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HERBAL MEDICINES FOR CARDIOPROTECTION: CURRENT EVIDENCE AND FUTURE DIRECTION

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ABSTRACT

Cardiovascular diseases (CVDs) remain the leading cause of morbidity and mortality worldwide, highlighting the need for effective preventive and therapeutic strategies. Medicinal plants have gained significant attention as potential cardioprotective agents due to their rich content of bioactive phytochemicals, including flavonoids, polyphenols, alkaloids, terpenoids, saponins, and tannins. These natural compounds exhibit antioxidant, anti-inflammatory, antihypertensive, hypolipidemic, antithrombotic, and anti-apoptotic activities that help protect the myocardium and vascular endothelium from damage. This review provides a comprehensive overview of cardiovascular diseases, their major risk factors, pathophysiology, and the concept of cardioprotection, while emphasizing the role of medicinal plants in maintaining cardiovascular health. Traditional systems of medicine such as Ayurveda and Siddha have long utilized herbal remedies for the prevention and management of heart diseases, and many of these claims are now supported by modern pharmacological studies. Important cardioprotective plants discussed include Terminalia arjuna, Allium sativum, Tinospora cordifolia, Picrorhizakurroa, Daucus carota, Ginkgo biloba, Salvia miltiorrhiza, and Centella asiatica, among others. Evidence from preclinical studies demonstrates their ability to reduce oxidative stress, improve lipid profiles, regulate blood pressure, preserve cardiac function, and minimize myocardial injury. Although several clinical studies have shown promising therapeutic benefits, further large-scale, well-designed clinical trials and standardized herbal formulations are required to confirm their long-term safety and efficacy. Recent advances in nanotechnology-based herbal drug delivery systems offer improved bioavailability and targeted therapeutic action, enhancing the clinical potential of plant-derived cardioprotective agents. Overall, medicinal plants represent a promising complementary approach for the prevention and management of cardiovascular diseases and warrant continued scientific investigation.

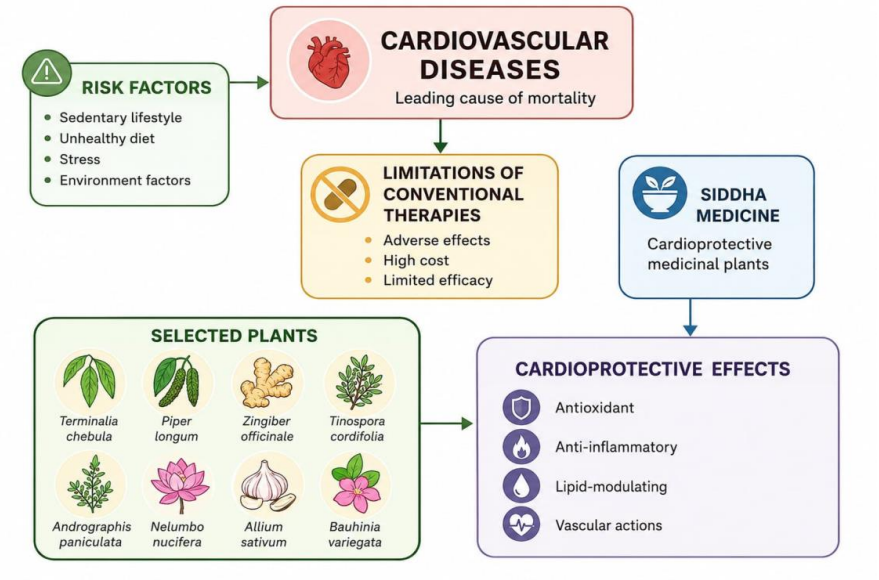
KEYWORDS: Cardio protection, Medicinal plants, Cardiovascular diseases, Antioxidant activity, Herbal therapeutics.

INTRODUCTION

Medicinal plants have long been recognized as valuable sources of therapeutic agents because they contain a wide range of bioactive secondary metabolites and essential oils with medicinal properties. They are widely used in the management of various diseases due to their affordability, safety, effectiveness, easy availability, and accessibility. These advantages have contributed to the extensive use of herbal remedies by traditional healers, making herbal medicine an integral part of daily healthcare practices in many communities. Across the world, herbal medicines continue to play an important role in maintaining health, and many indigenous populations have preserved their knowledge of medicinal plants as part of their cultural traditions.[1–3]

Plant-derived phytochemicals, particularly polyphenols, have attracted considerable attention for their cardioprotective properties. One of their major mechanisms of action is the prevention of low-density lipoprotein (LDL) oxidation, thereby reducing the risk of cardiovascular disorders. Numerous clinically important drugs used in modern medicine have originated from plants, highlighting their significance in both human and veterinary healthcare. Medicinal plants are utilized not only for the treatment of diseases but also for disease prevention and health promotion. Herbal therapies have been traditionally employed for the management of ischemic heart disease and related cardiovascular conditions for many years. During the past few decades, extensive phytochemical, pharmacological, and clinical studies have provided strong evidence supporting the effectiveness of plant-based medicines in the treatment of various diseases, leading to their increasing global acceptance.[4]

Cardiovascular disease (CVD) remains one of the leading causes of death worldwide and continues to impose a major public health burden. More than 14 million deaths were attributed to CVD in 1990, and this number was projected to rise to approximately 25 million by 2020.[3] The prevalence of CVD has increased steadily across both developed and developing countries, with developing nations experiencing a rapid epidemiological transition. Lifestyle-related factors, including unhealthy dietary habits, physical inactivity, obesity, and diabetes, are among the major contributors to the growing incidence of cardiovascular diseases.[2]



CARDIOVASCULAR DISEASES: AN OVERVIEW

Cardiovascular diseases (CVDs) are a group of disorders affecting the heart and blood vessels and are the leading cause of death worldwide. They include coronary artery disease, stroke, heart failure, hypertension, peripheral arterial disease, and cardiomyopathies. According to the World Health Organization (WHO), CVDs account for approximately 17.9 million deaths annually, representing nearly one-third of all global deaths.

The development of CVDs is associated with modifiable risk factors such as hypertension, diabetes, dyslipidemia, obesity, smoking, unhealthy diet, and physical inactivity, as well as non-modifiable factors including age, sex, and genetic predisposition. These factors contribute to oxidative stress, inflammation, endothelial dysfunction, and atherosclerosis, leading to cardiovascular complications.[5]

Current management includes lifestyle modification and pharmacological therapy; however, long-term drug use may cause adverse effects. Therefore, medicinal plants rich in bioactive phytochemicals have gained increasing attention due to their antioxidant, anti-inflammatory, antihypertensive, and cardioprotective properties, making them promising candidates for the prevention and management of cardiovascular diseases.[4]

AYURVEDIC AND SIDDHA PERSPECTIVES ON CARDIOPROTECTION

Traditional Indian systems of medicine, particularly Ayurveda and Siddha, have long utilized medicinal plants for maintaining cardiovascular health and treating heart-related disorders. These systems emphasize a holistic approach, combining herbal medicines, dietary modifications, lifestyle practices, and rejuvenation therapies to prevent and manage cardiovascular diseases.[6]

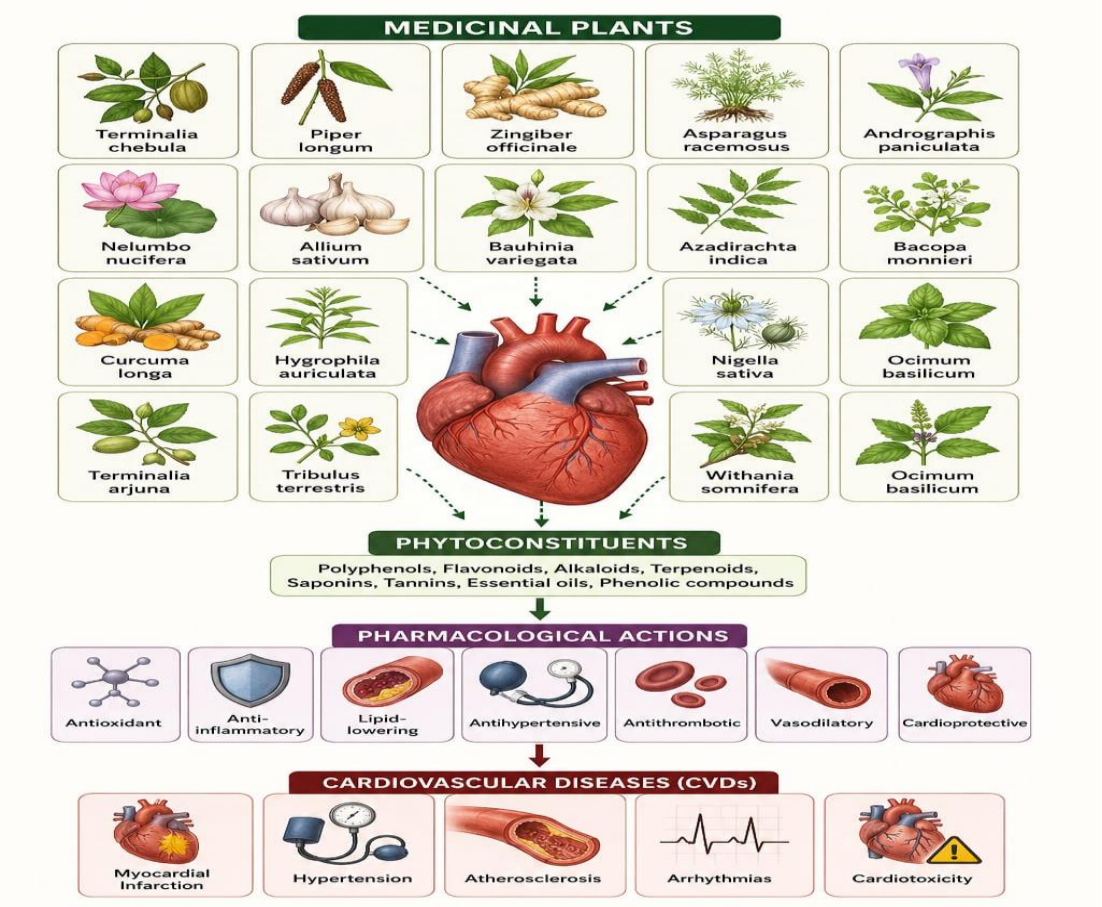
In Ayurveda, the heart (Hridaya) is regarded as a vital organ responsible for the circulation of blood and maintenance of life. Cardiovascular disorders are primarily associated with an imbalance of the Tridoshas (Vata, Pitta, and Kapha), leading to impaired circulation and cardiac dysfunction. Herbs such as Terminalia arjuna (Arjuna), Withaniasomnifera (Ashwagandha), Allium

sativum (Garlic), and Ocimum tenuiflorum (Tulsi) are widely used for their antioxidant, antihypertensive, hypolipidemic, anti-inflammatory, and cardioprotective properties.[5] Similarly, Siddha medicine attributes cardiovascular disorders to disturbances in the three humors (Vatham, Pitham, and Kabam). Siddha formulations prepared from medicinal plants, minerals, and natural products are traditionally used to improve blood circulation, strengthen cardiac muscles, regulate blood pressure, and reduce oxidative stress. Commonly used cardioprotective herbs include Terminalia arjuna, Phyllanthus emblica (Amla), Tinospora cordifolia (Seenthil), Andrographis paniculata (Nilavembu), and Allium sativum (Garlic).[5]

Modern pharmacological studies support many of these traditional claims by demonstrag that these medicinal plants possess antioxidant, anti-inflammatory, lipid-lowering, vasodilatory, and anti-apoptotic activities. These findings highlight the potential of Ayurvedic and Siddha medicinal plants as complementary approaches for the prevention and management of cardiovascular diseases.[5]

Table 1: Ayurvedic herbs used in cardiovascular disease.

