].

Currently, close to 1 billion adults or over 20% of the world population suffer from hypertension [13]. This leads to enormous medical, economic, and human costs. In the USA alone, the total economic burden of hypertension in terms of healthcare services, medications, and absent workforce was estimated at USD 47 billion to USD 73.4 billion between the years 2009 and 2011 [14]. And management of hypertension accounts for 30% of office visits for individuals of 45–64 years, and for more than 40% of visits in those aged 60–74 years and over 75 years [15].

Hypertension occurs slightly more often in males, individuals of low socioeconomic status, and those of older age [13, 16]. It is correspondingly common in high-, medium-, and low-income countries [13, 17], but prevalence rates vary widely throughout the world, with values as low as 3.4–6.8% in rural India and as high as 68.9–72.5% in Poland [17]. There are also large differences in prevalence rates within certain countries. For instance, African American adults in the USA have among the highest rates in the world at 44% but hypertension is less common in US whites and Mexican Americans [16, 18]. Still, deaths due to non-communicable diseases including those related to hypertension occur more frequently and at earlier stages in low- and middle-income countries when compared to industrialized countries [19]. By 2030, low-income countries are even expected to have eight times more deaths due to these ailments than high-income countries [19].

2. Background on Suriname

2.1. Geography, people, and economy

The Republic of Suriname is located on the north-east coast of South America and borders the Atlantic Ocean to the north, French Guiana to the east, Brazil to the south, and Guyana to the west (**Figure 1**). The country's land area of roughly 165,000 km^2 can be distinguished into a northern narrow low-land coastal area that harbors the capital city Paramaribo as well as other urbanized areas, a broad but sparsely inhabited savannah belt, and a southern forested area that comprises about three-quarters of its surface area and largely consists of dense, pristine, and highly biodiverse tropical rain forest. Roughly 80% of the population of about 570,000 lives in the urbanized northern coastal zone while the remaining 20% populates the rural and interior savannas and hinterlands [20].

Suriname is renowned for its ethnic, religious, and cultural diversity, harboring various Amerindian tribes, the original inhabitants of the country; descendants from runaway enslaved Africans brought in between the sixteenth and the nineteenth century (called Maroons); those from mixed Black and White origin (called Creoles); descendants from contract workers from China, India (called Hindustanis), and Java, Indonesia (called Javanese) who arrived between the second half of the nineteenth century and the first half of the twentieth century; descendants from a number of European countries; and more recently, immigrants from various

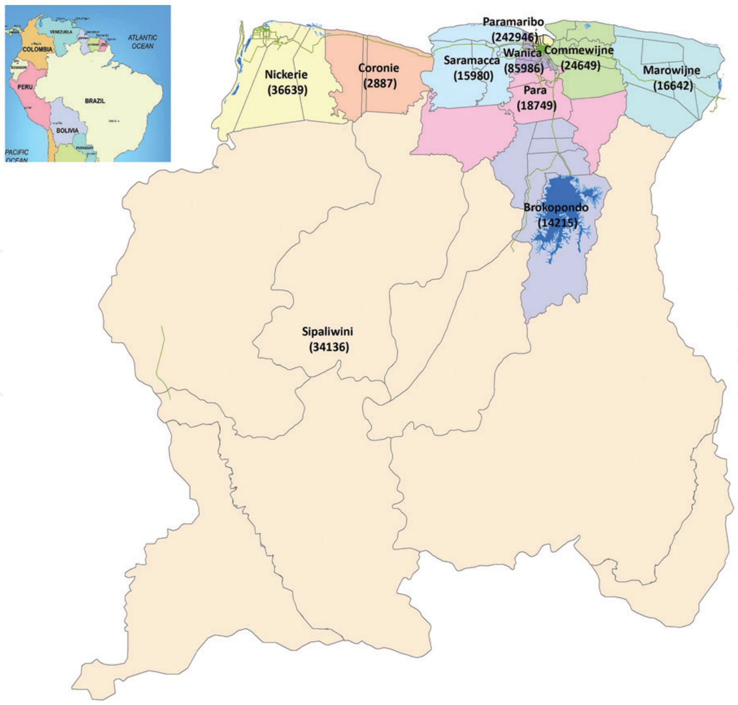

Figure 1. Map of Suriname depicting the administrative districts (from: https://goo.gl/images/gqdxwn). The insert (from: https://goo.gl/images/rWXrAL) indicates the location of Suriname in South America.

Latin American and Caribbean counties including Brazil, Guyana, French Guiana, Haiti, etc. [20]. The largest ethnic groups in the country are the Hindustanis, Maroons, Creoles, and Javanese, accounting for 27.4, 21.7, 17.0, and 15.7%, respectively, of the total population [20]. All ethnic groups have largely preserved their own specific identity [21], making Suriname one of the culturally most diverse countries in the world [22].

Suriname is situated on the Guiana Shield, a Precambrian geological formation estimated to be 1.7 billion years old and one of the regions with the largest expanse of undisturbed tropical rain forest in the world with a very high animal and plant biodiversity [23]. The high mineral density of Suriname's soil contributes to its ranking as the 17th richest country in the world in terms of natural resources and development potential [24]. Suriname's most important economic means of support are crude oil drilling, bauxite and gold mining, agriculture, fisheries, forestry, and ecotourism [24]. These activities contributed substantially to the gross domestic income in 2014 of USD 5.21 billion and the average *per capita* income in that year of USD 9325 [24]. This positions Suriname on the World Bank's list of upper-middle income economies [25].

2.2. Non-communicable diseases

At the same time, as observed in many low- and middle-income countries [19], more and more Surinamese are adapting a Western lifestyle. For instance, only about half of the country's overall population met the levels for physical activity recommended by the World Health Organization (WHO) [26]; almost three-quarters of school children aged 13–15 years had less than 1 hour of physical activity per day and 81% had a high calorie intake [27]; and

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the average tobacco and alcohol consumption *per capita* in individuals of 15 years and older was unacceptably high [28].

As a result, in 2008, 25.1% of Surinamese was obese [28, 29]; 7.4% had prediabetes and 13.0% diabetes mellitus [30]; the overall estimated prevalence of the metabolic syndrome was 39.2% [31]; and more than 25% of adults had a raised blood pressure [29, 32]. These observations indicate that Suriname, similarly to many other economically developing countries [19], is facing increasing public health threats of lifestyle-related non-communicable diseases including cardiovascular disease.

Indeed, WHO assessments from 2014 attributed 68% of total deaths in Suriname to the four main non-communicable diseases (cardiovascular, neoplastic, diabetic, and chronic respiratory diseases) and estimated that the probability of dying between age 30 and 70 years from these conditions was 14% [29]. Notably, in all approximations and previsions, cardiovascular disease was the most important cause of morbidity and mortality in Suriname. For instance, in 2012, stroke (11%), ischemic heart disease (9.1%), diabetes mellitus (7.3%), and hypertensive heart disease (4.5%) were among the leading causes of mortality, together accounting for about 800 or almost one-third of the total number of deaths in that year [29]. Indeed, with 864 fatalities in 2013 (or more than one-quarter of the total number of 3260 deaths in that year), cardiovascular disease was by far the leading cause of mortality in Suriname, ahead of death due to malignant neoplasms, external causes, perinatal complications, diabetes mellitus, and acute respiratory infections [33].

