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PHYTOTHERAPEUTIC POTENTIAL OF MEDICINAL PLANTS IN THE MANAGEMENT OF HYPERTENSION: A PHARMACOGNOSTIC REVIEW

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ABSTRACT

Hypertension, being one of the major health issues in the world is not well controlled despite many pharmacological interventions because of side effects, cost, and poor compliance. The use of medicinal plants is known as phytotherapy and this has again become a subject of concern as far as the complementary and alternative methods of treatment of high blood pressure is concerned. This pharmacognostic review brings to the ethnomedical significance, bioactive constituents and the mechanism of different antihypertensive medicinal plants. Most of these plants have vasodilatory, diuretic, ACE-inhibitory, calcium blockers and antioxidant properties, which reflect the current areas of focus in pharmacology. Such plants have been used in the tradition of Ayurvedic, Traditional Chinese Medicine, and Persian Medicine systems in the treatment of hypertension. As Phyto therapeutic agents continue to have increased scientific evidence in their efficiency and safety, they portray great cost-effective, beneficial prospects in the enhancement of effective hypertension treatment worldwide as an accompaniment to conventional treatment.

INTRODUCTION

One of the most widespread non-communicable diseases of the world and a significant risk factor for cardiovascular diseases, stroke, kidney failure, and early death is hypertension, or so-called high blood pressure. Clinically, it is diagnosed when systolic blood pressure (SBP) chronically remains above 140 mmHg and/or when diastolic blood pressure (DBP) is about 90 mmHg or higher. It is a problem of almost 1.3 billion adults globally, and a substantial proportion of those patients live in low- and middle-income countries (LMICs), where health care services are rather scarce (1). This is maybe because despite the presence of several synthetic antihypertensive agents, e.g., beta blockers, calcium channel blockers, ACE inhibitors, and diuretics, blood pressure is still not under control in the general population. Only 21 percent of the diagnosed patients control their blood pressure according to the WHO. The non-adherence to treatments has been associated with negative impacts like dizziness, fatigue, imbalance of electrolytes, and drug interaction, especially in the elderly who have many comorbidities(Baharvand-Ahmadi et al., 2016). Such constraints have given rise to the increased interest in complementary and alternative treatment, especially in the use of medicinal plants. Most of the time, herbal medicines have been thought of being safer, accessible, and even less expensive as compared to drug-induced medicines. Modern medicine systems like Ayurveda, Traditional Chinese Medicine (TCM), and Persian Medicine have focused extensively on using plant products in cardiovascular health, that is, hypertension(Goorani et al., 2025). WHO estimates reveal that about 75-80 percent of the world population depends on herbal medicine in case of their first-line healthcare requirements. The medical plants are a good source of bioactive compounds that are therapeutically significant. Various plants have been reported to have vasodilatory, diuretic, ACE inhibitors, calcium channel blockers, and antioxidant effects, which, in the case of hypertension, are consistent with the current pharmacological aims(Mills et al., 2020). There are abundant antihypertensive plants that have been identified in ethnobotanical inquiries used by varied cultures. In India, Iran, and West Africa, typical plants would be Allium sativum (garlic), Hibiscus sabdariffa, Tribulus terrestris, Crataegus spp., and Rauwolfia serpentina. They are made in decoctions, in infusions, or in powder and are commonly prescribed according to individual constitution and symptoms(Jin et al., 2024). Some of the identified compounds that have shown pharmacological activities in these plants include flavonoids, alkaloids, tannins, terpenoids, and saponins.