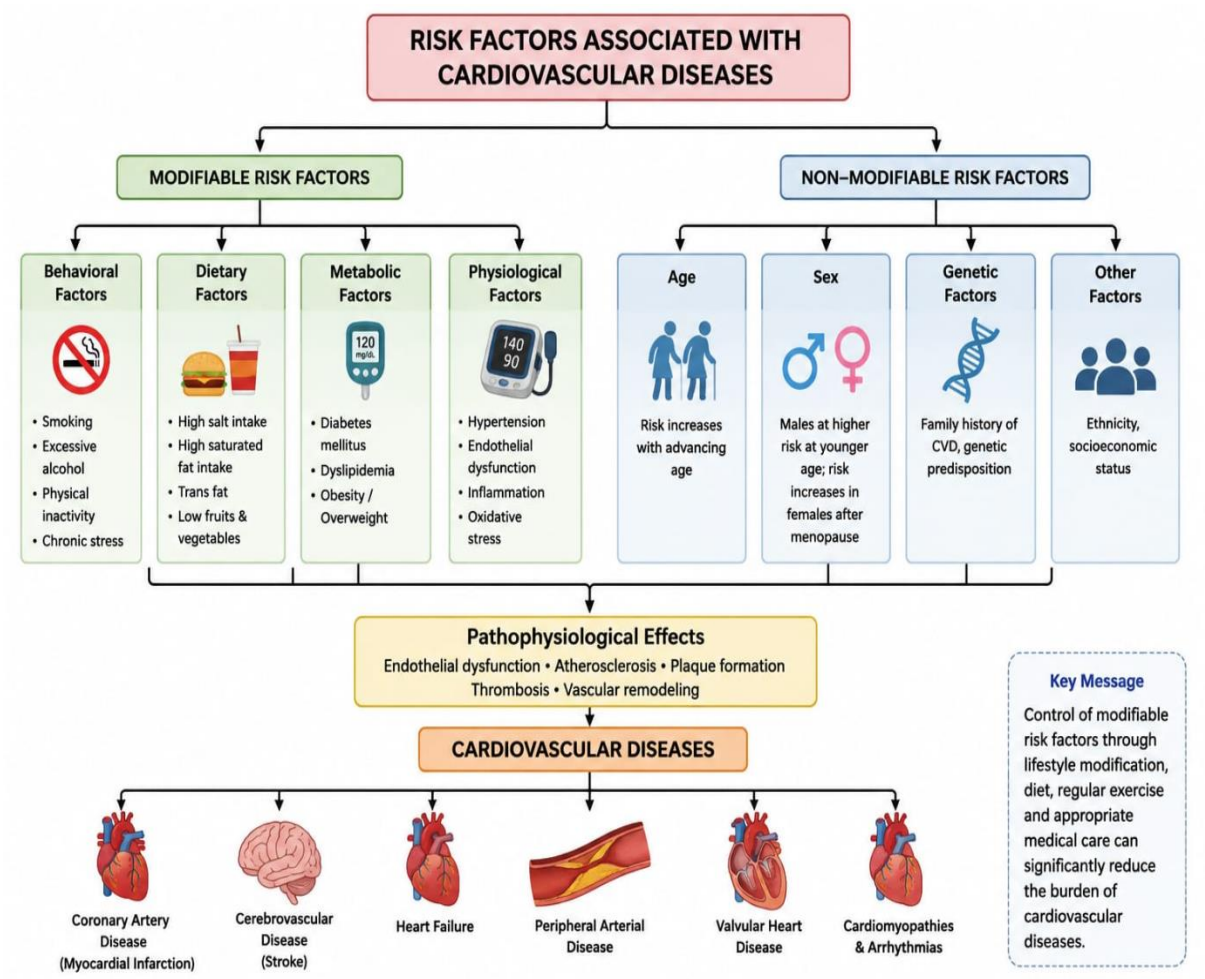
Condition	Name of the plants
Herbs which decrease blood pressure	Rauwolfia serpentina (sarpagandha), daucuscarota (carrot seeds) fumaria indica (parpata), cassiaabsus (chaksu), Acorus calamus (vacha)
Herbs which are diuretic	Tribulus terrestris (Gokshura), Boerhaaviadiffusa (Punarnava), Phyllanthus Herbs Which Are Diureticniruri (Bhumi amalaki), Tinospora cordifolia (Guduchi), Taraxacum officinale(Dandelion)
Herbs Which Reduce Serum cholesterol	Commiphora mukul (Guggulu)
Herbs Acting as Cardiac Tonics	Tonics Terminalia arjuna (Arjuna), Saussurealappa (Kushtha), Sida cordifolia (Bala), Digitalis purpurea (Foxglove)
Herbs That Decrease Platelet Aggregation	Allium sativum (Garlic)
Herbs With Anti-Stress/ General tonic properties	Withaniasomnifera (Ashwagandha), Bacopa monnieri (Brahmi), Evolvulus Tonic Propertiesalsinoides (Shankhpushpi)



RISK FACTORS ASSOCIATED WITH CARDIOVASCULAR DISEASES

Cardiovascular diseases (CVDs) arise from the interaction of multiple modifiable and non-modifiable risk factors. Modifiable risk factors include hypertension, diabetes mellitus, dyslipidemia, obesity, smoking, excessive alcohol consumption, unhealthy diet, physical inactivity, and psychological stress.[6] These factors contribute to endothelial dysfunction, oxidative stress, chronic inflammation, and atherosclerosis, ultimately increasing the risk of myocardial infarction, stroke, and heart failure.

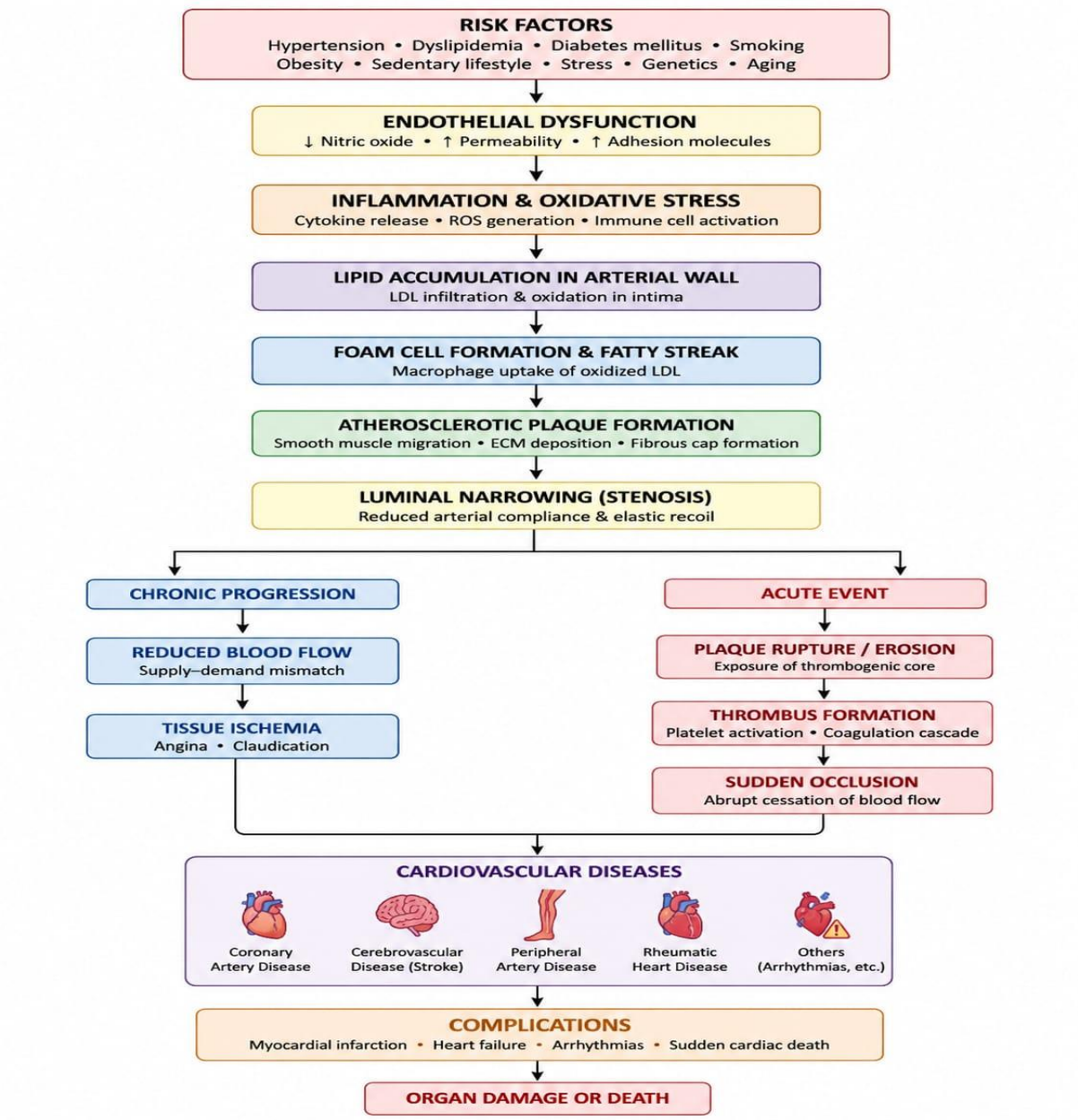
Non-modifiable risk factors include advancing age, male sex, genetic predisposition, and a family history of cardiovascular disease. The coexistence of multiple risk factors significantly increases the likelihood of developing CVDs. Early identification and effective management of these risk factors through lifestyle modifications, pharmacological interventions, and preventive healthcare strategies are essential for reducing cardiovascular morbidity and mortality.[6-7]



PATHOPHYSIOLOGY OF CARDIOVASCULAR DISEASES

Cardiovascular diseases (CVDs) result from complex interactions among genetic, environmental, and lifestyle factors that impair the structure and function of the heart and blood vessels. The initial event is often endothelial dysfunction, triggered by hypertension, hyperglycemia, dyslipidemia, smoking, and oxidative stress. Endothelial injury promotes inflammation and increases vascular permeability, facilitating the accumulation of low-density lipoprotein (LDL) cholesterol within the arterial wall.

Oxidized LDL activates inflammatory cells, leading to the formation of foam cells and fatty streaks, which progressively develop into atherosclerotic plaques.[8] Plaque growth narrows the arterial lumen and reduces blood flow, while plaque rupture can trigger thrombus formation, causing myocardial infarction or ischemic stroke. In addition, chronic inflammation, oxidative stress, apoptosis, and vascular remodeling further contribute to cardiac dysfunction and heart failure. Understanding these mechanisms is essential for developing effective preventive and therapeutic strategies, including the use of medicinal plants with antioxidant, anti-inflammatory, and cardioprotective properties.[6-8]



CARDIOPROTECTION: DEFINITION AND IMPORTANCE

Cardioprotection refers to strategies, interventions, or therapeutic agents that preserve the structure and function of the heart by preventing or reducing myocardial injury caused by ischemia, oxidative stress, inflammation, apoptosis, and other pathological processes. The primary goal of cardioprotection is to minimize cardiac damage, maintain normal cardiac function, and improve clinical outcomes in patients with cardiovascular diseases.[9]

Cardioprotective approaches include lifestyle modifications, pharmacological therapies, and the use of natural products such as medicinal plants and their bioactive phytochemicals. Plant-derived compounds, including flavonoids, polyphenols, alkaloids, saponins, and terpenoids, exhibit antioxidant, anti-inflammatory, antihypertensive, antihyperlipidemic, and anti-apoptotic activities, which help protect the myocardium and vascular endothelium from injury.[10] Therefore, cardioprotection plays a crucial role in the prevention and management of cardiovascular diseases and has become an important area of research for developing safe and effective therapeutic agents.