2.3. Hypertension

The comprehensive, nation-wide Suriname Health Study on non-communicable diseases found an overall prevalence of hypertension of 26.2% [32]. This was in the range of values reported for many other developing countries [34] as well as the relatively large Surinamese diaspora in The Netherlands [35]. Mean values for systolic and diastolic blood pressure were higher in males than in females; increased with older age; and were highest in Creoles Hindustanis, and Javanese, and lowest in Maroons and Amerindians [32]. The prevalence of hypertension in demographic risk factor subgroups differed between ethnic groups, as did the associations of ethnic groups with hypertension [32], implying the need of tailor-made intervention programs to control hypertension in Suriname [32].

The findings from two other Surinamese studies suggest that an urban lifestyle may also contribute to the development of prehypertension and hypertension in Suriname, reporting higher prevalence rates in the urban areas of the country (39 and 41%, respectively [36]), and in an urban middle-income population (31 and 41%, respectively [37]). These studies found neither gender differences nor racial/ethnic differences in the prevalence of hypertension in their participants [36, 37], but prehypertension was more common in urban males than in urban females [36] and after adjusting for age, urban African-Surinamese had significantly higher odds of having hypertension than their Asian counterparts [36].

An apparent ethnic/racial predilection of hypertension was also observed in several Dutch epidemiological studies that included Surinamese migrants. These studies reported a higher incidence of prehypertension, hypertension, malignant hypertension, and related renal complications in participants from Afro-Surinamese and Hindustani descent compared to white individuals [35, 38–40]. These differences were tentatively explained by ethnic disparities in the perception of hypertension (supporting one of the findings of the Suriname Heath Study [32]), as well in drug adherence, blood pressure control, and/or insurance status [38, 40–42].

2.4. Health care system

Suriname's healthcare system is coordinated by the Ministry of Health which is headed by the Minister of Health and the Director of Health (the Chief Medical Officer). The main responsibilities of the ministry are the planning, coordination, inspection, and monitoring and evaluation of, as well as policy development and setting standards to the country's health system [43].

In 2014, the Ministry spent 5.7% of the country's gross domestic product for health expenditures which corresponded to an average *per capita* sum of USD 589. The costs of those who cannot afford these expenses are covered by the Ministry of Social Affairs. Government employees and employees of government-related companies are mandatory insured at the State Health Foundation. Essential pharmaceuticals including those for treating hypertension are imported, stocked, and distributed by the National Pharmaceutical Import and Distribution Company and are in general readily available. These medicines are identified by the Board for Essential Pharmaceuticals that consists of various players in the field of pharmacy and pharmacology in Suriname.

Primary healthcare in Suriname's coastal area and hinterlands is provided by the government-subsidized Regional Health Service and Medical Mission, respectively, each operating about 40 clinics which also dispense medicines. In 2004, Suriname had 0.45 physicians per 1000 population. Secondary care and specialist care including that for patients suffering from complications of hypertension are provided by two private and two government-supported hospitals in Paramaribo and one public hospital in the western district of Nickerie.

The Academic Hospital Paramaribo also functions as training facility for both general practitioners and medical specialists, and has to its disposal a Thorax Center for specialized cardiology care and cardiothoracic surgery. Patients with kidney failure are treated by the government-supported Kidney Dialysis Center. Cases of hypertensive crisis and other medical emergencies can get help around-the-clock from the First-aid Stations of the Academic Hospital Paramaribo and the Sint Vincentius Hospital Suriname.

Patients who need specialized therapy that is not available in Suriname (particularly those suffering from certain malignancies) are sent abroad – in general to the Netherlands or Colombia – for treatment. All expenses are covered by the Ministry of Health that has reserved a special budget for these cases.

2.5. Use of traditional medicines against hypertension in Suriname

Despite the broad availability of affordable and accessible modern health care throughout the entire country, the use of traditional medicines is deeply rooted in all ethnic groups in Suriname [21, 44]. This is probably for an important part attributable to the fact that all ethnic

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and cultural groups in the country have preserved much of their original cultural and ethnopharmacological practices as a means of strengthening the ethnic identity during the secluded lifestyle the former colonial authorities had forced them into [21, 22]. Furthermore, Suriname's large biodiversity provides ample and readily available raw material that can be processed into traditional medicines [23]. As a result, many disease conditions including hypertension are often treated with traditional plant-based medicines and may be used instead of, or in conjunction with prescription drugs.

The medicinal plants used throughout the country have extensively been discussed in the literature [45], and those used more commonly by Hindustanis, Maroons, and Javanese have also been reviewed [46–48]. Less comprehensive accounts of these plants have been presented as well [49–55]. Together, these publications have compiled 789 Surinamese medicinal plants, 65 of which (roughly 8%) are used for treating hypertension. The latter plants, plant parts, and methods of processing are given in **Table 1**. They belong to 38 different families, the most represented of which are the Fabaceae with 7 species, the Solanaceae with 5 species, the Malvaceae and the Piperaceae with 4 species each, and the Asteraceae and the Cucurbitaceae with 3 species each (**Table 1**). In 31 cases the leaves are used, in 9 cases the whole plant, in 6 cases the fruits, in 5 cases the bark, and in 1–3 cases other plant parts such as roots and flowers (**Table 1**).

Family	**Species** **(Vernacular names in English; Surinamese)**	**Part(s) used**	**Mode of preparation**
Acanthaceae	*Justicia pectoralis* Jacq. (Freshcut; tonkawiwiri)	Leaves	Infusion
Acanthaceae	*Ruellia tuberosa* L. (Minnieroot; watrakanu)	Roots and leaves	Infusion
Amaranthaceae	*Alternanthera brasiliana* (L.) Kuntze (Brazilian joyweed; weti ede)	Whole plant	Infusion
Anacardiaceae	*Mangifera indica* L. (Mango; manya)	Leaves	Infusion
Anacardiaceae	*Spondias dulcis* L. (Ambarella; pomme cythère)	Fresh fruits; fresh peels	Pressed to obtain juice to drink; infusion
Annonaceae	*Annona muricata* L. (Soursop; zuurzak)	Fresh leaves	Infusion
Apiaceae	*Apium graveolens* L. (Celery; soepgroenten)	Fresh leaves	Infusion
Apocynaceae	*Catharanthus roseus* (L.) G.Don, 1837 (Rosy periwinkle; kotomisi)	Whole plant	Infusion
Apocynaceae	*Geissospermum laeve* (Vell.).Miers (Pao-pereira bark; bergi bita)	Fresh stem bark	Decoction