The pharmacological activities include their behaviour as reducing oxidative agents, a vasorelaxant, and activity on the renin-angiotensin-aldosterone system (RAAS)(Han et al., 2021). The Preclinical studies have confirmed that plant-derived compounds can significantly reduce blood pressure in animal models, with some even progressing to human trials(Burnier, 2019). In Persian traditional medicine views hypertension is viewed as a multifactorial disorder due to the humoral imbalances, errors in lifestyle, and vascular inflexibility. The choice of individual plants in herbal formulations is based on syndromic manifestations, e.g., fire syndrome or fluid retention syndrome, where the ultimate effect of the combination of plants is to achieve internal balance by diuresis, lowering of nervous tension, or restoration of endothelial activity(Kamyab et al., 2021). Additionally, new studies of Chinese herbal medicine have also shown that some herbal products decrease the oxidative stress of hypertensive patients by elevating the antioxidant enzymes and decreasing the reactive oxygen species (ROS). It concurs with the general therapeutic hypothesis that herbal drugs are capable of protecting the end organs as they help in controlling blood pressure(Traore et al., 2022). Considering the growing international increase in the prevalence of hypertension, the side effects and the cost burden of conventional treatment, and the rising scientific confirmation of healing plants, it is timely to reevaluate the place of phytotherapy in the contemporary treatment of hypertension. The aim of this review is to discuss pharmacognostic aspects, ethnomedical importance, and the mechanism of medicinal plants in the management of hypertension

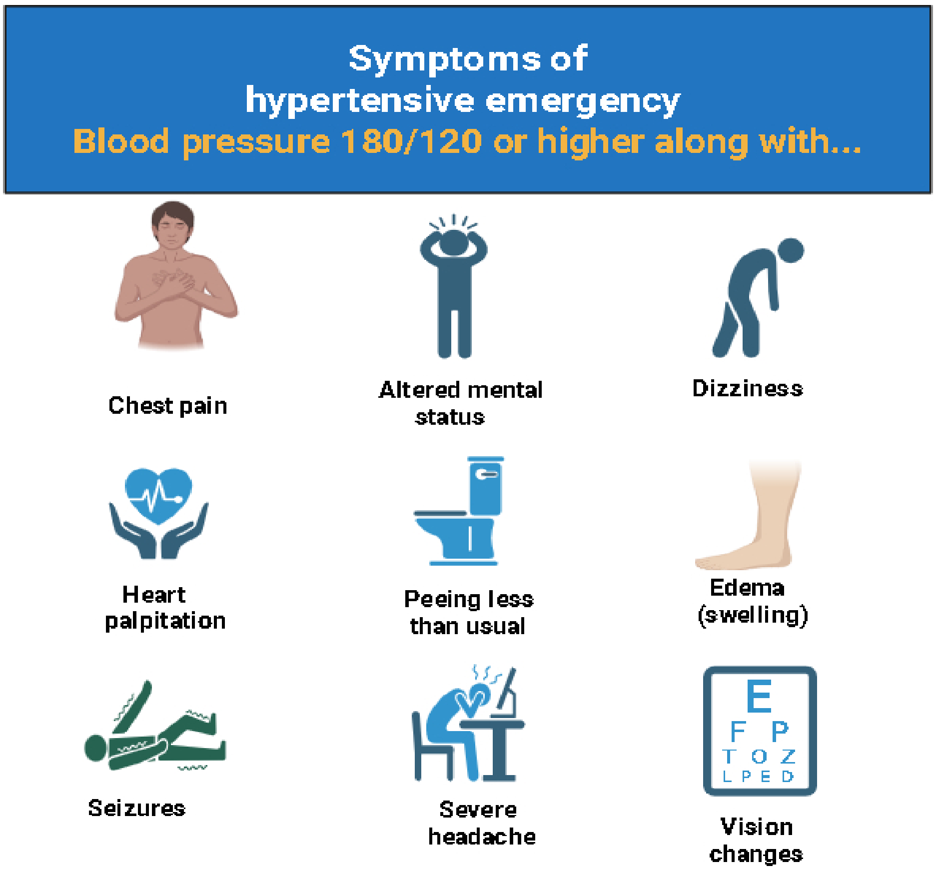

Fig.1: Symptoms of hypertension

2. PATHOPHYSIOLOGY OF HYPERTENSION

Hypertension is a complex systemic cardiovascular disease, the main risk factor of stroke, myocardial infarction, renal illness, and heart failure, which is associated with constantly high blood pressure in arteries. Pathogenesis occurs in hypertension and includes many closely connected mechanisms, influenced by the vascular resistance, cardiac output, renal function, and neurohormonal regulations(10).