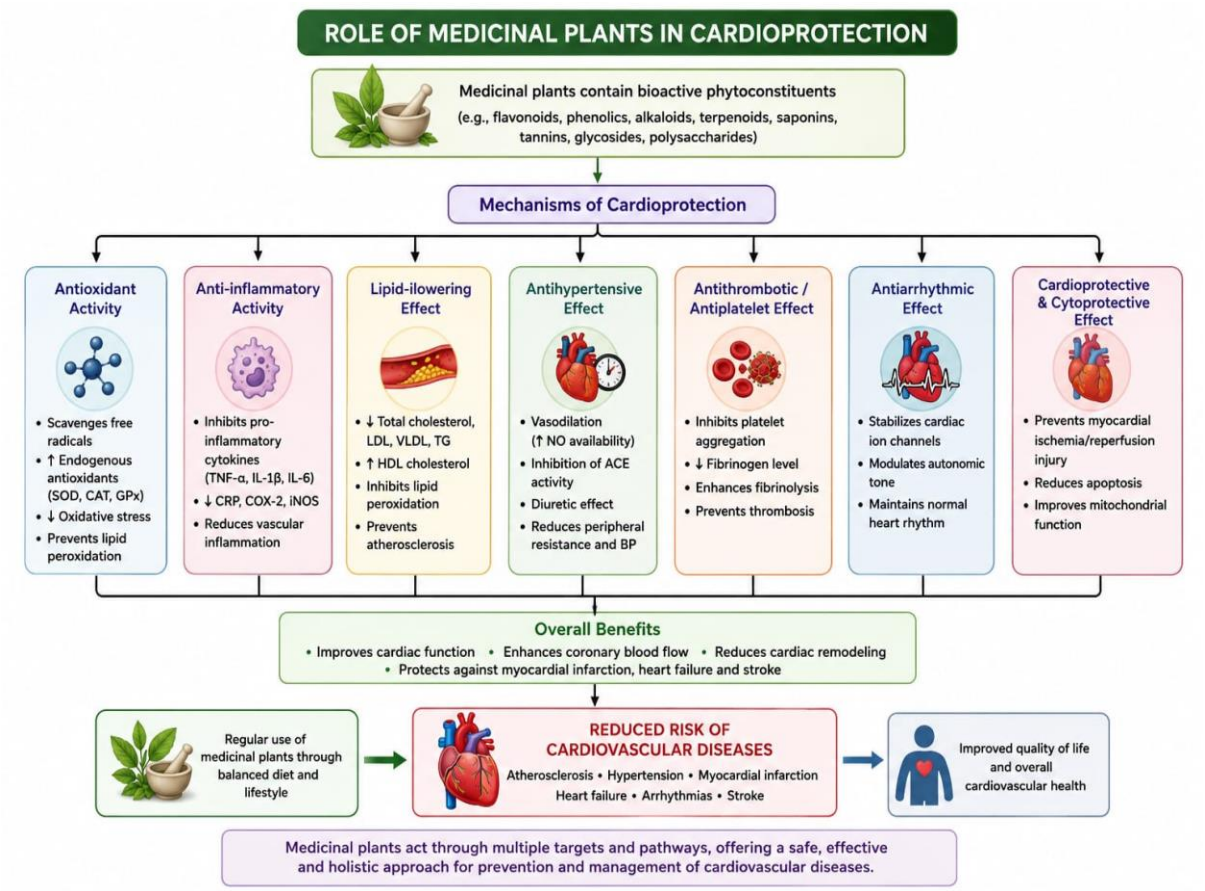
ROLE OF MEDICINAL PLANTS IN CARDIOPROTECTION

Medicinal plants play an important role in the prevention and management of cardiovascular diseases (CVDs). They contain a wide range of bioactive phytochemicals, including flavonoids, polyphenols, alkaloids, terpenoids, saponins, and tannins, which exert cardioprotective effects through multiple mechanisms. Compared with many synthetic drugs, medicinal plants are generally considered cost-effective, readily available, and

associated with fewer adverse effects when used appropriately.[11]

The major cardioprotective mechanisms of medicinal plants include:

- Antioxidant activity: Neutralizes reactive oxygen species (ROS), reducing oxidative stress and preventing damage to cardiac cells.
- Anti-inflammatory activity: Suppresses inflammatory mediators and cytokines involved in the progression of atherosclerosis.
- Lipid-lowering effect: Reduces total cholesterol, triglycerides, and LDL cholesterol while increasing HDL cholesterol, thereby lowering the risk of plaque formation.
- Antihypertensive effect: Promotes vasodilation, improves endothelial function, and helps regulate blood pressure.[12]
- Antithrombotic effect: Inhibits platelet aggregation and reduces thrombus formation, decreasing the risk of heart attack and stroke.
- Anti-atherosclerotic activity: Prevents lipid accumulation in arterial walls and slows the development of atherosclerotic plaques.



PHYTOCHEMICAL CONSTITUENTS RESPONSIBLE FOR CARDIOPROTECTIVE ACTIVITY

Medicinal plants contain a wide range of bioactive phytochemicals that contribute to their cardioprotective effects. These naturally occurring compounds exert antioxidant, anti-inflammatory, antihypertensive, hypolipidemic, antithrombotic, and anti-apoptotic activities, thereby protecting the heart and blood vessels from damage.

Among these, polyphenols (e.g., flavonoids and phenolic acids) are potent antioxidants that scavenge reactive oxygen species (ROS), reduce oxidative stress, and improve endothelial function. Flavonoids, such as quercetin, catechins, and rutin, exhibit anti-inflammatory, vasodilatory, and lipid-lowering properties.[14] Terpenoids enhance myocardial function and protect against ischemic injury, while alkaloids help regulate blood pressure and improve vascular function. Saponins reduce serum cholesterol levels and inhibit the progression of atherosclerosis. Tannins possess strong antioxidant and anti-inflammatory activities that protect cardiac tissues, whereas glycosides, particularly cardiac glycosides, improve cardiac contractility in specific cardiovascular conditions.[15]

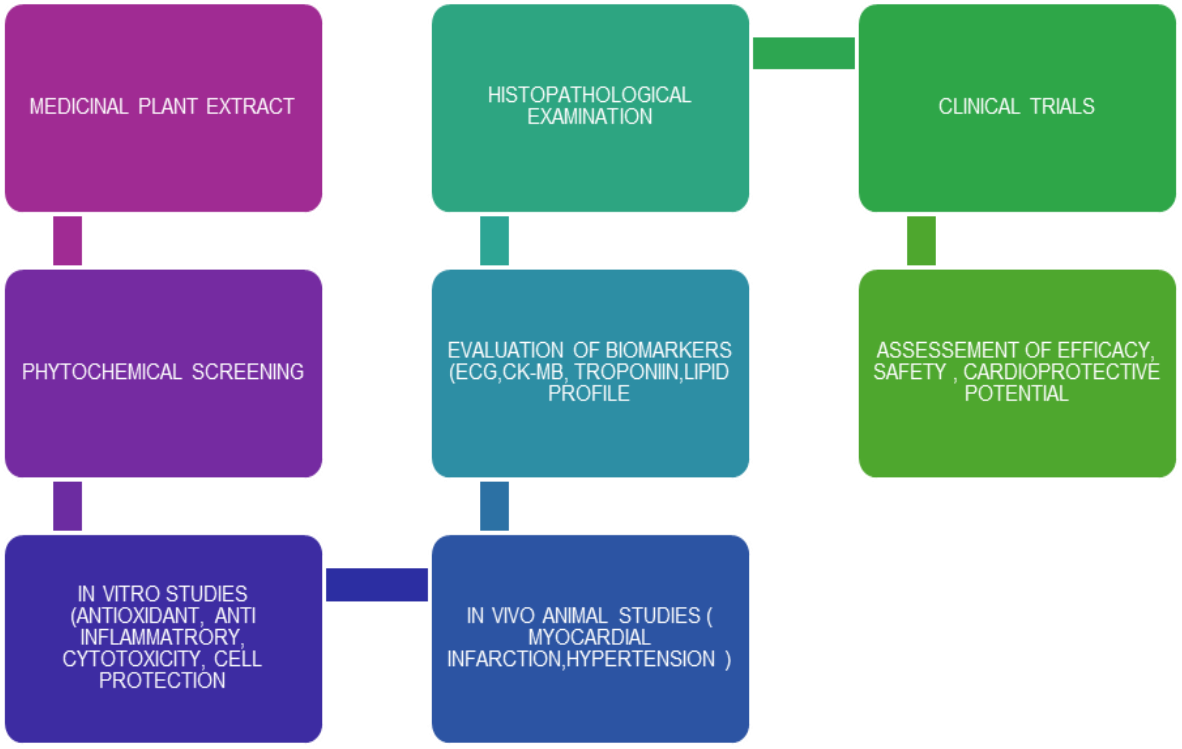
Endothelial dysfunction, and lipid accumulation. Therefore, phytochemical-rich medicinal plants represent promising sources for the development of novel cardioprotective agents.

Table 1: Cardioprotective Medicinal Plants and Their Properties.

S. No.	Botanical Name	Common Name	Family	Key Phytochemicals	Cardioprotective Activity	References
1	Allium sativum	Garlic	Amaryllidaceae	Organosulfur compounds (allicin)	Lowers LDL, improves endothelial function, antihypertensive, antiatherosclerotic	Singh et al., 2006; Banerjee SK et al., 2002
2	Andrographis paniculata	Kalmegh	Acanthaceae	Andrographolide	Protects cardiac myocytes from hypoxia-induced injury	Thakur et al., 2012; Singh et al., 2015
3	Ananas comosus	Pineapple	Bromeliaceae	Bromelain, Vitamins A/C	Reduces oxidative stress in isoproterenol-induced myocardial infarction	Saxena & Bardia, 2013; Saxena et al., 2013
4	Arachis hypogaea	Peanut	Fabaceae	Resveratrol	Prevents oxidative stress-induced myocardial damage and inflammation	Karthik et al., 2011
5	Artocarpus heterophyllus	Jackfruit	Moraceae	Flavonoids, phenolic acids	Antioxidant and myocardial protective effects	Santhi et al., 2011
6	Asparagus racemosus	Shatavari	Asparagaceae	Shatavarins (saponins)	Reduces serum lipids, prevents atherosclerosis	Alok et al., 2013; Panda et al., 2006
7	Azadirachta indica	Neem	Meliaceae	Nimbin, nimbolide	Antioxidant, hypolipidemic effects	Kaur et al., 2005
8	Bacopa monnieri	Brahmi	Plantaginaceae	Bacosides A & B	Cardioprotective via antioxidant pathways	Kongkeaw et al., 2014
9	Bauhinia variegata	Mountain Ebony	Fabaceae	Saponins, flavonoids	Enhances Na^+/K^+ ATPase activity, antiarrhythmic	Kumar et al., 2010
10	Boerhaviadiffusa	Punarnava	Nyctaginaceae	Alkaloids, rotenoids	Cardioprotective, diuretic, anti-inflammatory	Jadon et al., 2007
11	Bryophyllumpinnatum	Air Plant	Crassulaceae	Bufadienolides, flavonoids	Cardiotonic, antioxidant	Jadon et al., 2007
12	Camellia sinensis	Green Tea	Theaceae	Catechins (EGCG)	Antioxidant, endothelial protection	Kumar et al., 2012
13	Carissa opaca	Wild Karonda	Apocynaceae	Flavonoids, phenolics	Reverses CCl_4-induced myocardial injury via antioxidant restoration	Sahreen et al., 2011
14	Cassia tora	Sickle Senna	Caesalpiniacea e	Anthraquinones, flavonoids	Protects against isoproterenol/doxorubicin-	Nagarathna et al., 2016;
15	Centaurea behen	Behen Root	Asteraceae	Phenolics, flavonoids	Cardioprotective, antioxidant	Kumar et al., 2012
16	Cinnamomum tamala	Indian Bay Leaf	Lauraceae	Cinnamaldehyde, monoterpenes	Attenuates doxorubicininduced cardiotoxicity	Nagaraju et al., 2015
17	Commiphora mukul	Guggul	Burseraceae	Guggulsterones	Lipid-lowering, antiinflammatory; used in hyperlipidemia/atherosclerosis	Sandhya et al., 2000
18	Coriandrum sativum	Coriander	Apiaceae	Flavonoids, glycosides	Protects against salbutamol-induced cardiac stress	Kousar et al., 2012
19	Cornus mas	Cornelian Cherry	Cornaceae	Antioxidants	Restores antioxidant enzymes, limits ISOinduced damage	Eshaghi et al., 2011
20	Crataegus monogyna	Hawthorn	Rosaceae	Flavonoids, procyanidins	Positive inotropy, antiarrhythmic	Kousar et al., 2012
21	Croton sparsiflorus	Croton	Euphorbiaceae	Flavonoids, alkaloids	Significant cardioprotection in oxidative stress models	Beaulah et al., 2015
22	Curcuma longa	Turmeric	Zingiberaceae	Curcumin, demethoxycurcumin, cineole	Antioxidant, anti-inflammatory; protects in cardiotoxicity/MI models	Aggarwal et al., 2007; El-Sayed & Abd El-Fattah, 2017
23	Cynara scolymus	Artichoke	Asteraceae	Chlorogenic acid, cynarin	Reduces LDL/total cholesterol in clinical trials	Gail et al., 1998
24	Cyperus rotundus	Nut Grass	Cyperaceae	Phenolics,	Reverses	Nazish