Family	Species (Vernacular names in English; Surinamese)	Part(s) used	Mode of preparation
Arecaceae	*Cosos nucifera* L. (Coconut tree; kronto)	Dried husk fibers	Infusion
Asteraceae	*Ayapana triplinervis* (Vahl) R.M. King & H. Rob (Water hemp; sekrepatuwiwiri)	Fresh or dried leaves	Infusion
Asteraceae	*Cyanthillium cinereum* (L.) H. Rob (Little ironweed; doifiwiwiri)	Whole plant	Infusion
Asteraceae	*Melampodium camphoratum* (L.F.) Baker (Sand bitters; kanfrubita)	Whole plant	Infusion
Bignoniaceae	*Mansoa alliacea* (Lam.) A.H. Genry (Garlic vine; konofrukutetey)	Leaves and hardwood	Infusion
Boraginaceae	*Cordia schomburgkii* DC. (Canalette; blaka uma)	Fresh leaves	Infusion
Boraginaceae	*Cordia tetrandra* Aubl. (Clammy cherry; tafrabon)	Dried leaves	Infusion
Caricaceae	*Carica papaya* L. (Papaya; papaya)	Fresh fruits	None; fresh fruit eaten
Cecropiaceae	*Cecropia peltata* L. (Trumpet tree; uma busipapaya)	Dried leaves	Infusion
Cecropiaceae	*Cecropia sciadophylla* Mart. (Congo pump; man busipapaya)	Dried leaves	Infusion
Combretaceae	*Terminalia catappa* L. (Tropical almond; zoete amandel)	Leaves	Infusion
Commelinaceae	*Tripogandra serrulata* (Vahl.) Handlos. (Pink trinity; redi gado dede)	Dried leaves	Infusion
Convolvulaceae	*Ipomoea aquatica* Forssk. (Water spinach; dagublad)	Young leaves and stem	Cooked and eaten as a vegetable
Cucurbitaceae	*Cucumis sativus* L. (Cucumber; komkommer)	Fresh fruits	Pressed to obtain juice to drink
Cucurbitaceae	*Cucurbita moschata* Duchesne (Squash; pompoen)	Dried flowers	Infusion
Cucurbitaceae	*Momordica charantia* L. (Bitter melon; sopropo)	Dried whole plant	Infusion
Dilleniaceae	*Davilla nitida (*Vahl.) Kubizki (Sandpaper tree; schuurpapier)	Stem	Pressed to obtain sap to drink

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Family	Species (Vernacular names in English; Surinamese)	Part(s) used	Mode of preparation
Euphorbiaceae	*Acalypha hispida* Burm. f. (Red hot cat's tail; pus'pusitere)	Leaves	Infusion
Fabaceae	*Copaifera guyanensis* Desf. (Copaiba; hoepelhout)	Fresh stem bark	Infusion
Fabaceae	*Desmodium adscendens* (Sw.) DC. (Beggar lice; toriman)	Roots	Pressed to obtain sap to drink
Fabaceae	*Hymenaea courbaril* L. (West Indian locust; loksi)	Stem bark	Infusion
Fabaceae	*Machaerium lunatum* (L.f.) Ducke (Manatee bush; brantimaka)	Leaves	Infusion
Fabaceae	*Mimosa pudica* L. (Shy plant; Sing sing tap yu koto)	Whole plant	Infusion
Fabaceae	*Senna alata* (L.) Roxb. (Candle bush; slabriki)	Leaves	Infusion
Fabaceae	*Tamarindus indica* L. (Tamarind; tamarinde)	Leaves	Infusion
Lamiaceae	*Ocimum campechianum* Mill. (Amazonian basil; smeriwiwiri)	Whole plant	Macerated for herbal bath
Lauraceae	*Persea americana* Mill. (Avocado; advocaat)	Dried leaves	Infusion
Malvaceae	*Gossypium barbadense* L. (Sea island cotton; redi katun)	Leaves	Infusion
Malvaceae	*Hibiscus sabdariffa* L. (Roselle; syuru)	Leaves	Infusion
Malvaceae	*Waltheria indica* L. (Sleepy morning; malva)	Leaves	Infusion
Meliaceae	*Azadirachta indica* A. Juss. (Neem; nim)	Leaves	Infusion
Meliaceae	*Carapa guianensis* Aubl. (Crabwood; witte krapa)	Dried stem bark	Decoction
Meliaceae	*Carapa procera* D.C. (African crabwood; rode krapa)	Dried stem bark	Decoction
Musaceae	*Musa sp., Musa x paradisiaca* (Banana; banaan)	Leaves	Infusion
Oxalidaceae	*Averrhoa bilimbi* L. (Bilimbi; birambi)	Fresh fruits	Pressed to obtain juice to drink

Family	Species (Vernacular names in English; Surinamese)	Part(s) used	Mode of preparation
Passifloraceae	*Passiflora cocciea* Aubl. (Scarlet passion flower; sneki markusa)	Leaves and stem	Infusion
Phyllanthaceae	*Phyllanthus amarus* Schumach. & Thonn. (Stonebreaker; finibita)	Whole plant	Infusion
Phytolaccaceae	*Microtea debilis* Sw. (Weak jumby pepper; eiwitblad)	Fresh or dried whole plant or leaves	Infusion
Piperaceae	*Peperomia pellucida* (L.) Kunth. (Pepper elder; konsakawiwiri)	Fresh leaves or whole plant	Pressed to obtain sap to drink
Piperaceae	*Peperomia rotundifolia* (L.) Kunth. (Swan spice; tinsensiwiwiri)	Fresh leaves or whole plant	Pressed to obtain sap to drink
Piperaceae	*Piper betle* L. (Betel; pahnblad)	Leaves	Infusion
Piperaceae	*Piper marginatum* Jacq. (Marigold pepper; aneysiwiwiri)	Leaves	Infusion
Poaceae	*Eleusine indica* L. (Indian goosegrass; mangrasi)	Leaves	Infusion
Poaceae	*Zea mais* L. (Maize; karu)	Ripe ears	Decoction
Rhamnaceae	*Ziziphus jujuba* L. (Jujube; olijf)	Leaves	Infusion
Rubiaceae	*Sipanea pratensis* Aubl. (Water lagaga; wetibaka)	Leaves	Infusion
Sapindaceae	*Paullinia pinnata* L. (Bread and cheese; feyfifingawiwiri)	Leaves	Pressed to obtain sap to drink
Sapotaceae	*Chrysophyllum cainito* L. (Star apple; sterappel)	Dried leaves	Infusion
Scrophulariaceae	*Scoparia dulcis* L. (Licorice weed; sibiwiwiri)	Aerial parts	Infusion
Simarubaceae	*Quassia amara* L. (Bitter wood; kwasibita)	Hard wood	Infusion
Siparunaceae	*Siparuna guianensis* Aubl. (Ant bush; yarakopi)	Aerial parts	Macerated for herbal bath
Solanaceae	*Physalis angulata* L. (Angular winter cherry; batotobita)	Dried leaves	Infusion

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Family	Species (Vernacular names in English; Surinamese)	Part(s) used	Mode of preparation
Solanaceae	*Solanum leucocarpon* Dual. (Bitayouli; uma parabita)	Leaves	Macerated for herbal bath
Solanaceae	*Solanum macrocarpum* L. (African eggplant; antruwa)	Fresh fruits	Cooked and eaten as a vegetable
Solanaceae	*Solanum stramoniifolium* Jacq. (Coconilla; makadroyfi)	Fresh fruits	None; fresh fruit eaten
Solanaceae	*Solanum subinerme* Jacq. (Juhuna; droyfimaka)	Leaves	Infusion

Table 1. Plants used for treating hypertension in Suriname.

3. Scientific rationale for using Surinamese plants against hypertension

In this section, 15 plants that are commonly used against hypertension in Suriname, as well as preclinical and clinical indications for their blood pressure-lowering effect and their presumed bioactive constituent(s) and mechanism(s) of action are in detail addressed. The plants are most frequently mentioned as traditional treatments for hypertension in the above-mentioned publications [45–55]. The data are summarized in **Table 2**.