2.1 Sympathetic Nervous System Overactivity

The sympathetic nervous system (SNS) is an essential part of the short-term and long-term blood-pressure control in the modulation of the heart-rate frequency, vascular tone, and sodium processing in the kidney(11). Chronic excess SNS activity is a factor that helps the condition develop in the presence of hypertension in the individual. This prolonged stimulating effect on the sympathetic nervous system causes a rise in the resistance created by peripheral vasculature because of a prolonged vasoconstrictive effect, elevated secretion of renin by juxtaglomerular cells, the activation of the renin-angiotensin-aldosterone system (RAAS), and an impaired responsiveness of the baroreceptors to compensate for the changes in blood pressure. Moreover, SNS is overstimulated because of the age-related changes. High levels of production of reactive oxygen species (ROS) and inflammation in discrete areas of the central nervous system, including the paraventricular nucleus (PVN) and the rostral ventrolateral medulla (RVLM), have been demonstrated to increase sympathetic outflow. This increases the activity of the neurons, leading to sustained elevation of blood pressure in the long term(Hirooka, n.d.).

2.2 Dysregulation of the Renin-Angiotensin-Aldosterone System (RAAS)

Renin-angiotensin-aldosterone system (RAAS) is one of the most important cascades of hormones that is involved in the maintenance of fluid-electrolyte balance and the control of the vascular tone. Angiotensin II (Ang II), in the event of hypertension, consists of the actions executed mostly via angiotensin type 1 (AT1) receptors, which involve vasoconstriction, stimulating secretion of aldosterone, and sodium retention(13). Also, Ang II plays a part in vascular hypertrophy, oxidative stress, and tissue fibrosis. In aging, despite the potential down-regulation of the overall activity of the RAAS system, the local (tissue-specific) RAAS activity goes up and, thus, contributes to the development of a hypertension pathology to a further degree. Also, an impairment of the protective ACE2/Ang (17) receptor axis, which ultimately opposes the detrimental impacts of the conventional ACE/Ang II/AT1R pathway, is frequently reported. This mismatch results in a continued vasoconstriction and the eventual damage to target organs(14,15).

2.3 Oxidative Stress and Inflammatory Pathways

Oxidative stress describes the resulting imbalance in the ratio between the endogenous formation of reactive oxygen species (ROS) to poor antioxidant defence. Oxidative stress is considered to be the key factor in the pathology of high blood pressure(16). NADPH oxidase is activated by angiotensin II (Ang II), which results in overproduction of ROS. These ROS oxidize nitric oxide (NO), an important endothelium-derived vasodilator, to give rise to impaired vasodilation and endothelial dysfunction. Also, ROS stimulates the redox-sensitive transcription factors like nuclear factor-kappa B (NF-kB) that induce expression of pro-inflammatory cytokines, such as tumour necrosis factor-alpha (TNF-alpha) and interleukin-6 (IL-6)(17). This process of pro-inflammatory environment has a role to play in vascular injury and remodelling. Redox-sensitive signalling cascade also contributes to arterial stiffening, ongoing vasoconstriction, and target-organ damage, especially the heart, the brain, and the kidneys(Gallo et al., 2022).

2.4 Endothelial Dysfunction

The endothelium is of great importance to the regulation of the vascular tone and the avoidance of thrombosis and inflammation. In hypertension, endothelial dysfunction also acquires the status of one of the causes of the disease progression. Extensive inhibition occurs in the synthesis of vasodilators (like nitric oxide (NO) and prostacyclin), and there is a severe increase in the expression of potent vasoconstrictors (such as endothelin-1). This cannot be balanced, leading to prolonged vasoconstriction and increased vascular resistance. Moreover, changes in vasculature have been observed in terms of structural alterations, including thickening of the arterial wall and a decrease in vascular compliance, which further increases stiffness of the vascular system. These alterations, along with disturbed shear stress, high reactive oxygen species (ROS) concentrations, as well as pro-inflammatory cytokine expression, lead to a dysfunctional endothelial phenotype. The outcome becomes a prothrombotic and pro-inflammatory vascular environment, which heightens target organ damage and cardiovascular risks(19).