				flavonoids	isoproterenolinduced cardiotoxicity	Jahan et al., 2019
25	Digitalis purpurea	Foxglove	Plantaginaceae	Cardiac glycosides (digoxin)	Positive inotropy for congestive heart failure (narrow therapeutic index)	Stuhlemmer et al., 1993
26	Embeliaribes	Vidanga	Primulaceae	Embelin, alkaloids	Reduces oxidative cardiac damage in diabetic models	Maurya et al., 2012; Ghosh et al., 2014
27	Emblica officinalis	Amla	Phyllanthaceae	Gallic acid, emblicanin	Hypolipidemic, antioxidant	Ahmed et al., 2010
28	Ficus racemosa	Cluster Fig	Moraceae	Polyphenols	Attenuates doxorubicininduced cardiac injury	Ahmed et al., 2010
29	Garcinia indica	Kokum	Clusiaceae	Garcinol, xanthones	Reduces lipid peroxidation, antioxidant	Hegde et al., 2014
30	Garcinia pedunculata	-	Clusiaceae	Garcinol	Cardioprotective in rat models	Kannan et al., 2012
31	Ginkgo biloba	Ginkgo	Ginkgoaceae	Ginkgolides,	Antioxidant, neuro-/cardioprotective, improves	Kleijnen et al., 1992;
32	Gymnema sylvestre	Gurmar	Apocynaceae	Gymnemic acids	Anti-obesity, hypolipidemic, antihypertensive	Kumar et al., 2012
33	Hibiscus sabdariffa	Roselle	Malvaceae	Gossypetin, anthocyanins	Improves cardiac function/antioxidant status in hypertensive/MI models	Obouayeba et al., 2012
34	Hygrophila auriculata	-	Acanthaceae	Sterols, alkaloids	Cardioprotection via antioxidant/enzyme regulation	Koti et al., 2009
35	Justicia tranquebariensis	Water Willow	Acanthaceae	Umbelliferone, flavonoids	Prevents oxidative myocardial injury	Radhika & Sundarraj, 2010
36	Lagenaria siceraria	Bottle Gourd	Cucurbitaceae	Flavone-C glycosides, sterols	Protects against ISO-induced cardiotoxicity	Upaganlawar et al., 2010
37	Lavandula angustifolia	Lavender	Lamiaceae	Cineole, limonene	Maintains cardiac histoarchitecture, reduces lipid peroxidation	Ziaee et al., 2014
38	Lepidium sativum	Garden Cress	Brassicaceae	Flavonoids, minerals	Improves myocardial tissue function	Mohamed et al., 2017
39	Mangifera indica	Mango	Anacardiaceae	Mangiferin, quercetin	Antioxidant, restores lipid profiles, protects myocardial tissue	Awari et al., 2009; Prabhu et al., 2011
40	Medicago sativa	Alfalfa	Fabaceae	Vitamins A/C/E, flavonoids	Antioxidant, anti-inflammatory	Gomathi et al., 2014
41	Momordica charantia	Bitter Melon	Cucurbitaceae	Triterpenoids, cucurbitins	Dose-dependent protection against oxidative stress/inflammation	Temitope et al., 2019
42	Moringa oleifera	Drumstick Tree	Moringaceae	Alkaloids, saponins, polyphenols	Decreases MI markers, improves cardiac enzymes	Oseni et al., 2015
43	Nardostachysjatamansi	Spikenard	Caprifoliaceae	Jatamansone, sesquiterpenes	Antiarrhythmic, cardioprotective	Tripathi et al., 2011
44	Nelumbo nucifera	Lotus	Nymphaeaceae	Nuciferine, kaempferol, quercetin	Antiarrhythmic, membrane-stabilizing; attenuates oxidative stress	Zhao et al., 2006; Pillai et al., 2010; Kirithika et al., 2012
45	Newbouldia laevis	African Border Tree	Bignoniaceae	Tannins, cardiac glycosides	Protects against cardiotoxicity via antioxidant/antiinflammatory effects	Agbafor et al., 2012
46	Nigella sativa	Black Cumin	Ranunculaceae	Thymoquinone	Antioxidant, lipidlowering; reduces myocardial necrosis/lipid peroxidation	Shafiq et al., 2014

THERAPEUTIC EVALUATION OF CARDIOPROTECTIVE MEDICINAL PLANTS



MECHANISMS OF CARDIOPROTECTIVE ACTION

Medicinal plants exert cardioprotective effects through multiple biological mechanisms that collectively prevent or reduce cardiovascular damage. Their bioactive phytochemicals help maintain normal cardiac function by combating oxidative stress, inflammation, hypertension, dyslipidemia, thrombosis, and apoptosis.

1. Antioxidant Activity

Medicinal plants are rich in antioxidants such as flavonoids, polyphenols, and vitamins that neutralize reactive oxygen species (ROS). This reduces oxidative stress, prevents lipid peroxidation, protects myocardial cells, and improves endothelial function.[16]

2. Anti-inflammatory Activity

Plant-derived phytochemicals suppress the production of pro-inflammatory cytokines, including tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), and C-reactive protein (CRP). By reducing chronic inflammation, they inhibit endothelial dysfunction and slow the progression of atherosclerosis.[16]

3. Antihypertensive Activity

Several medicinal plants promote vasodilation by enhancing nitric oxide (NO) production and inhibiting the angiotensin-converting enzyme (ACE). These effects reduce vascular resistance, lower blood pressure, and improve cardiac performance.[16]

4. Lipid-Lowering Effects

Bioactive compounds such as saponins, flavonoids, and phytosterols decrease total cholesterol, low-density lipoprotein (LDL), and triglycerides while increasing high-density lipoprotein (HDL). This helps prevent plaque formation and reduces the risk of atherosclerosis.[16]

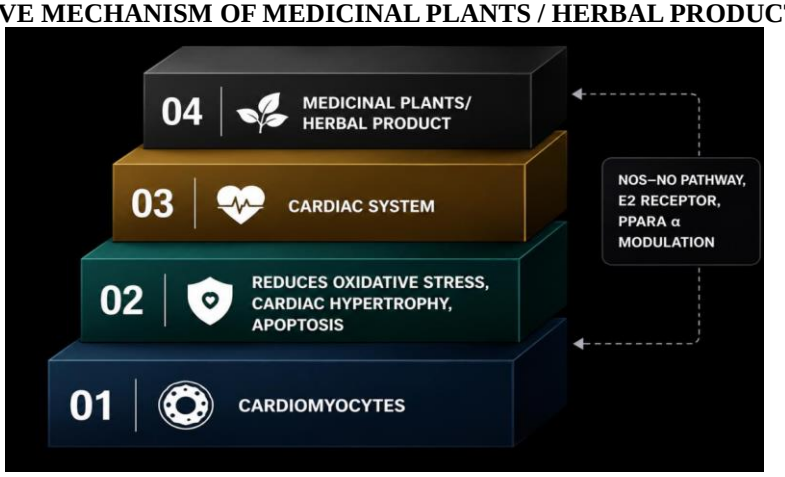
5. Antithrombotic Activity

Many phytochemicals inhibit platelet aggregation and thrombus formation by modulating platelet activation and coagulation pathways. These effects reduce the risk of myocardial infarction and ischemic stroke.[16]

6. Anti-apoptotic Effects

Medicinal plant constituents regulate apoptosis-related signaling pathways by increasing anti-apoptotic proteins (Bcl-2) and decreasing pro-apoptotic proteins (Bax and caspases). This protects cardiomyocytes from ischemia-induced cell death and preserves cardiac function.[16]