Family	Plant species (Vernacular name in English; Surinamese)	Preclinical evidence	Clinical evidence	Presumed key active constituent(s)	Presumed mechanism of action
Acanthaceae	*Ruellia tuberosa* L. (Minnieroot; watrakanu)	No	No	Unknown	Decreased blood lipid levels
Anacardiaceae	*Mangifera indica* L. (Mango; manya)	Yes	No	Mangiferin	Vasodilation; stimulated diuresis
Annonaceae	*Annona muricata* L. (Soursop; zuurzak)	Yes	No	Alkaloids, essential oils	Vasodilation
Apiaceae	*Apium graveolens* L. (Celery; soepgroente)	Yes	Yes	3-n-butylphthalide	Vasodilation, stimulated diuresis
Arecaceae	*Cocos nucifera* L. (Coconut; kronto)	Yes	Yes	Phenolics, flavonoids	Vasodilation; decreased blood lipid levels; stimulated diuresis

Family	Plant species (Vernacular name in English; Surinamese)	Preclinical evidence	Clinical evidence	Presumed key active constituent(s)	Presumed mechanism of action
Caricaceae	*Carica papaya* L. (Papaya; papaya)	Yes	No	Unknown	Vasodilation; stimulated diuresis
Cucurbitaceae	*Cucumis sativus* L. (Cucumber; komkommer)	Yes	Yes	Unknown	Stimulated diuresis
Fabaceae	*Desmodium adscendens* (Sw.) DC. (Beggar lice; toriman)	No	No	Unknown	Vasodilation
Fabaceae	*Hymenaea courbaril* L. (West Indian locust; loksi)	No	No	Unknown	Unknown
Fabaceae	*Tamarindus indica* L. (Tamarind; tamarinde)	Yes	No	Unknown	Sympatico-inhibition; decreased blood lipid levels
Lauraceae	*Persea americana* Mill. (Avocado; advocaat)	Yes	No	Unknown	Vasodilation; decreased blood lipid levels
Malvaceae	*Gossypium barbadense* L. (Sea island cotton; redi katun)	Yes	No	Unknown	Vasodilation
Malvaceae	*Hibiscus sabdariffa* L. (Roselle; syuru)	Yes	No	Polyphenolics, flavonoids	Vasodilation; stimulated diuresis; decreased blood lipid levels
Meliaceae	*Azadirachta indica* A. Juss. (Neem; nim)	Yes	No	Azadirachtin, nimbinin	Vasodilation
Oxalidaceae	*Averrhoa bilimbi* L. (Bilimbi; birambi)	Yes	No	Unknown	Vasodilation; decreased cardiac output; stimulated diuresis

Table 2. Preclinical and clinical evidence for blood pressure-lowering activity of 15 commonly used plants in Suriname for treating hypertension, the presumed key active constituent(s) in these plants, and their presumed mechanism of action.

3.1. Acanthaceaea – *Ruellia tuberosa* L.

The minnie root *R. tuberosa* (**Figure 2**) is probably native to Central America but has spread to various other tropical regions in South America as well as South and South east Asia. Both the English vernacular name 'cracker plant' and the Surinamese vernacular name *watrakanu* ('water canon') are probably derived from the loud crack emitted when the ripe fruits in a pod with seven to eight seeds burst open on contact with water, hurdling the seeds away. The whole plant, the leaves, and/or the roots are used in various traditional medicinal systems including those in Suriname as an antidiabetic, antipyretic, analgesic, diuretic, antihypertensive, gastroprotective, anthelmintic, antigonorrheal, antioxidant, blood-purifying, and abortifacient agent [46, 48, 49, 55, 56]. Some of these activities were supported by the results from pharmacological studies [57, 58] and could be associated with certain alkaloids, triterpenoids, saponins, sterols, and flavonoids in the plant [59].

So far, no formal experimental evaluations on the presumed antihypertensive activity of *R. tuberosa* have been reported. However, crude extracts from the leaves of the closely related species *R. patula* and *R. brittoniana* as well as n-butanolic extracts and the aqueous layers of both plant extracts displayed cardiotonic effects in isolated rabbit hearts [60]. More importantly, a preparation from *R. patula* elicited a clear blood pressure-lowering effect in pentothal sodium-anesthetized rats [61]. This effect may be attributed, at least partially, to the blood lipid-lowering actions of *Ruellia* preparations [57, 58].

3.2. Anacardiaceae – *Mangifera indica* L.

The mango tree *M. indica* is indigenous to Bangladesh, India, and Pakistan where it is found in the wild. It has been domesticated in India around 2000 BC, and many cultivated varieties have been produced in other tropical countries including Suriname. Both sour, unripe, and sweet, ripe mangoes are widely used in cuisine, among others, in chutneys, curries, pickles, or side dishes, and to prepare juices, smoothies, nectars, jams, and as a flavoring in ice creams, sorbets, fruit bars, and pies.

Figure 2. Acanthaceaea – *Ruellia tuberosa* L. (from: https://goo.gl/images/vk862o).

Preparations from flowers, unripe fruits, stone, leaves, stembark, and roots of *M. indica* also have many traditional medicinal uses, among others, to treat certain parasitic infections, uterus disorders, gastrointestinal problems, and syphilis; strengthen the blood vessels; cure varicose veins; and lower an elevated blood pressure [46, 62–64]. Several of these properties have been attributed to a number of bioactive substances in leaves and stem bark of the plant including the polyphenolic compound mangiferin [65]. This compound also displayed notable blood pressure-lowering effects in *in vitro* models and laboratory animals [66].

The apparent antihypertensive effect of *M. indica* preparations and constituents may be attributed to at least two mechanisms, namely the induction of vasodilation and the stimulation of diuresis. Indications for the former possibility are provided by the inhibition of noradrenaline-induced contractions of mesenteric arteries isolated from spontaneously hypertensive rats by a *M. indica* stem bark extract (called 'Vimang' from 'vida del mango' meaning 'life of the mango') [62]. Support for the second possibility comes from the diuretic effect of 'Vimang' in laboratory rats [67].

3.3. Annonaceae – *Annona muricata* L.

The exact origin of the soursop or graviola *A. muricata* (**Figure 3**) is unknown, but it is believed to be native to the Caribbean and the tropical regions of the Americas. It is now widely cultivated for its fruit, the pulp of which contains substantial amounts of vitamin C, vitamin B1, and vitamin B2 and is used to make fruit juice drinks, smoothies, as well as candies, sorbets, and ice cream flavorings. Relatively recently, *A. muricata* fruit and graviola capsules have been promoted as an alternative treatment for cancer. However, there is no medical evidence for such an activity, even though preclinical studies have shown cytotoxic effects of *A. muricata* extracts against cultured cancer cells [68].

Importantly, *Annona* species including *A. muricata* are a rich source of annonaceous acetogenins such as annonacin and annonamine, potent neurotoxins that inhibit mitochondrial

Figure 3. Annonaceae – *Annona muricata* L. (from: https://goo.gl/images/K9WNHr).

complex I, thereby shutting down cellular respiration [69]. These compounds have been associated – although not conclusively – with the unusually high incidence of atypical parkinsonism in the Caribbean island of Guadeloupe where relatively large amounts of *A. muricata* fruits as well as infusions and decoctions from the leaves of the plant are consumed [70].