2.5 Renal Dysfunction and Salt Sensitivity

The long-term blood pressure is mainly controlled by the kidneys because of their effects on fluid and electrolyte balance. Hypertension involves various renal processes, which cause an increase in blood pressure. Diminished glomerular filtration rate (GFR) interrupts the excretion of sodium, and an enhanced resistance to renal vascular resistance additionally constrains the pressurized sodium discharge. There is also stimulation of the intrarenal renin-angiotensin-aldosterone system (RAAS) to increase tubular sodium reabsorption that facilitates expanded volume. These kidney changes also create volume overload and the development of salt-sensitive hypertension, especially in older people and in obese people. Reduced Klotho activity as a result of aging is also related to decreases in vascular health. Lower activity of Klotho leads to poor sodium excretion, renal dysfunction, and vascular dysfunction that serve to worsen high blood pressure[20].

2.6 Aging and Vascular Stiffness

Aging is the greatest among the non-modifiable risk factors of hypertension. The aging of vascular tissue manifests itself in structural and functional alterations of the arterial wall, the weakening of the elastic fibres, and the proliferation of the collagen fibres, which all result in an increased stiffness in the arterial wall. The change causes high pulse wave velocity and an early reaction that causes high systolic pressure. Isolated systolic hypertension (ISH), as one of the most representative occurrences of the vascular aging condition, is especially prevalent among the elderly. Repeated mechanical stress as a product of lifelong heartbeat is suggested, as well as oxidative injury and chronic inflammation. Moreover, reduced baroreflex sensitivity and ventricular-arterial coupling are typical with age due to increased difficulties in managing blood pressure with age[21].

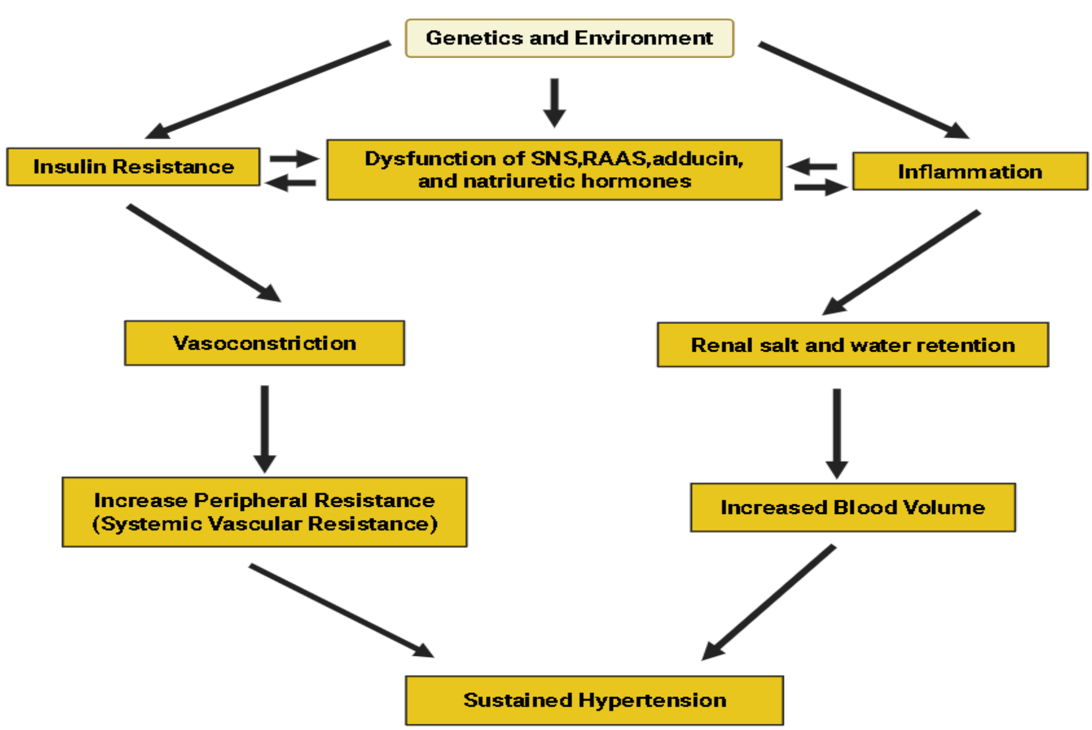

Fig.2 Pathophysiology of Hypertension

3. **Limitations of Current Antihypertensive Drugs**

The prevalence of uncontrolled hypertension all over the world is high, even though a great number of antihypertensive drugs are available. The current pharmacological treatment has several limitations, which are the side effects of drugs, cost and availability challenges, and resistance to treatment or lack of patient adherence. These restrictions are particularly severe in the low-resource and aging populations, where management of hypertension remains a great challenge to the common person[22].