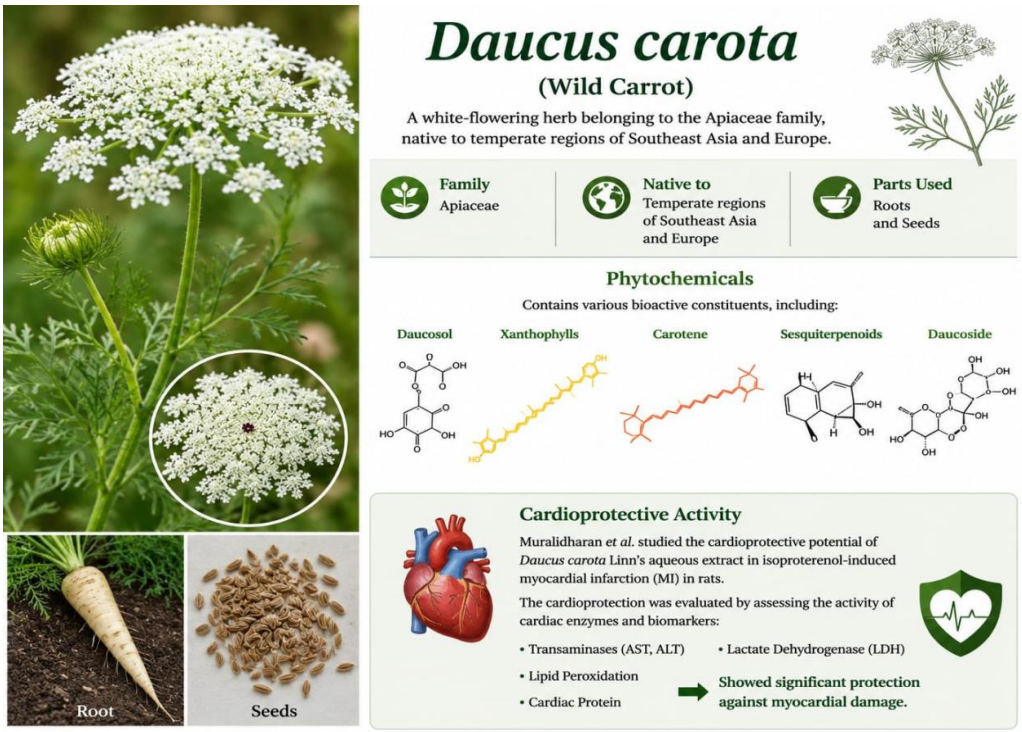
CARDIO PROTECTIVE MECHANISM OF MEDICINAL PLANTS / HERBAL PRODUCTS



MEDICINAL PLANTS WITH CARDIOPROTECTIVE POTENTIAL

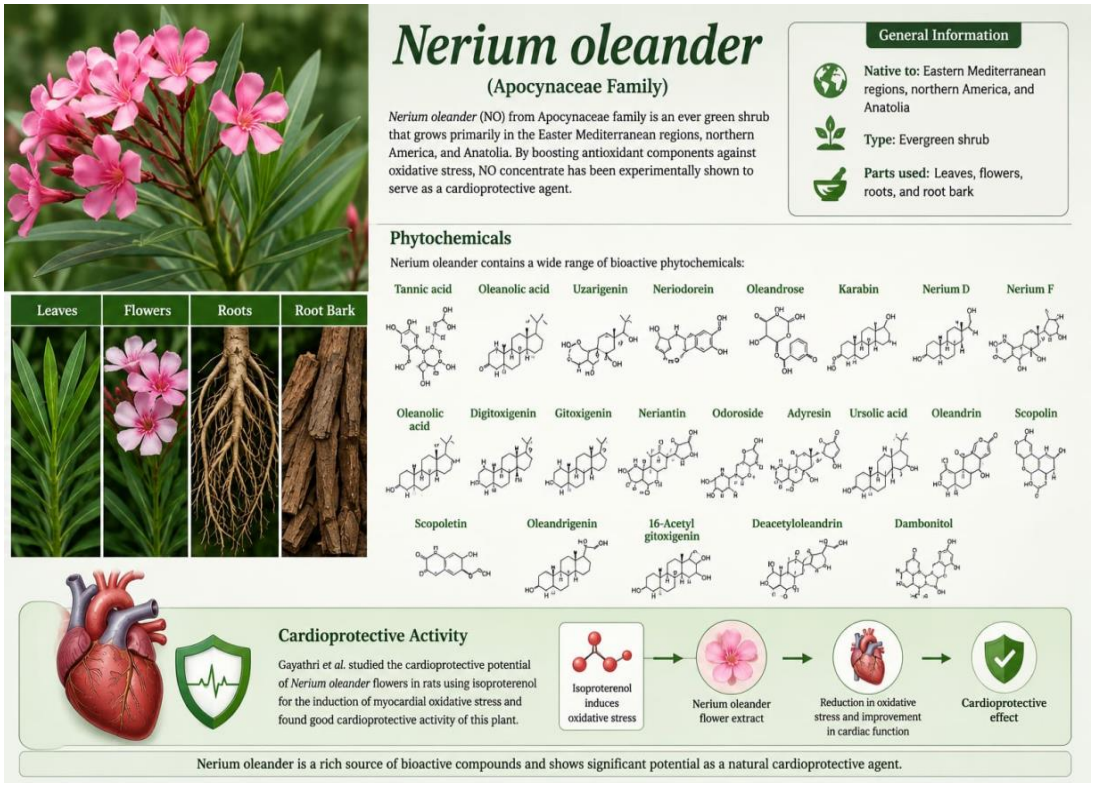
DAUCUS CAROTA

Daucus carota is a white-flowering herb belongs to Apiaceae plant family and is generally recognized as wild carrot. This plant is native to temperate regions of Southeast Asia and Europe. Parts used for medicinal preparations are roots and seeds. The phytochemicals present in this plant include daucosol, xanthophylls, carotene, sesquiterpenoids, and daucoside.[17] Mur studied dioprotective potential of D carota Linn's aqueous extract in isoproterenol-induced MI in rats. They studied the cardioprotection by determining the activity of cardiac enzymes like transaminases, lipid peroxidases, cardiac protein, and lactate dehydrogenase (LDH).



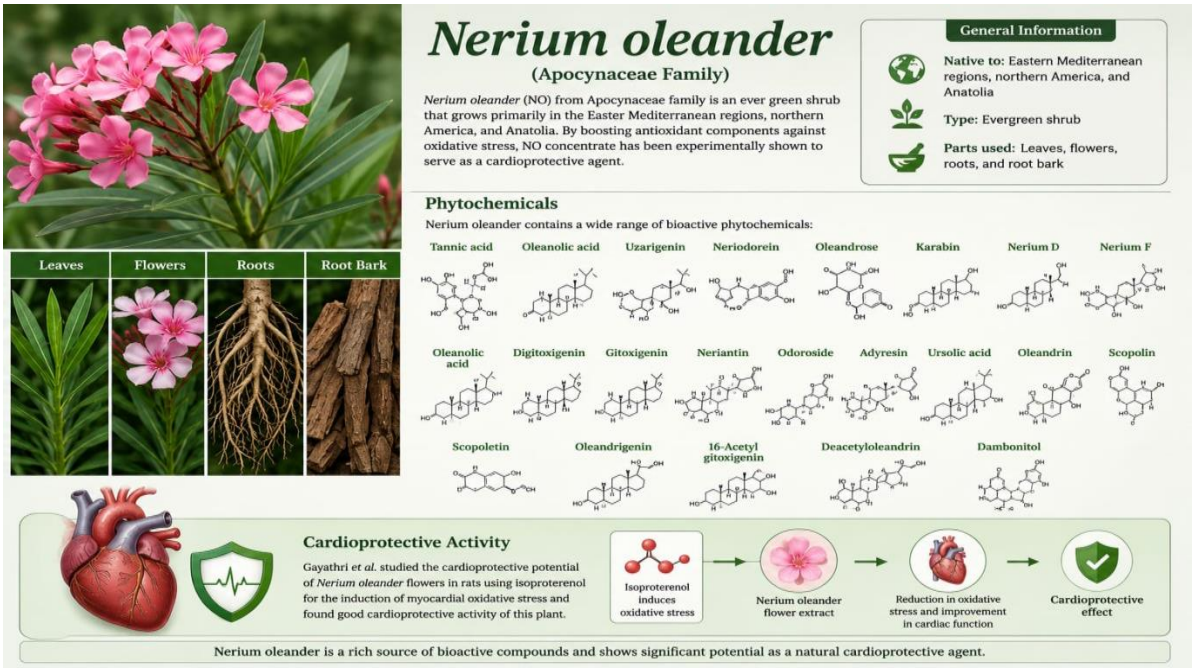
NERIUM OLEANDER

Nerium oleander (NO) from Apocynaceaefamily is an ever green shrub that grows primarily in the Easter Mediterranean regions, northern America, and Anatolia. By boosting antioxidant components against oxidative stress, NO concentrate has been experimentally shown to serve as a cardioprotective agent.Parts used for pharmaceutical preparations are leaves, flowers, roots, and root bark. Phytochemicals present in this plant includes tannic acid, oleanolic acid, uzarigenin, neriodorein, oleandrose, karabin, neriodin, nerium D, nerium F, oleanolic acid, digitoxigenin, gitoxigenin, neriantin, odoroside, adyresin, ursolic acid, oleandrin, scopolin, scopoletin, oleandrigenin, 16-acetyl gitoxigenin, deacetyloleandrin, and dambonitol. studied the cardioprotective potential of NO flowers in rats using isoproterenol for the induction of myocardial oxidative stress and found good cardioprotective activity of this plant.[18]



AMARANTHUS VIRIDIS

Amaranthus viridis Linn is commonly known as slender amaranth in English while it was called as never fading flower in Greek. It is an annual herb. Various parts such as leaves, roots, and whole plants are used for pharmacological purpose. Active phytoconstituents are quercetin and rutin. This plant also contains variety of amino acids, including leucine, lysine, isoleucine, arginine, cystine, histidine, valine, phenylalanine, methionine, threonine, tryptophan, and tyrosine. Various studies reported the cardioprotective potential of A viridis Linn in ratsto evaluate the cardioprotective potential of this plant using isoproterenol to induce MI at a dose concentration of 20 mg/kg body weight subcutaneously for 2 consecutive days. They observed significant variation in cardiac enzymes. Amaranthus viridis was orally administered at dose concentrations of 100, 200, and 300 mg/kg body weight for 45 days. Lower levels of cardiac enzymes were observed in plant-treated groups of rats, showing its cardioprotective activity. Amaranthus viridis was found more effective at a dose of 300 mg/kg body weight.[17]



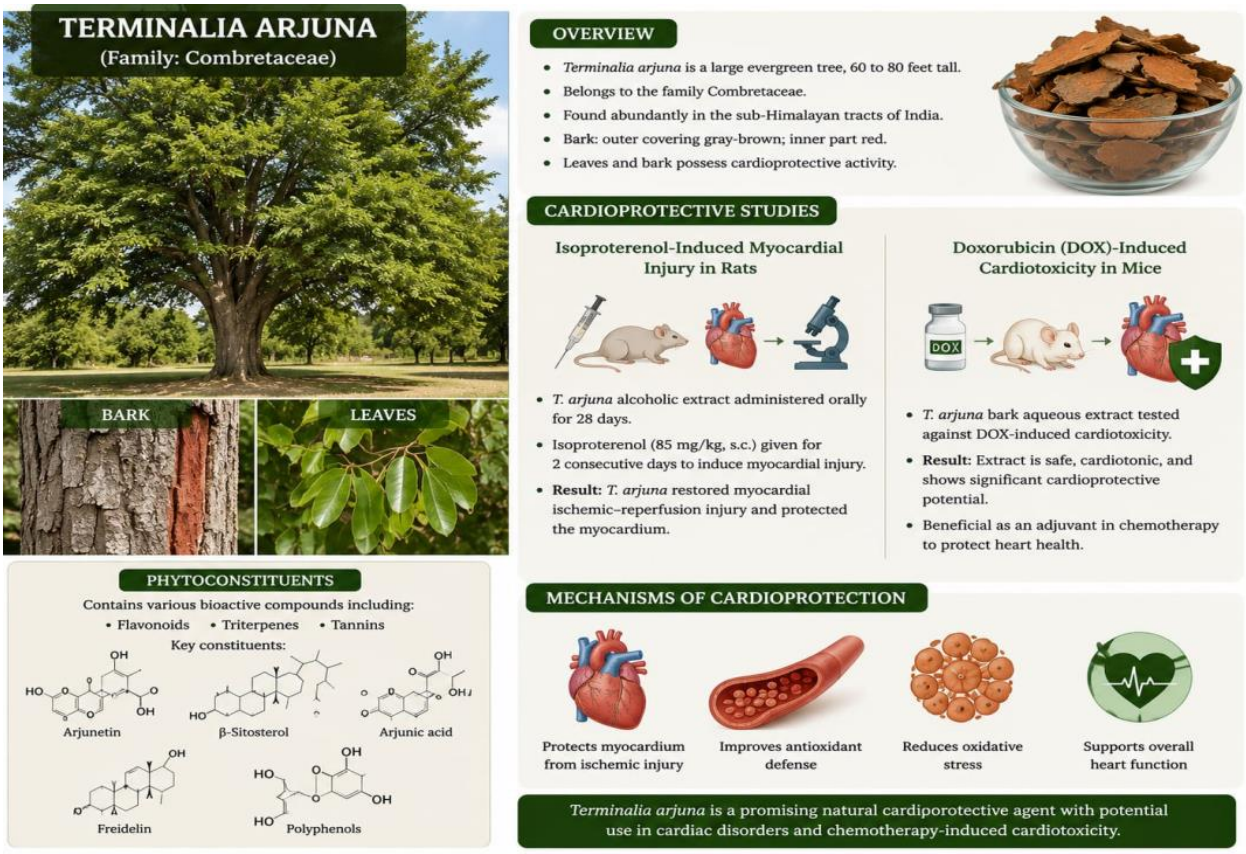
GINKGO BILOBA

Ginkgo biloba L belongs to Ginkgoaceae plant family. This plant is also known as "living fossils" because of its existence among the oldest seed plants. It contains Ginkgolides, flavones glycosides, flavonol, ascorbic acid, diterpen lactones, catechin, sesquiterpenes, and iron-based superoxide dismutase. Variety of biological activities of this plant have been reported, including antioxidants, antimicrobial, anti-inflammatory, memory enhancer, hepatoprotective, antidepressant, anticoagulant, antiulcer, cytotoxic, antiaging, and antistress activities. This plant is also popular for its medicinal and nutritional potential. Ginkgo biloba also contains many other phytoconstituents, including fatty acids, resins, essential oils, tannins, carotenoids, quercetin, and myricetin. Ginkgo biloba extract was observed in improving the blood flow, preventing hypoxia, improving blood rheology, causing platelet aggregation, and reducing the capillary permeability due to the release of prostaglandinsl.[16-17]