Nevertheless, all parts of *A. muricata* are extensively used – also in Suriname – as traditional medicines against a wide diversity of conditions, among others, insomnia; nervousness, anxiety, and depression; a hangover; epilepsy; parasitic and helminth infections; diabetes mellitus; cancer; and hypertension [45, 48, 49, 55, 71]. Pharmacological studies with preparations from leaves, bark, and roots of the plant have indeed shown sedative, anxiolytic, smooth muscle-relaxant, antispasmodic, and antihypertensive effects [71–73]. Some of these effects may be attributed to the presence in the plant of bioactive constituents such as alkaloids, flavonol triglycosides, phenolics, and essential oils [71].

Indications for an antihypertensive effect were provided by the decrease in blood pressure in normotensive Sprague-Dawley rats which were intravenously treated with an aqueous leaf extract of *A. muricata* [74]. Furthermore, the extract decreased the phenylephrine-induced contractions of isolated rat and guinea pig aortic rings [74, 75], and relaxed the contractions of isolated rat aortic rings caused by high K^+ while apparently blocking Ca^{2+} channels [74]. These findings suggest that the hypotensive effects of the *A. muricata* leaf extract may involve vasodilation mediated through peripheral mechanisms involving antagonism of Ca^{2+} [74]. This effect has been attributed to alkaloids such as coreximine, anomurine, and reticulin, and some essential oil components such as β-caryophyllene [74].

However, in light of the affinity of both crude extracts and isoquinoline alkaloids isolated from *Annona* species to 5-HT_{1A} receptors *in vitro* [72], and the well-known decreasing effect of 5-HT_{1A} receptor agonists on blood pressure and heart rate [76], it is also possible that the antihypertensive effect of these plants occurs through a central mechanism that causes peripheral vasodilation and stimulates the vagus nerve.

3.4. Apiaceae – *Apium graveolens* L.

The celery *A. graveolens* (**Figure 4**) originates from the Mediterranean region, but many cultivars are now grown throughout the world. This plant has been cultivated since ancient times, initially only for its medicinal qualities, but later also as a vegetable to counter the salt-sickness of winter diets based on salted meats without green vegetables. Today, *A. graveolens* stalks, leaves, and hypocotyl are eaten raw or as an ingredient in salads, cooked as a vegetable, or as a flavoring – either fresh or dried – in soups, stews, and pot roasts.

A. graveolens seeds – which are in fact very small fruits – yield a valuable volatile oil that is used in perfumes and, when ground and mixed with salt, to produce celery salt for enhancing the flavor of, for instance, Bloody Mary cocktails [77]. However, celery seeds contain relatively high levels of the phenylpropene apiole that can cause abortion – sometimes with fatal consequences [78] – as well as liver and kidney damage [79] and severe allergic reactions including potentially fatal anaphylactic shock [80].

Figure 4. Apiaceae – *Apium graveolens* L. (from: https://goo.gl/images/7RWqQ4).

Nevertheless, *A. graveolens* is extensively used in traditional medicinal systems – including those in Suriname-against numerous diseases ranging from respiratory ailments and liver diseases to menstrual problems and hypertension [45, 81, 82].

Support for an antihypertensive effect of preparations from *A. graveolens* came from the decreased blood pressure and heart rate in salt-induced hypertensive rats, normotensive rats, and normotensive rabbits following intraperitoneal administration of extracts from seeds, stalks, or roots of the plant [83–86]. The results from studies with isolated rat aortic rings suggested that these effects occurred through vasodilation [83] or the stimulation of muscarinic receptors [84]. However, extracts from celery leaves, stalks, and roots have also been reported to stimulate diuresis in several experimental models [87, 88], providing an alternative explanation for their blood pressure-lowering effects.

The antihypertensive effects of *A. graveolens* have been attributed to the presence in the plant of the benzofuran 3-n-butylphthalide [86, 89] that, along with sedanolide, is also primarily responsible for the aroma and taste of celery. Clinical studies indeed showed a reduction in blood pressure of patients who had been given celery juice [90, 91]. These and other clinical data first led to the approval in China of 3-n-butylphthalide for the treatment of cerebral ischemia, and the preparation of clinical studies to assess n-butylphthalide formulated as softgel capsules for its safety in patients with mild to moderate acute ischemic stroke [92].

3.5. Arecaceae – *Cocos nucifera* L.

The coconut tree *C. nucifera* is believed to originate from the South East Asian peninsular region. It has probably spread to many other parts of the world by sea-faring traders and through marine currents, and is now cultivated in many subtropical and tropical countries. Refrigerated coconut water or coconut juice is a much appreciated refreshing drink all over the world; the fleshy coconut 'meat' is used fresh or dried in confections and desserts; coconut milk is frequently added to curries and other spicy dishes; and coconut oil is used for frying and preparing margarine and in various cosmetics [93].

Almost all parts of *C. nucifera* have long been used in traditional medicine for treating many disease conditions, among others, diarrhea, fever and malaria, renal diseases, asthma, diabetes mellitus, hair loss, menstrual disorders, venereal diseases, as an oral contraceptive, and against hypertension [45, 94]. Pharmacological studies with extracts, fractions, and isolated compounds from parts of *C. nucifera* indeed showed a variety of activities ranging from antimicrobial and antiparasitic activities to vasodilatory and antihypertensive effects [95]. Some of these observations may be related to the presence in the plant of polyphenols, tannins, flavonoids, triterpenes, saponins, steroids, alkaloids, and/or fatty acids [94].

Evidence for an antihypertensive activity from *C. nucifera* came from the relaxation of isolated rat aortic rings by an ethanolic extract of *C. nucifera* endocarp and the reduced blood pressure in salt-induced hypertensive rats treated with this preparation [96]; the decreased blood pressure in a rat model of insulin resistance and acquired systolic hypertension following administration of tender coconut water [97]; and the decrease in heart rate of hypertensive Wistar rats which were given coconut water [98]. Notably, in a small clinical study, coconut water given for 2 weeks reportedly lowered the blood pressure in 71% of hypertensive individuals [99], while the fresh vascular sap from the immature, unopened inflorescence given once per day for 5 consecutive weeks led to a decrease in blood pressure as well as a reduction in total serum cholesterol in women with stage one hypertension [100].

The antihypertensive effects have been attributed to vasodilation following the direct activation of the nitric oxide/guanylate cyclase pathway as well as stimulation of muscarinic receptors and/or the cyclooxygenase pathway which would be caused by phenolic compounds and flavonoids [96]; inhibition of lipid peroxidation, upregulation of antioxidant status, and improved insulin sensitivity [97]; a decreased cardiac beating frequency [98]; and/or a (potassium-sparing) diuretic activity [99].

3.6. Caricaceae – *Carica papaya* L.

The papaya plant *C. papaya* probably has its origin in Mexico and the northern parts of South America and has subsequently become naturalized throughout other tropical and subtropical regions. Various cultivars are grown for their edible ripe fruits which are usually consumed raw. The juice from ripe papayas is a popular low-calorie beverage and is also added as a flavoring in candies, jellies, and ice cream; the unripe fruit is incorporated in various dishes; the young leaves and flower buds may be consumed as vegetables; and the ground black seeds are sometimes used as a substitute for black pepper.