3.1 Side Effects and Tolerability

The antihypertensive drugs have a wide difference in tolerability, taking into consideration the class of drugs and also individuals. Most frequently used agents, such as 0-blockers, ACE inhibitors, diuretics, and calcium channel antagonists, are linked with negative effects. These can be fatigue, electrolyte imbalance, metabolic imbalance, sexual dysfunction, or cough, which has the effect of limiting the long-term adherence to the treatment and poor long-term control[23].

Moreover, many of the available antihypertensive drugs were created empirically on a clinical level instead of focusing on location and specificity. Consequently, although there are several classes of drugs available, patients tend to discontinue and alternate treatments based on side effects of drugs or drug-drug interactions[24].

3.2 Cost and Accessibility

The cost of antihypertensive drugs is one of the main obstacles to the successful treatment of high blood pressure, especially in low- and medium-income states. A cost analysis of global access to treatment concluded that most developing nations are unable to afford the implementation of the same pharmacological regimens as the high-income countries use. The newer or combination therapies may not be affordable to the poor, who may manage only the older and cheaper thiazide or the ACE inhibitors. Poor access to quality healthcare services and unavailability of infrastructural support to health systems, especially in the sub-Saharan Africa region and certain parts of Asia, further compromise the identification and management of hypertension (Seedat, n.d.). The cost of treating hypertension is also high in the richer countries. Examples of this include the fact that in the United States, antihypertensive drugs cover a large part of the cost of hypertension treatment, which is pegged at 733 dollars a year, per capita (Park et al., 2017).

3.3 Drug Resistance and Poor Compliance

An increasing clinical issue is hypertension that is resistant to treatment, with a reduction in blood pressure measures occurring in the presence of at least three antihypertensive medical products, one being a diuretic. Researchers hold that its prevalence in hypertensive patients who receive treatment ranges between 5% and 30% of the population(Sarafidis & Bakris, 2008). Obesity and high amounts of salt consumption are factors that increase resistance, along with more signs of sympathetic influx and overactivity of the renin-angiotensin-aldosterone system (RAAS). Treatment adherence Nonadherence with treatment, because of the presence of side effects, the complexity of the regimen, or the cost of treatment, can lead to apparent resistant hypertension, which can be indistinguishable from compliance with adequate pharmacologic intensity. This is important in drawing a line between them to know how to relate to them in terms of management(Faconti et al., 2025). Moreover, based on the results of large cohort studies including the Atherosclerosis Risk In Communities (ARIC) study, it has been established that people who have resistant hypertension have a high probability of cardiovascular events, including myocardial infarction, heart failure, and even stroke. These risks occur irrespective of whether there is use of older or newer blood pressure target settings(Wijkman et al., 2021)

Table 1: Conventional Antihypertensive Drug Therapy

S. No	Drug Class	Example Drugs	Mechanism of Action	Indications	Adverse Effects	Reference
1.	Thiazide Diuretics	Hydrochlorothiazide, Chlorthalidone	Inhibit sodium and chloride reabsorption in the distal convoluted tubule, leading to decreased plasma volume and reduced peripheral resistance.	First-line treatment in most patients, including the elderly	Hyperglycaemia, increased uric acid	(Patel & Preuss, 2025)
2.	Loop diuretics	Furosemide, Torsemide	Block the Na + /K + /2Cl - common transporter in the thick portion of the loop of Henle, resulting in a powerful diuretic and a decrease in volume.	Can be a useful agent in renal impairment and fluid overload	Hypokalaemia, ototoxicity, dehydration	(Sica et al., 2011)
3.	Potassium-sparing Diuretics	Amiloride, Triamterene	The epithelial sodium channels (ENaC) get blocked in the distal nephron, causing sodium excretion while retaining potassium	It prevents diuretic-induced hypokalaemia	Hyperkalaemia, nausea, dizziness	(Chapman et al., 2007; Williams et al., 2015)
4.	Aldosterone Antagonists	Spironolactone, Eplerenone	It inhibits aldosterone binding at the mineralocorticoid receptor, transfer natriuresis and potassium retention.	Heart failure, hyperaldosteronism	Hyperkalaemia, gynecomastia (spironolactone)	(Khosla et al., 2009)