Leaves and seeds of G biloba have been reported to have cardioprotective effect. Panda59 in his study administered Ocimum sanctum and G biloba extract in isoproterenol-induced myocardial necrosis rats. He found an increase in serum enzymes of isoproterenol-induced myocardial necrosis rats compared with serum enzymes of normal rats. The rats were given O sanctum (50 and 75 mg/kg body weight) and G biloba (100 mg/kg body weight) orally for 1 month. Isoproterenol at a dose of 85 mg/kg body weight was administered through subcutaneous route. Serum enzymes level was reduced significantly on the 29th and 30th days of therapy. Ocimum sanctum (100 mg/kg body weight) and G biloba (50 mg/kg body weight) showed significant cardioprotection as compared to combined administration of O sanctum (50 mg/kg body weight) and G biloba (100 mg/kg body weight).[18]

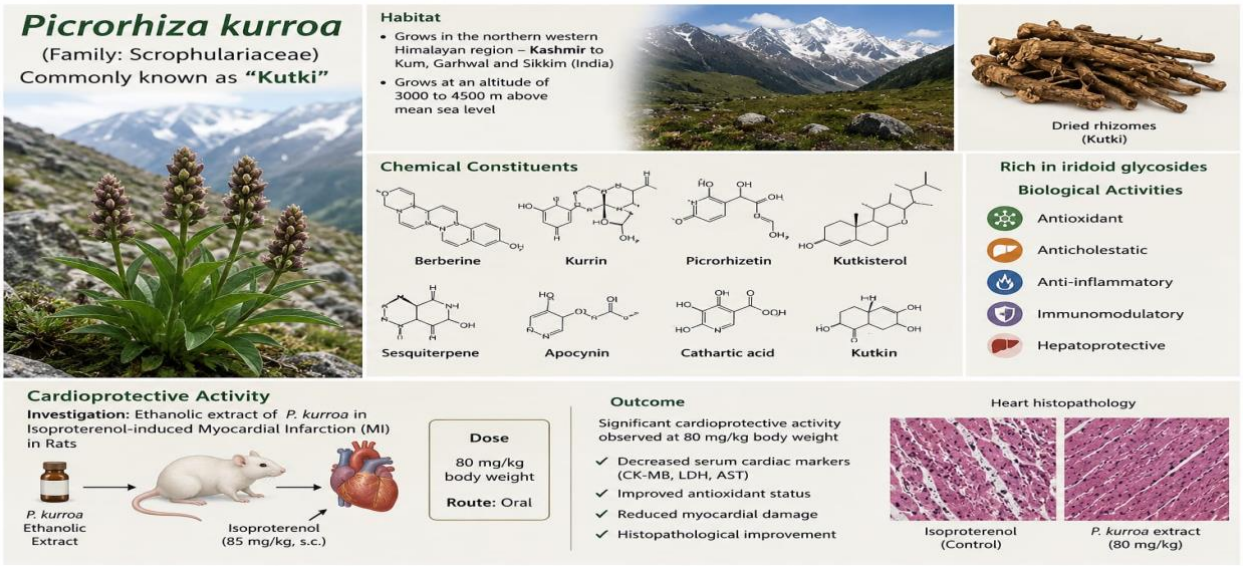
TERMINALIA ARJUNA

Terminalia arjuna is a large ever green tree with an average height of about 60 to 80 feet. This plant belongs to family Combretaceae. It is found most abundantly all around the sub-Himalayan tracts in India. It's bark outer covering is gray brown while the inside is red. Arjuna plant contains variety of phytoconstituents, including flavonoids, triterpenes, and tannins.Leaves and barks of Arjuna plant have cardioprotective activity. Phytoconstituents are arjunetin, polyphenols, β-sitosterol, freidelin, arjunic acid, and triterpenes.Cardioprotective potential of T arjuna alcoholic extract was investigated against isoproterenol-induced myocardial injury in Wistar rats by administering extract dose concentrations orally for a period of 28 days.[19] After 4 weeks treatment period, the rats were administered subcutaneously with isoproterenol (85 mg/kg body weight) for 2 consecutive days to all the treated animals, except control group rats (normal untreated rats) to induce myocardial injury. Results of the study showed that T arjuna restored the myocardial ischemic–reperfusion injury induced by isoproterenol protecting the myocardium.31 In another study conducted for investigating the cardioprotective effect of T arjuna bark aqueous extract on mice model against DOX-induced cardiotoxicity. The study concluded that T arjuna aqueous extract is a relatively safe and promising cardiotonic with cardioprotective potential. The bark extract of this plant is beneficial for healthy heart that can be used as cardioprotective agent in adjuvant chemotherapy for patients with cancer.[19]



PICRORHIZA KURROA

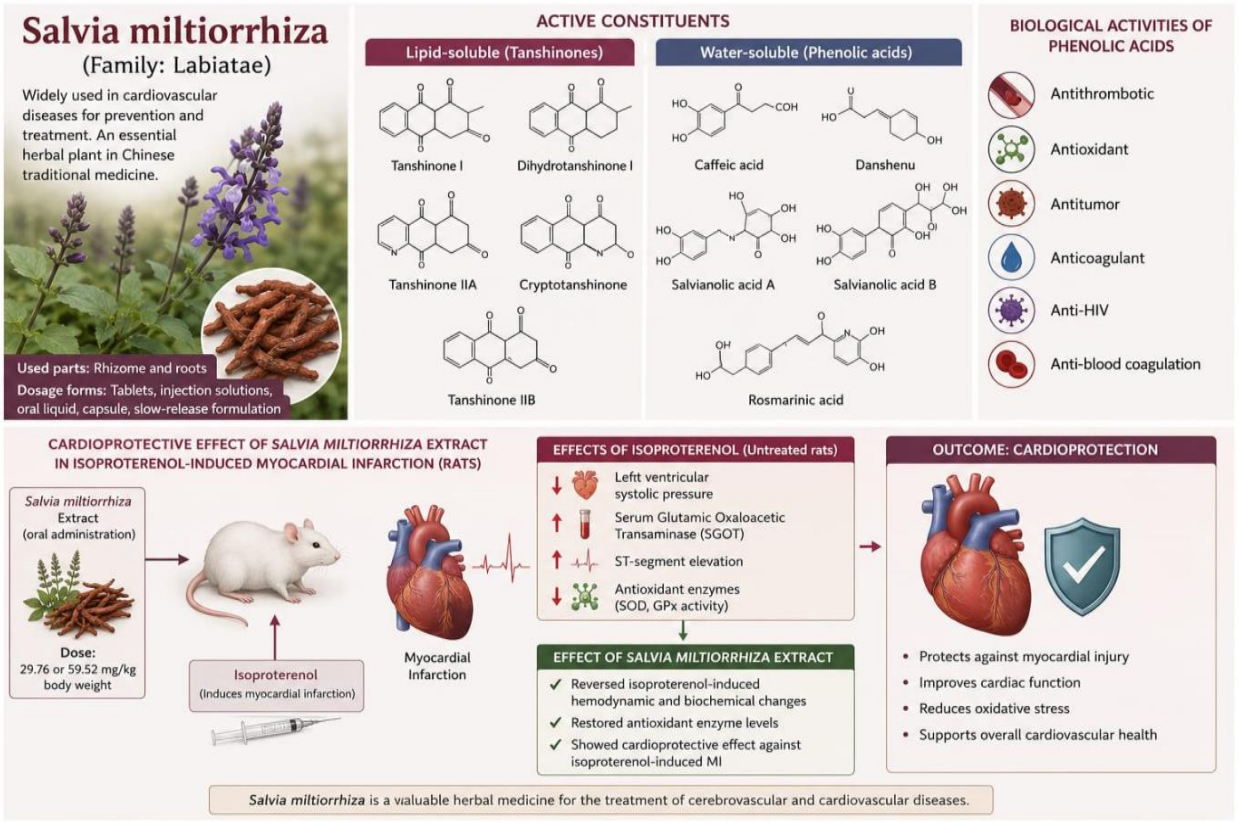
Picrorhizakurroa from Scrophulariaceae plant family is a high-value medicinal plant commonly known as "Kutki." This plant grows mainly in Kashmir to Kum in the northern western Himalayan region while in India's Garhwal and Sikkim regions; it grows above mean sea level at an altitude of 3000 to 4500 miles. The genus Picrorhiza in recent past has attracted the great interest and the promising role of P kurroa formulations has been revealed in many chemical and pharmacological investigations.Picrorhizakurroa is considered a bitter drug that is rich in iridoid glycosides with many biological activities such as antioxidant, anticholestatic, anti-inflammatory, immunomodulatory, and hepatoprotective activities. Chemical constituents found in this plant are berberine, kurrin, picrorhizetin, kutkisterol, sesquiterpene, apocynin, cathartic acid, and kutkin.Cardioprotective activity of P kurroa ethanolic extract was investigated in isoproterenol-induced MI using rats model. Significant cardioprotective activity of P kurroa extract was observed at dose concentration of 80 mg/kg body weight.[18]