The relatively high amount of the protease papain in unripe fruits has been taken advantage of for centuries by the indigenous peoples of the Americans and Caribbean to tenderize meat [101]. Based on this practice, papain is now included as a component in some powdered meat tenderizers [102]. A few other important contemporary uses of papain are its medical use against dyspepsia and other digestive disorders and disturbances of the gastrointestinal tract [103], and its addition to beer as a clarifying agent [104].

Preparations from papaya leaves are traditionally used for treating a wide variety of diseases ranging from dengue fever and malaria to diabetes mellitus, hypercholesterolemia, and hypertension [51, 101, 105]. Some of these claims may be explained, at least partially, by the presence of carotenoids and polyphenols, benzyl isothiocyanates and benzyl glucosinolates, and/or the cyanogenic substance prunasin in papaya skin, pulp, and seeds [101].

Support for the alleged antihypertensive effect of *C. papaya* was provided by the decrease in blood pressure in renal and salt-induced hypertensive Wistar rats treated with a crude ethanol extract from the unripened fruit [106]. This preparation, as well as a pentane extract from papaya seeds and an aqueous extract from papaya leaves relaxed vascular muscle tone of isolated rabbit arterial strips [106], strips of dog carotid artery precontracted with phenylephrine [107], and rat aortic ring preparations [108]. The relaxing effect of the fruit preparation was counteracted by phentolamine, suggesting that *C. papaya* contains (an) antihypertensive substance(s) that mainly exhibits α-adrenoceptor activity [108]. *C. papaya* preparations may also exert a blood pressure-lowering effect by stimulating diuresis, as suggested by the diuretic action of an aqueous root extract in laboratory rats, accomplishing similar effects on electrolyte excretion as hydrochlorothiazide [109].

3.7. Cucurbitaceae – *Cucumis sativus* L.

The cucumber plant *C. sativus* is originally from South Asia, most probably India, where it has been cultivated for more than 3000 years. Nowadays, hundreds of cultivars are grown throughout the world and traded on the global market. The mature fruit contains about 90% water and is relatively low in nutrients, and many enjoy its appetizing flavor and texture, making it a popular ingredient of fresh salads as well as pickles and relishes. Cucumber extracts are also widely used in facial tonics and moisturizers, presumably because their high water and antioxidant content would protect the skin from aging [93].

Preparations from *C. sativus* leaves, seeds, flowers, and fruits are also used in various traditional medicines for treating, among others, bacterial and parasitic infections, kidney and gall stones, as well as thrombosis and hypertension [45, 50, 52, 56, 110]. Preclinical evaluation of the plant parts showed various pharmacological activities including blood pressure-lowering effects [111, 112]. Some of these effects may be associated with the presence in the plant of bioactive compounds such as cucurbitacins, cucumegastigmanes I and II, cucumerin A and B, vitexin, and orientin [111, 112].

Importantly, a Chinese study found a significant reduction in blood pressure and a marked increase in coronary blood flow of patients receiving *C. sativus* vine compound tablets, as well as improved myocardial contraction in laboratory animals while no toxic effects were noted [113]. Furthermore, a relatively recent study conducted in Indonesia reported a reduction in mean blood pressure in elderly patients receiving 100 g of cucumber in juice form for 7 days [114].

The antihypertensive effects of these preparations may be associated with the stimulation of diuresis. Indeed, an ethanolic extract from the leaves of *C. sativus*, either alone or as part of a polyherbal formulation, had a moderately stimulatory effect on diuresis in laboratory rats when compared to furosemide [115]. Also, an ether extract from the seeds of *C. melo* increased diuresis in anesthetized dogs [116], and an aqueous extract from the leaves of *C. trigonus*

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caused a comparable diuretic effect as hydrochlorothiazide in conscious albino rats [117]. In the former study, urinary chloride excretion was increased suggesting that the extract had decreased tubular reabsorption [116].

3.8. Fabaceae – *Desmodium adscendens* (Sw.) DC.

The glue sticks *D. adscendens* is commonly encountered in forests, grasslands, secondary/disturbed vegetation, old cultivated fields, and roadsidesin tropical areas. The leaves and stems have probably been used for thousands of years by native peoples for a variety of health issues, including liver ailments, respiratory diseases, backache, rheumatism, gonorrhea, ovarian inflammation, and epilepsy [118, 119].

Main compounds in *D. adscendens* are flavonoids, triterpenes, saponins, amines, and alkaloids [120]. Pharmacological studies with *D. adscendens* leaf extracts showed, among others, spasmolytic effects in isolated guineas pig trachea and ilei precontracted with histamine [121, 122].

In Suriname, *D. adscendens* is generally known as '*konkruman*' ('informer') or '*toriman*' ('story teller') because the sticky pods stay clinging to clothing, betraying the unapproved presence of the bearer 'in the field', that is, away from home. Indigenous folklore believes that preparations from the plant attract and hold fortune and prosperity while at the same capturing and removing bad luck and disease [45]. A tea prepared from the macerated roots is also used as an antihypertensive [46]. This effect may be attributable to the above-mentioned relaxing effect of certain constituents of the plant on smooth muscle cells [121, 122] – possibly including those in blood vessel walls – but there are no scientific indications to support this presumption.

3.9. Fabaceae – *Hymenaea courbaril* L.

The courbaril, West Indian locust, or jatoba *H. courbaril* (**Figure 5**) is a common tree in the Caribbean, Central America, and South America. The hardwood is very durable and is used for manufacturing furniture, flooring, window frames, staircases, as well as canoes. The seeds are situated in a hard pod and are surrounded by an edible dry pulp that has an unpleasant scent reminiscent of foot odor. For this reason, the tree is also known as 'stinking toe' and 'old man's toe'. However, the pulp has a high content of starches and proteins and a sweet taste. It is often eaten raw; may be dried and powdered for making snacks; and may also be mixed with water to prepare a drink called 'atole'.

The stembark of the tree produces an orange, soft, sticky resin called 'animé', French for 'animated', referring to the large numbers of insects that are entrapped in it [123]. Animé has a pleasant fragrance and is used for the production of incense, perfume, and varnish [123]. Interestingly, the indigenous peoples of the Amazon have used *H. courbaril* resin for centuries to preserve the colors on their pottery [45]. Preparations from this substance, along with those from several other parts of the plant, have traditionally also been used in various South American and African countries for treating a variety of conditions such as anemia, kidney problems, dysfunctions of the respiratory system, and abdominal ailments [45, 123, 124].

Figure 5. Fabaceae – *Hymenaea courbaril* L. (from: https://goo.gl/images/ePJjyr).

Many bioactive compounds have been identified in leaves, seeds, and trunk resin of *H. courbaril*, including flavonoids, terpenoids, phenolic acids, steroids, and coumarins [124, 125]. Some of these compounds have been related to the myorelaxant, anti-inflammatory, and antimicrobial effects including activity against dengue virus type-2 observed in pharmacological studies with *H. courbaril* preparations [124, 126, 127]. In Suriname, the stembark is used to prepare a tea that would treat a similar variety of ailments as well as hypertension [45]. Whether the latter activity may be associated with vasodilation following relaxation of the smooth muscles [126] including those in the blood vessel walls remains to be determined.

3.10. Fabaceae – *Tamarindus indica* L.

The tamarind *T. indica* is probably indigenous to tropical Africa where it grows in the wild. It has been cultivated for centuries on the Indian subcontinent, and has been introduced in South America including Suriname by Spanish and Portuguese colonists in the sixteenth century. The fruit is a pod with a hard, brown shell that contains up to 12 seeds surrounded by a sweet and sour pulp that is used in cooking, to flavor foods, in refreshing drinks, and as a key ingredient of Worcestershire sauce.