5.	Calcium Channel Blockers	Amlodipine, Nifedipine	L-type calcium channels get inhibited in vascular smooth muscle, causing vasodilation and a reduction in peripheral resistance	First-line treatment in black and elderly populations	Headache, edema, flushing	(McKeever et al., 2025)
6.	Beta blockers	Atenolol, Metoprolol, Propranolol	Inhibit beta 1-adrenergic receptors in the heart, reducing heart rate and contractility, and also reducing renin release.	Heart Failure, high blood pressure	Hypertension, heart failure	(Khan & McAlister, 2006)

4. PHYTOTHERAPEUTIC MEDICINAL PLNATS IN HYPERTENSION MANAGEMENT

Hypertension is an extremely widespread lifestyle-based ailment infecting millions of human beings globally. It causes a lot of severe complications such as heart attack, stroke, and kidney damage. It has several modes or treatments, which are more or less divided into allopathic (modern medicine) and ayurvedic/natural types of treatment (such as herbal/phytotherapy). Each of them has strengths and weaknesses. The most common method in the entire world is the Allopathic one. It includes synthetic medications such as ACE inhibitors, beta blockers, diuretics, and calcium blockers. These drugs directly work on the physiological systems to maintain the blood pressure by slowing down the heartbeat, dilating the vessels, or eliminating excess body fluid. As an illustration, such pills as captopril have proven efficient in reducing blood pressure and enhancing cardiovascular status. However, as well, Allopathic medications appear to have side effects, such as an electrolyte imbalance, fatigue, dizziness, or sexual dysfunction(Chou, n.d.)

Ayurvedic and natural therapies, on the contrary, pay more attention to long-term body equilibrium. They involve the use of plant extracts and natural products that normally work on an antioxidant or a vasodilator, or a diuretic effect. They are more natural solutions that also assist in controlling related conditions such as stress, digestion, and cholesterol. To illustrate, a study that compared the olive leaf extract directly with the current medication, captopril, had virtually the same results, as it reduced blood pressure in patients with stage-1 hypertension. Interestingly enough, there was also an improvement in lipid profile (cholesterol levels) by olive leaf extract, and this could be a possible added advantage to its natural treatment(Susalit et al., 2011)

The antihypertensive abilities of natural products such as alkaloids, flavonoids, and terpenes present in herb plants have been demonstrated by acting through mechanisms such as venous calcium blocking mechanisms, enhancement of nitric oxide, and blockage of alpha-receptors. Part of them is rhynchophylline, dicentrine, and oleuropein(Bai et al., 2015)

Further, other plants such as Vitex cienkowskii demonstrated high antihypertensive activity among rats due to vasorelaxation and antioxidant properties, thereby being indicative in African traditional medicine systems (Metchi Donfack et al., 2021). Likewise, the ayurvedic medicine pays greater attention to the body constitution (prakriti), diet, detoxification treatments, and herbal medication.

But herbal medication also has its setbacks, such as a lack of standard dosage, the possibility of adulteration or contamination, and slow rates of occurrence as compared to synthetic ones. There are risks of some herbs reacting with allopathic medicines, too, hence the safety assessment is highly essential. It is, however, regarded as safer, but can elevate to a state of toxicity in small cases due to improper or unregulated use (Balkrishna et al., 2024)

Table 2: Plant-Derived Agents for Hypertension Management: Mechanism and Botanical Source