SALVIA MILTIORRHIZA

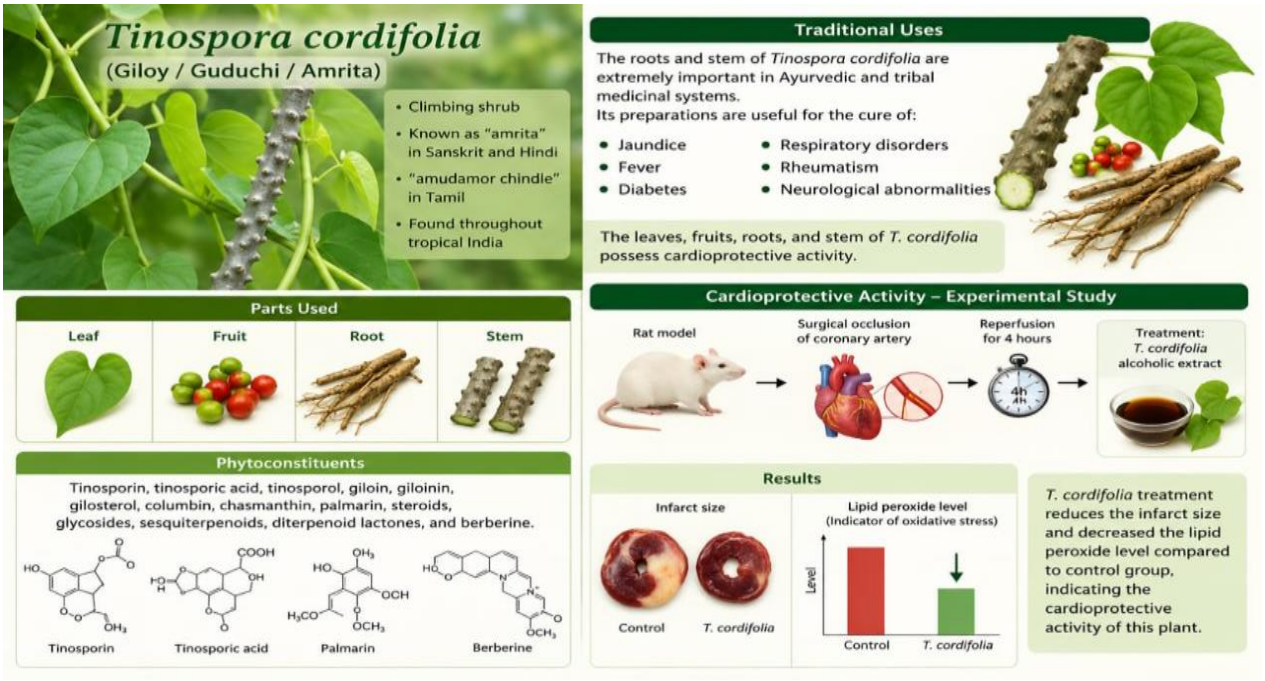
Salvia miltiorrhiza belongs to Labiatae plant family that is widely used against cardiovascular abnormalities for disease prevention and treatment. This plant has a long history of its medicinal use as well as healthy food and is considered as an essential herbal plant widely used in Chinese traditional medicinal system. In Asia, Europe, and the United States, the rhizome and roots of this plant are extensively used in treating cerebrovascular and cardiovascular diseases in the form of tablets, injection solutions, oral liquid, capsule, and slow-release formulation.[20]

The active ingredients of this plant include both the lipid-soluble and water-soluble substances. The lipophilic substances are tanshinones, which includes tanshinone I, dihydrotanshinone I, tanshinone IIA, cryptotanshinone, and tanshinoneIIB.While the water-soluble constituents are phenolic acids such as caffeic acid, danshenu, salvianolic acid A, salvianolic acid B, and rosmarinic acid. Salvia miltiorrhiza phenolic acids showed many biological actions including antithrombotic, antioxidant, antitumor, anticoagulant, anti-HIV, and anti-blood coagulation activities. Cardioprotective potential of S miltiorrhiza extract was investigated in experimental rats against isoproterenol-induced MI. Isoproterenol-treated rats showed reduction in left ventricular systolic pressure with increased serum glutamic oxaloacetic transaminase (SGOT) level and elevated ST-segment.[18] Antioxidant enzymes such as superoxide dismutase and glutathione peroxidase activity were reduced in isoproterenol-treated rats. Salvia miltiorrhiza extract was administered orally at dose of 29.76 or 59.52 mg/kg body weight. Salvia miltiorrhiza extract reversed the isoproterenol-induced hemodynamic and biochemical changes, indicating cardioprotection against isoproterenol-induced MI.



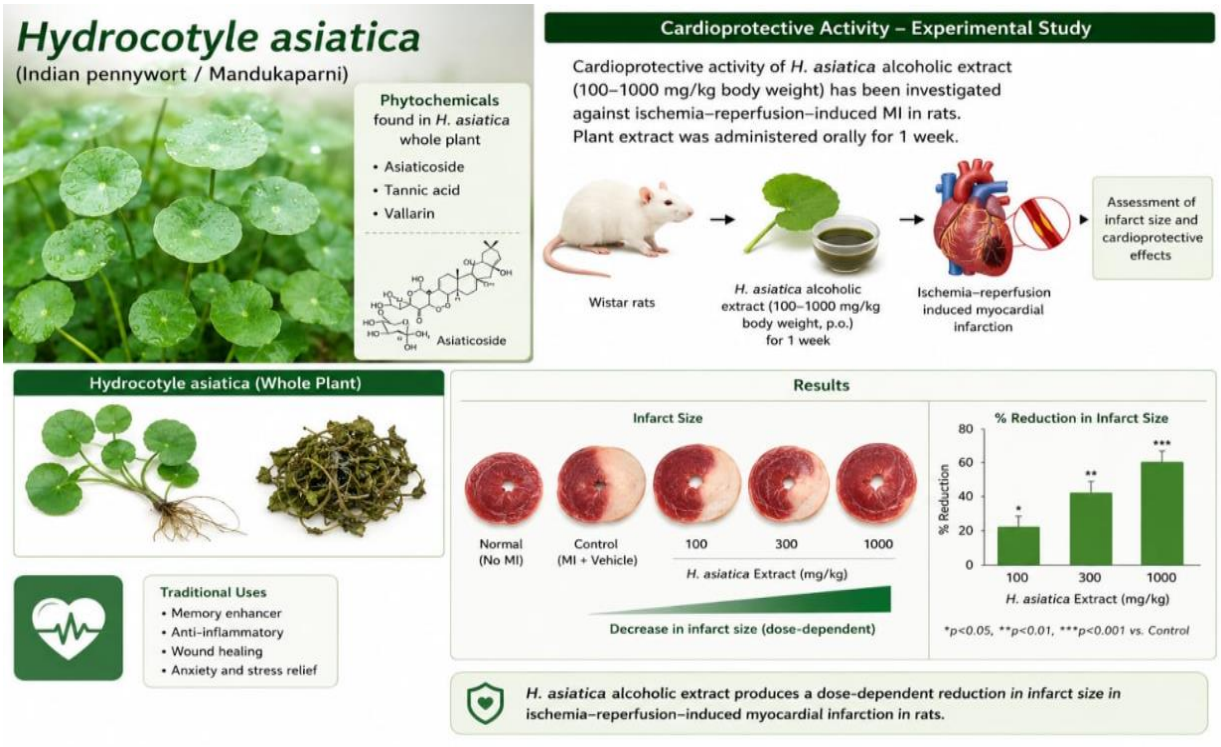
TINOSPORA CORDIFOLIA

Tinospora cordifolia (Wild) from genus Tinospora is a climbing shrub and is well known as “amrita” in Sanskrit and Hindi while “amudamorchindle” in Tamil. It is found throughout the tropical India. The roots and stem of this plant are extremely important in Ayurvedic and tribal medicinal systems. Its preparations are useful for the cure of jaundice, fever, diabetes, respiratory disorders, rheumatism, and neurological abnormalities. The leaves, fruits, roots, and stem of T cordifolia possess cardioprotective activity. Phytoconstituents are tinosporin, tinosporic acid, tinosporol, giloin, giloinin, gilosterol, columbin, chasmanthin, palmarin, steroids, glycosides, sesquiterpenoids, diterpenoid lactones, and berberine.Cardioprotective activity of T cordifolia alcoholic extract was investigated in a study using rat models. Surgical occlusion of coronary artery was performed to induce myocardial ischemia and then reperfusion for 4 hours. Results showed that T cordifolia treatment reduces the infarct size and decreased the lipid peroxide level compared to control group, indicating the cardioprotective activity of this plant.[20]



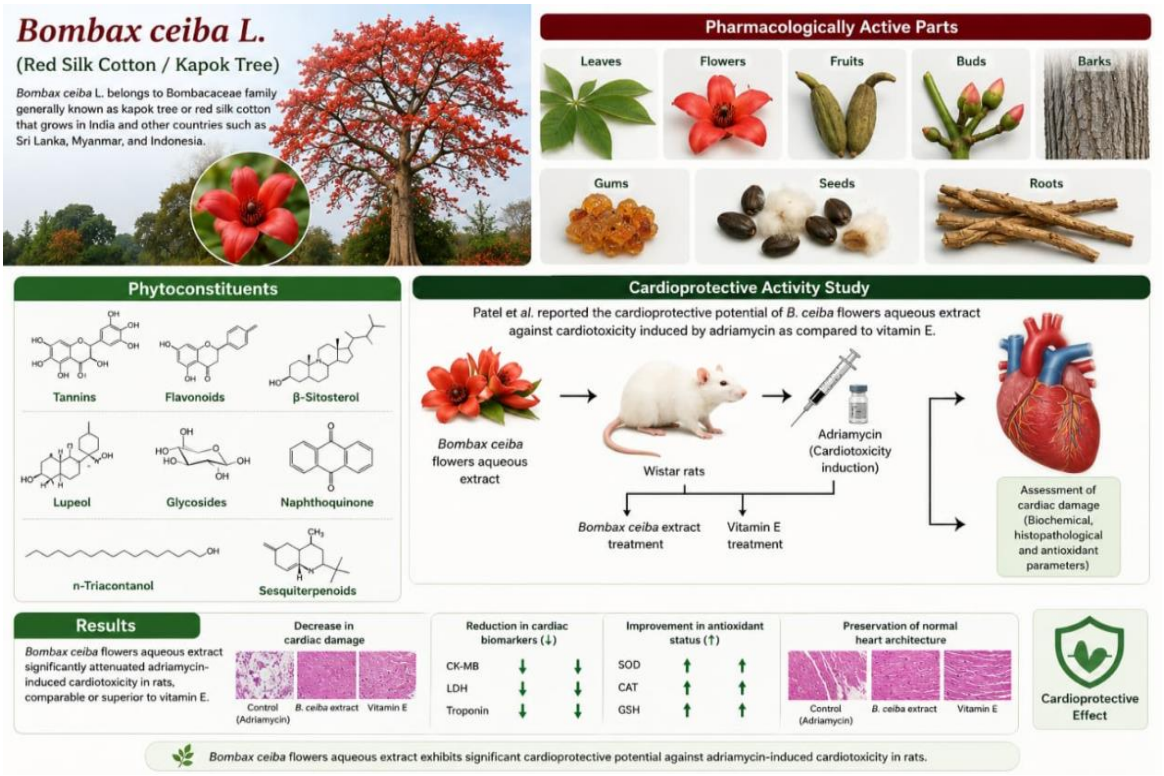
HYDROCOTYLE ASIATICA

Phytochemicals found in H asiatica whole plant are asiaticoside, tannic acid, and vallarin. Cardioprotective activity of H asiatica alcoholic extract (100-1000 mg/kg body weight) has been investigated against ischemia-reperfusion–induced MI in rats by oral administration of plant extract for 1 week. Dose-dependent response was observed. Results showed considerable decrease in infarct size in extract treated rats as compared to normal untreated rats.[21]