Preparations from *T. indica* leaves, seeds, fruits, and roots are extensively used in folk medicine, among others, for treating abdominal discomfort, microbial and parasitic infestations, as an aphrodisiac, and against hypertension [48, 128, 129]. These parts of the plant contain various phenolic compounds, terpenes, sugars, as well as mucilage and pectin [128, 129]. Some of these constituents have been associated with, among others, antioxidant, anti-hyperlipidemic, and cardioprotective effects of the plant in laboratory models [130].

Furthermore, an aqueous tamarind seed extract produced a decrease in blood pressure, heart rate, as well as serum LDL, cholesterol, and HDL levels in streptozotocin-induced diabetic and hypertensive rats [131]. As well, administration of the dried and pulverized fruit pulp led to a decrease in diastolic blood pressure as well as total cholesterol and LDL-cholesterol levels in human subjects [132]. The blood pressure-lowering effects of the *T. indica* preparations have

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been suggested to occur through direct sympatho-inhibition [131], protection of the body against oxidative assault that could initiate the development of hypertension [131, 133], and/or lowering of blood lipid levels [133, 134].

3.11. Lauraceae – *Persea americana* Mill.

The avocado tree *P. americana* probably originates from Central America and the western parts of South America and was presumably domesticated as early as 5000 BC. Today, avocados are a successful cash crop with a high commercial value. Avocado is mostly eaten raw; (prolonged) cooking makes it inedible, causing a chemical reaction that confers a bitter taste to it. It is an ingredient of many servings and dishes and is often used in vegetarian cuisine as a substitute for meats because of its relatively high content of monounsaturated fats [135]. The rather expensive oil extracted from avocados is mostly used for salads or dips and in cosmetics and toiletries [136].

The stem bark, fruits, seeds, and leaves of *P. americana* are used in traditional medicine in Africa, the West Indies, as well as South and Central America including Suriname for treating, among others, menstrual problems, gastrointestinal ailments, bronchitis, diabetes mellitus, hypercholesterolemia, and hypertension [45, 46, 49, 52, 55, 137, 138]. Pharmacological evaluations with animal models provided some support for these ethnopharmacological claims [139]. These effects may partially be associated with the aliphatic acetogenins, terpenoid glycosides, furan ring-containing derivatives, flavonoids, and coumarins in various parts of the plant [140].

Evidence for an antihypertensive effect of *P. americana* leaf and seed preparations came from the relaxing effects they produced in isolated guinea pig atrial muscle strips, rat portal veins, and rat thoracic aortic rings precontracted with noradrenaline [141] and the blood pressure-lowering effects they produced in laboratory animals [141–143].

The mechanisms responsible for these effects may involve vasorelaxation by substances that inhibit Ca^{2+} influx and stimulate the synthesis and release of endothelium-derived relaxing factors and vasoactive mediators [144], modulation of ACE activity [145], and/or lowering of total cholesterol, triglycerides, VLDL, and/or LDL [143, 145, 146]. However, a clinical study found no benefit with respect to body weight, BMI, and percentage body fat, and no difference in serum lipids, fibrinogen, blood flow, or blood pressure when avocados were substituted for mixed fats in an energy-restricted diet [147].

3.12. Malvaceae – *Gossypium barbadense* L.

The sea island cotton or Egyptian cotton *G. barbadense* (**Figure 6**) is believed to have emerged in Peru as a cross between *G. herbaceum* L. and *G. raimondii* Ulbrich or *G. gossypioides* (Ulbrich) Standley. It is now widely cultivated in the warmer parts of the world, and is an important industrial and export product of Egypt, the West Indies, Sudan, Peru, and the USA.

Cotton is the soft white fibrous substance that surrounds the seeds of the plant and helps in the dispersal of the seeds [148]. It consists of 88–96% α-cellulose, 3–6% hemicellulose, and 1–2%

Figure 6. Malvaceae – *Gossypium barbadense* L. (from: https://goo.gl/images/NN46ra).

lignin [148]. Since about 2500 BC, the fibers are used for making sewing thread, yarn, cordage, and fishing nets, and more recently also for making coffee filters, paper, surgical dressings, and nitrocellulose-based explosives [148]. The seed oil can be incorporated in, among others, margarine and mayonnaise, but also in soaps, cosmetics, lubricants, and protective coatings [148]. The oil as well as other parts of *Gossypium* species contains the triterpenoid aldehyde gossypol that causes infertility in males [149]. Other constituents of *G. barbadense* are alkaloids, flavonoids, total phenols, cyanogenic glycosides, and saponins [148, 150].

G. barbadense preparations are widely used in traditional medicine. In many African countries as well as the Guianas including Suriname, preparations from leaves, roots, and seed oil are used for treating a multitude of diseases ranging from eye affections, otitis media, bronchitis, and menstrual problems to malaria, convulsions, gonorrhea, leprosy, and hypertension [45, 51, 52, 55, 151]. Pharmacological studies have supported some of these folk medicinal uses [151, 152].

The presumption of a blood pressure-lowering effect of *G. barbadense* was supported by the dose-dependent hypotensive effect of a fraction of a crude leaf extract in laboratory rats [153]. The results from parallel studies with several agonists and antagonists of acetylcholine receptors suggested that this occurred through an action on the central nervous system comparably to that of the centrally acting α_2-adrenergic agonist clonidine [153]. On the other hand, an aqueous extract from *G. barbadense* leaves decreased the tension of isolated guinea pig aorta rings stimulated with phenylephrine (a selective α_1-adrenergic receptor agonist) by 15–35% [75], suggesting that it may lower an elevated blood pressure by decreasing the peripheral vascular resistance.

3.13. Malvaceae – *Hibiscus sabdariffa* L.

The roselle *H. sabdariffa* (**Figure 7**) probably originates from Africa and is presumably domesticated in Sudan about 6000 years ago. It was initially cultivated for its seed and later for its leaves and bright red colored calyces which are particularly in the USA and Germany

Figure 7. Malvaceae – *Hibiscus sabdariffa* L. (from: https://goo.gl/images/BRZcTZ).

processed to give food colorings. The seed oil can be used for cooking and the seeds are eaten roasted as a snack. However, *H. sabdariffa* seeds probably contain toxic substances and may be better used for manufacturing soaps and shrubs [154]. Young shoots, leaves, and calyces can be included in certain dishes, and fresh or dried calyces are used to prepare flavorful and slightly acidic herbal teas, refreshing beverages that may be carbonated, cocktails with rum, as well as jams.

Preparations from *H. sabdariffa* leaves, calyces, and roots are widely used in traditional medicines because of their presumed antimicrobial, antioxidant, anticancer, hepatoprotective, hypocholesterolemic, antidiabetic, diuretic, and antihypertensive properties [45, 155, 156]. Phytochemical and pharmacological studies supported some of these uses [155, 156].