S. No	Scientific Name	Family	Plant Part Used	Mechanism/Effect	Reference
1	*Allium sativum*	Amaryllidaceae	Bulb	ACE inhibition, vasodilation	(Reinhart et al., 2008)
2	*Persea americana*	Lauraceae	Leaves, Seeds	Antioxidant, lipid-lowering	(Gbolade, 2012)
3	*Acalypha godseffiana*	Euphorbiaceae	Leaves	Hypotensive activity (ethnobotanical)	(Ikewuchi et al., 2011)
4	*Zingiber officinale*	Zingiberaceae	Rhizome	Anti-inflammatory, Vasodilator	(Nicoll & Henein, 2009)
5	*Sida acuta*	Malvaceae	Whole Plant	Antioxidant, hypotensive	(Karou et al., 2006)
6	*Rauwolfia vomitoria*	Apocynaceae	Roots	Adrenergic neuron Inhibitor (reserpine content)	(Al Disi et al., 2016)
7	*Moringa oleifera*	Moringaceae	Leaves, Seeds	Antioxidant, vasorelaxant	(Aumeeruddy & Mahomoodally, 2020)
8	*Cymbopogon citratus*	Poaceae	Leaves	Diuretic, vasodilatory	(Bekoe et al., 2017)

9	*Bambusa vulgaris*	Poaceae	Leaves	Antioxidant, diuretic	(Aumeeruddy & Mahomoodally, 2020)
10	*Olea europea*	Oleaceae	Leaves	Antioxidant, vasodilator	(Susalit et al., 2011)
11	*Annona muricata*	Annonaceae	Leaves, Roots	Diuretics, sedatives	(Moradi et al., n.d.)
12	*Catharanthus roseus*	Apocynaceae	Leaves	Alkaloids, hypotensive	(Moradi et al., n.d.)
13	*Berberis vulgaris*	Berberidaceae	Fruits	ACE inhibition, hypotensive	(Moradi et al., n.d.)
14	*Ziziphus spina-christ*	Rhamnaceae	Leaves Bark	Vasorelaxant	(Asadi-Samani et al., 2017)
15	*Crataegus spp.*	Rosaceae	Berries, Flowers	ACE inhibition, cardiac Tonic	(Brixius et al., 2006)
16	*Hibiscus sabdariffa*	Malvaceae	Calyces	Diuretic, ACE inhibition	(Aloufi et al., 2022)
17	*Nigella sativa*	Ranunculaceae	Seeds	Antioxidant, ACE Inhibition, No enhancement	(Jaarin et al., 2015)
18	*Apium graveolens*	Apiaceae	Whole plant	Diuretic, catecholamine Suppression	(Siska et al., 2018)
19	*Ajwain (Carum copticum)*	Apiaceae	Seeds	Calcium channel blocker	(Boskabady et al., 2014)
20	*Passiflora edulis*	Passifloraceae	Leaves, Fruit	Mild sedative, hypotensive	(Falzon & Balabanova, 2017)
21	*Achillea wilhelmsii*	Asteraceae	Aerial parts	Vasorelaxant	(Rawat et al., 2016)
22	*Panax guinguefolius*	Araliaceae	Root	Reduces vascular Resistance	(Priyanka Baramati et al., n.d.)
23	*Anethum graveolens*	Apiaceae	Leaves	Diuretic, antioxidant	(Priyanka Baramati et al., n.d.)
24	*Vitex cinekowskii*	Verbenaceae	Stem Bark	Antioxidant, vasorelaxant	(Metchi Donfack et al., 2021)
25	*Clerodendron trichotomum*	Lamiaceae	Stem	ACE inhibitor, Antihypertensive	(Kang et al., 2003)
26	*Tanacetum vulgare*	Asteraceae	Leaves	NO production enhancer, Vaso relaxing	(Lahlou et al., 2008)

CONCLUSION

Hypertension is one of the most critical health problems in the world, and nowadays, treatments with drugs have certain limitations related to side effects, overpricing, and low adherence. The resultant effect of this has been the increased interest in medicinal plants as safer, readily procurable, and effective medicines. Most plants have these properties, including Allium sativum, Rauwolfia vomitoria, and Hibiscus sabdariffa, that demonstrate antihypertensive characteristics via effects such as Alkaline conversion enzyme (ACE) inhibition, vasodilation, and antioxidants. These remedies have been in use in the traditional medicine system and are being increasingly supported by modern studies as to the fallings of these medicines. Phytotherapy has a promising and major role to play in the management of hypertension, with additional research and validation, more so in low-resource contexts.

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