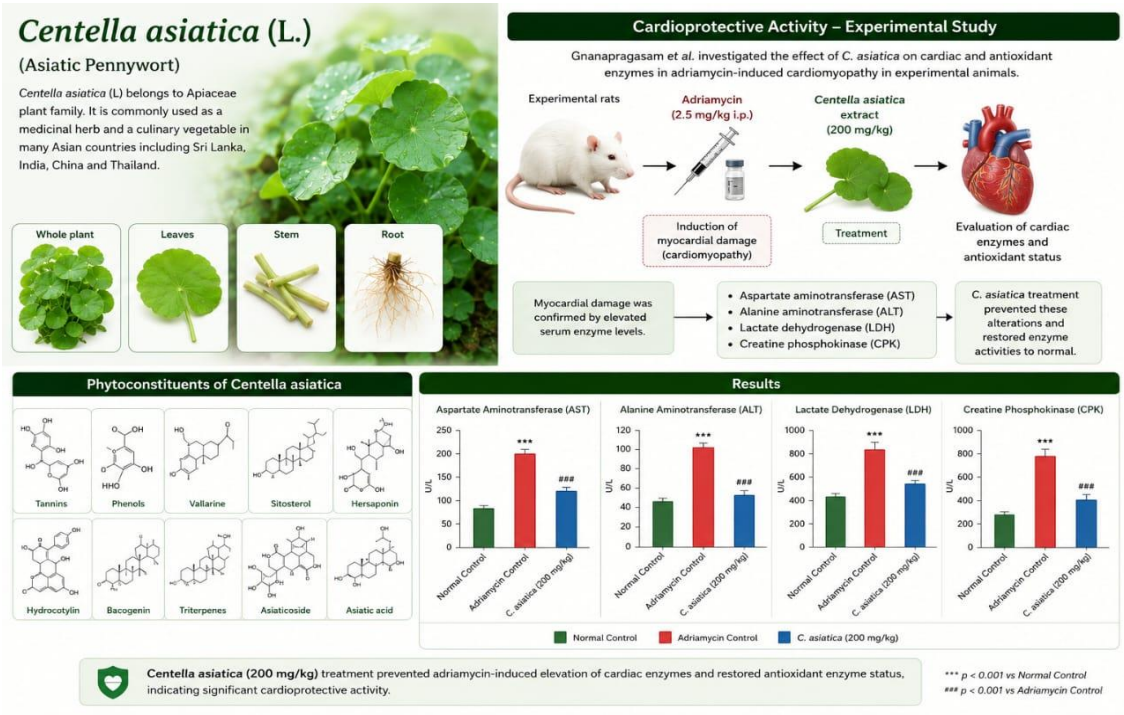
BOMBAX CEIBA

Bombax ceiba L belongs to Bombacaceae plant family generally known as kapok tree or red silk cotton that grows in India and other countries such as Sri Lanka, Myanmar, and Indonesia.Pharmacologically active parts are leaves, flowers, fruits, buds, barks, gums, seeds, and roots. This plant contains tannins, flavonoids, β-sitosterol, lupeol, glycosides naphthoquinone, n-triacontanol, and sesquiterpenoids.l75 reported the cardioprotective potential of B ceiba flowers aqueous extract against cardiotoxicity induced by adriamycin as compared to vitamin E.[22]



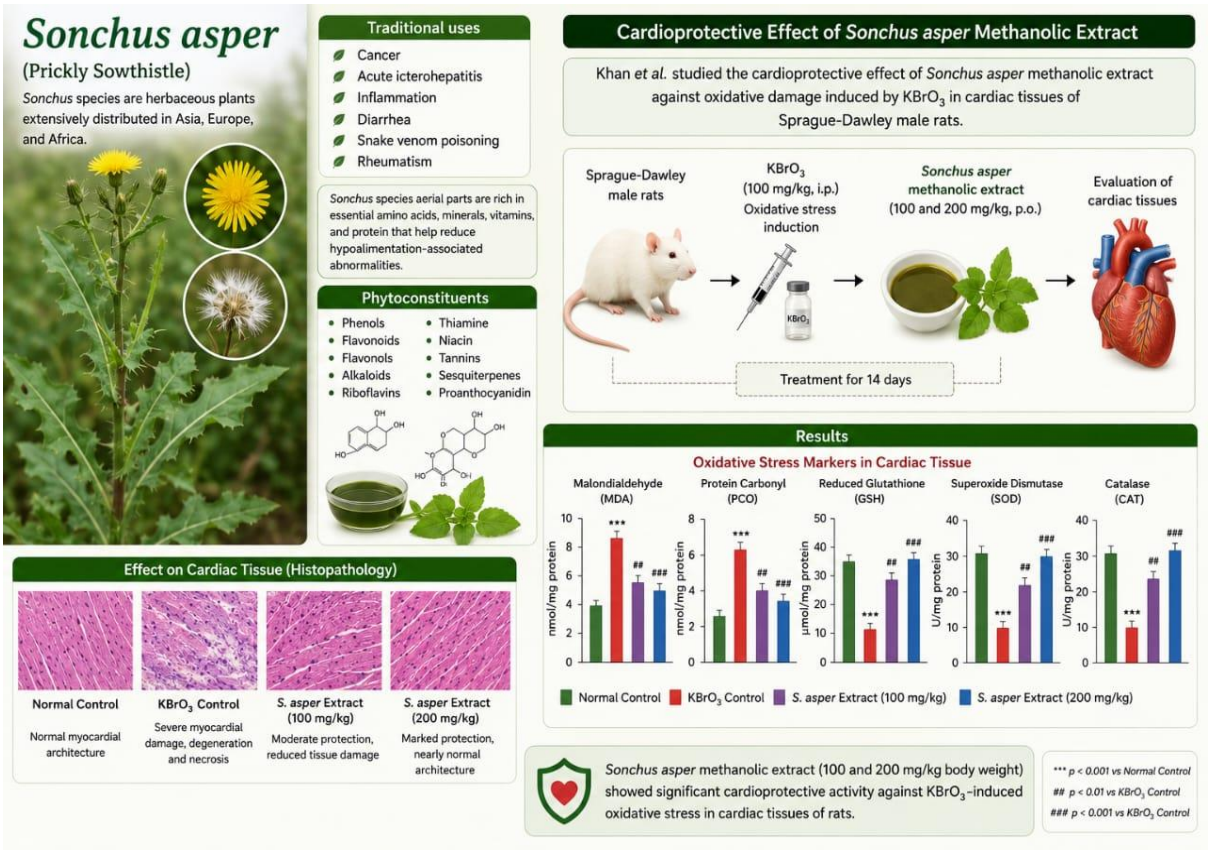
CENTELLA ASIATICA

Centella asiatica (L) belongs to Apiaceae plant family generally known as Asiatic pennywort. It is regularly used as medicinal herb or a culinary vegetable in many Asian countries, including Sri Lanka, India, China, and Thailand.Phytoconstituents found in this plant includes tannins, phenols, vallarine, sitosterol, hersaponin, hydrocotylin, bacogenin, triterpenes, asiaticoside, and asiatic acid. Gnanapragasam et al.78 investigated the effect of C asiatica on cardiac and antioxidant enzymes of experimental animals with adriamycin-induced cardiomyopathy. Induction of myocardial damage due to adriamycin (2.5 mg/kg body weight intraperitoneal) was evident from elevated levels of serum enzymes, including aspartate aminotransferase, alanine aminotransferase, LDH, and creatine phosphokinase. Centella asiatica (200 mg/kg body weight) treatment prevented these alterations and restored the enzyme activities to normal, indicating cardioprotective activity of this plant.[23]



SONCHUS ASPER

Sonchus species are herbaceous plants extensively distributed in Asia, Europe, and Africa. Sonchus species aerial parts are rich in essential amino acids, minerals, vitamins, and protein that help reduce hypoalimentation-associated abnormalities. These plant species are generally used in decoctions or infusions administered externally or orally in treating cancer, acute icterohepatitis, inflammation, diarrhea, snake venom poisoning, and rheumatism.This plant contains phenols, flavonoids, flavonols, alkaloids, riboflavins, thiamine, niacin, tannins, sesquiterpenes, and proanthocyanidin.80 Khan et al81 studied the cardioprotective effect of Sonchus asper methanolic extract against oxidative damage induced by KBrO3 in cardiac tissues of Sprague-Dawley male rats. They found significant cardioprotective activity of S asper methanolic extract (100 and 200 mg/kg body weight) against KBrO3-induced oxidative stress.[24]



PRECLINICAL STUDIES [IN VITRO AND IN VIVO]

Preclinical studies provide essential evidence supporting the cardioprotective potential of medicinal plants before clinical evaluation. In vitro studies use cultured cardiomyocytes, endothelial cells, and vascular smooth muscle cells to investigate antioxidant, anti-inflammatory, anti-apoptotic, and cytoprotective effects.[25] These studies also evaluate the ability of plant extracts and phytochemicals to inhibit oxidative stress, reduce lipid peroxidation, improve nitric oxide bioavailability, and protect against cellular injury.

In vivo studies are conducted using animal models of cardiovascular diseases, including isoproterenol-induced myocardial infarction, doxorubicin-induced cardiotoxicity, hypertension, atherosclerosis, and ischemia–reperfusion injury. Plant extracts are assessed for their ability to reduce cardiac biomarkers, improve lipid profiles, enhance antioxidant enzyme activity, decrease inflammation, preserve myocardial architecture, and improve cardiac function. Collectively, these preclinical findings demonstrate that medicinal plants exert cardioprotective effects through multiple mechanisms and provide a scientific basis for their further evaluation in clinical studies.[26]

CLINICAL STUDIES AND HUMAN TRIALS

Clinical studies are essential for confirming the safety and efficacy of medicinal plants in the prevention and treatment of cardiovascular diseases. Several randomized controlled trials and observational studies have demonstrated that medicinal plants such as Terminalia arjuna, Allium sativum (garlic), Crataegus (hawthorn), and Camellia sinensis (green tea) can improve cardiovascular health by lowering blood pressure, improving lipid profiles, enhancing endothelial function, and reducing oxidative stress and inflammation.[25] Despite these promising findings, variations in study design, dosage, treatment duration, and herbal formulations have resulted in inconsistent outcomes. Therefore, large-scale, well-designed clinical trials with

standardized herbal preparations are required to establish their long-term safety, efficacy, and therapeutic potential in cardiovascular disease management.[27]

NANOTECHNOLOGY – BASED HERBAL CARDIOPROTECTIVE FORMULATIONS

Nanotechnology has emerged as a promising strategy to enhance the therapeutic efficacy of herbal cardioprotective agents. Nanoformulations such as nanoparticles, liposomes, nanoemulsions, solid lipid nanoparticles, and polymeric nanoparticles improve the solubility, stability, bioavailability, and targeted delivery of plant-derived phytochemicals.[28] Encapsulation of bioactive compounds such as curcumin, quercetin, resveratrol, and catechins in nanocarriers enhances their antioxidant, anti-inflammatory, and cardioprotective activities while reducing systemic toxicity and improving therapeutic outcomes. Although preclinical studies have demonstrated encouraging results, further clinical investigations are required to establish the long-term safety, efficacy, and large-scale clinical application of herbal nanoformulations in cardiovascular disease management.[28]

SAFETY, TOXICITY AND LIMITATIONS

Although medicinal plants are generally considered safe due to their natural origin, their therapeutic use may be associated with adverse effects, toxicity, and herb–drug interactions when used improperly or in excessive doses. Factors such as variability in phytochemical composition, contamination with heavy metals, pesticides, microorganisms, and poor standardization can affect the safety, quality, and efficacy of herbal products.[29] In addition, limited clinical evidence, lack of standardized dosages, inconsistent manufacturing practices, and insufficient long-term toxicity studies remain major challenges for the clinical application of herbal cardioprotective agents. Therefore, rigorous quality control, standardized formulations, comprehensive toxicological evaluations, and well-designed clinical trials are essential to ensure the safe and effective use of medicinal plants in cardiovascular disease management.[30]

CONCLUSION

Medicinal plants represent a promising and complementary approach for the prevention and management of cardiovascular diseases. Their diverse phytochemicals, including flavonoids, polyphenols, alkaloids, terpenoids, saponins, and tannins, exert cardioprotective effects through antioxidant, anti-inflammatory, antihypertensive, hypolipidemic, antithrombotic, and anti-apoptotic mechanisms. Traditional medicinal systems such as Ayurveda and Siddha, together with modern experimental studies, support the therapeutic potential of plants such as Terminalia arjuna, Tinospora cordifolia, Ginkgo biloba, Salvia miltiorrhiza, and Picrorhizakurroa in improving cardiovascular health. Although preclinical and clinical studies have shown encouraging results, further well-designed, large-scale clinical trials, standardized herbal formulations, and comprehensive safety evaluations are essential to establish their long-term efficacy and safety. Advances in nanotechnology-based herbal formulations may further improve the bioavailability and therapeutic effectiveness of these natural products. Overall, medicinal plants offer a valuable and sustainable source of cardioprotective agents with significant potential for future cardiovascular disease management.

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