The results from preclinical studies have associated the potential antihypertensive (and cardioprotective) properties of particularly tea made from roselle calyces with its abundant content of polyphenolic compounds such as chlorogenic acids [157], as well as flavonoid compounds such as kaempferol, quercetin, and anthocyanins [156, 158]. Chlorogenic acids (modestly) reduced an elevated blood pressure [157, 159]. Kaempferol may have a protective effect in heart diseases [160]. Quercetin caused the release of NO from vascular endothelium, increasing renal vasorelaxation and kidney filtration, stimulating diuresis and decreasing blood pressure [161]. And the anthocyanins may exert antioxidant effects which inhibit LDL oxidation, impeding atherosclerosis, an important cardiovascular risk factor [162]. Alternatively, anthocyanins may decrease blood pressure by inhibiting ACE activity [163]. These compounds, along with the flavonoids and the chlorogenic acids, have also been suggested to decrease hypertension by stimulating diuresis following modulation of aldosterone activity [164].

However, comprehensive reviews and a meta-analysis suggest that the evidence for the use of *H. sabdariffa* preparations against hypertension is insufficient and recommend more high-quality animal and human studies to demonstrate benefit from these substances in this condition [162, 165, 166].

3.14. Meliaceae – *Azadirachta indica* A. Juss.

The neem tree *A. indica* is originally from the Asian subcontinent and is now grown in various tropical and semi-tropical regions. The bitter-tasting shoots and flowers are incorporated into various dishes, while preparations from leaves, bark, and fruits are consumed during many Hindu ceremonies, festivals, and commemorations.

A. indica leaves and seeds contain potent antiparasitic, insecticidal, and antimicrobial compounds such as the limonoids azadirachtin and nimbinin [167]. For this reason, dried neem leaves are placed in cupboards and storage facilities for grains to prevent damage from insects and burned to keep away mosquitoes, while the seed oil is used as a key ingredient of non-synthetic ecofriendly pesticides in agriculture, acting as an antifeedant, repellent, and egg-laying deterrent for insects [168]. The seed cake that remains after oil extraction is used as a fertilizer, enriching the soil with organic matter, and at the same time reducing nitrogen loss by inhibiting nitrification and averting damage to crops by termites and nematodes [168]. Neem oil is also a valuable ingredient of a large variety of cosmetics such as soaps, shampoos, balms, creams as well as toothpastes and nail polishes [169].

Parts of *A. indica* have been used for centuries in traditional and alternative medicinal systems in India and Suriname against a wide variety of diseases ranging from microbial infections and malaria to diabetes mellitus and hypertension [45, 170]. Some of these applications are supported by the results from pharmacological studies and may be related to the actions of, among others, azadirachtin and nimbinin [167, 171].

Indications for a potential antihypertensive effect of *A. indica* preparations were provided by the inhibitory effect of *A. indica* yogurt on ACE activity *in vitro* [172], and the blood pressure-lowering effect of leaf extracts in (salt-induced) rat models [173, 174]. Studies with laboratory rabbits suggested that these effects might also be due to vasodilation mediated through a combination of Ca^{2+} channel blockade, NO-inhibitory mechanisms, and cardiac depressant activity [175].

3.15. Oxalidaceae – *Averrhoa bilimbi* L.

The bilimbi *A. bilimbi* (**Figure 8**) presumably originates from Indonesia. It has been introduced in several Southeast Asian countries, and has spread to Australia as well as the Caribbean, Central America, and South America. The fruits can be eaten raw with salt and spice, pickled to obtain sweet and sour side dishes, incorporated in certain dishes as a souring agent, made into jams, or squashed to obtain a cooling beverage. However, *A. bilimbi* fruits (as well as leaves) contain high levels of oxalate [176] which may cause tubular necrosis and acute kidney failure when the concentrated juice is drunk on a daily basis [177].

Parts of *A. bilimbi* have been important sources of medicines since antiquity. Decoctions, infusions, powders, and pastes have been used in several traditional medicinal systems including those in Suriname for preventing and treating many diseases such as skin eruptions, cough, cold, syphilis, diarrhea, obesity, diabetes mellitus, microbial infections, and hypertension [46, 178]. Physicochemical and pharmacological studies supported some of these uses [179].

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Figure 8. Oxalidaceae – *Averrhoa bilimbi* L. (from: https://goo.gl/images/THfTgV).

Indications for efficacy against hypertension of *A. bilimbi* came from the decreased contractility of isolated guinea pig atria precontracted with norepinephrine upon exposure to an aqueous extract from the leaves [180]. Such an extract also produced a substantial antihypertensive effect in an *in vivo* study with cats [181]. The mechanisms underlying these observations may be associated with a decrease in cardiac output following alterations in intracellular calcium metabolism and/or phenomena involving the muscarinic receptor [180]. It is also possible that the relatively high levels of oxalate in these preparations [176] promote diuresis. A third possible mechanism involves inhibition of ACE activity, as suggested by the *in vitro* ACE-inhibitory effect of an *A. bilimbi* leaf ethanol extract which was comparable to that of captopril [182].

4. Concluding remarks

This chapter has addressed the plants that are used in Suriname for treating hypertension. About 60 of the approximately 800 medicinal plants in Suriname are used against this condition ([45–55]; **Table 1**), indicating both the high need of antihypertensive medications and the high demand for traditional plant-derived for treating this condition in the country. As mentioned above, the prevalence of hypertension and other cardiovascular diseases is relatively high in Suriname [32, 36, 37], while most Surinamese have a long tradition of using ethnopharmacological preparations for treating their diseases [21, 44].

However, an extensive evaluation of 15 plants that are commonly used against hypertension in Suriname indicates that there is little scientific evidence for clinical efficacy against this condition. As shown in **Table 2**, 3 of the 15 plants (*A. graveolens*, *C. nucifera*, and *C. sativus*) had undergone preclinical as well as clinical evaluation against hypertension and turned out positive in at least some of the clinical studies. However, the clinical studies merely comprised a handful, although those with 3-n-butylphthalide in *A. graveolens* were sufficiently encouraging to prepare larger scale clinical evaluations [90–92].

Nine other plants (*M. indica*, *A. muricata*, *C. papaya*, *T. indica*, *P. americana*, *G. barbadense*, *H. sabdariffa*, *A. indica*, and *A. bilimbi*) have only been tested in preclinical models of hypertension (**Table 2**), relatively few of which involved animal studies. And three of the plants (*R. tuberosa*, *D. adscendens*, and *H. courbaril*) have never been assessed for potential antihypertensive effects, not even in preclinical models (**Table 2**). On the bright side, with the exception of *H. courbaril*, there were in all cases suggestions about the mechanisms that may be involved in the antihypertensive effects (**Table 2**). Then again, the chemical substances responsible for these effects were only provided for 6 plants (*M. indica*, *A. muricata*, *A. graveolens*, *C. nucifera*, *H. sabdariffa*, and *A. indica*; **Table 2**).

These data clearly indicate that the scientific evidence accumulated so far to support the use of plant-based traditional medicines in Suriname against hypertension is scant. This raises not only the possibility that patients treat their disease with substances that may be ineffective, but also that they may run the risk of unknown or unforeseen adverse effects. For these reasons, it is necessary to subject these plants to comprehensive phytochemical and pharmacological investigations, elaborate preclinical evaluations, and well-designed and well-executed clinical studies to definitely establish their roles in the treatment of hypertension. Obviously, these enterprises will require considerable efforts from both academia and industry, but may eventually payoff when considering the importance of ancient wisdom and folk medicine to drug discovery and development programs [183].

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