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Dedicated to my parents as
without their prayers, I would not
have been able to work on this book

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Chapter 1
An Introduction to Medicinally Important Trees

Abstract This chapter gives an introduction to medicinally important trees with reference to their ecological distribution and economic and medicinal importance. It also includes a brief introduction to the natural products of plants, as medicinal activities of plants are mainly due to the wide variety of these natural products, which include alkaloids, glycosides, terpenoids, tannins, and flavonoids. Important medicinal activities of trees are briefly described, which include antidiabetic, anticancer, antimicrobial, antiviral, hepatoprotective, and cardioprotective activities. Aphrodisiac, abortifacient, antipyretic, and analgesic properties of trees are also briefly introduced.

1.1 Introduction

Plants have been used for treating different diseases and for alleviating pain since ancient times. However, how plants have been used for curing a particular disease or symptoms differs in different cultures. The Ayurvedic concept of using plants for healing purposes originated around 500 B.C. in India. Engravings of medicinal plants on ancient buildings indicate that they have been used for treating different diseases for a long time. Assyrian clay tablets almost 4000 years old revealed the use of 250 medicinal and poisonous plants, including *Atropa belladonna*, *Mandragora officinarum*, and *Papaver somniferum*. Emperor Shen Nung described the use of 350 drugs in 3000 B.C. Later in India, Ayurveda mentioned the use of traditional medicine in about 900 B.C.

Almost 3000 plants are known to possess medicinal potential but more than 6000 plants are used by traditional herbal practitioners. The World Health Organization has reported 20,000 plant species studied for medicinal purposes, as more than 80% of the population of developing countries is facing difficulties due to synthetic drugs and therefore relies on traditional medicines to maintain their health. Discovery of phytochemicals in making drugs and their use in dietary supplements are expected to increase in future, as through advancement in analytical techniques, more knowledge is becoming available about the phytochemistry and metabolomics of medicinally important plants, which is not only helpful in the identification of these compounds but many phytochemicals of medicinal importance can be identified and used for various therapeutic purposes.

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Many phytochemicals with medicinal importance include molecules which are synthesized during secondary metabolic activities of plants and are therefore commonly known as *plant secondary metabolites* or *plant natural* or *functional products*. They include many *alkaloids*, *glycosides*, *flavonoids*, *terpenoids*, and *tannins*. They also form an important criterion in plant classification. Identification and isolation of these bioactive compounds is crucial in the development of modern plant-based drugs. Medicinal activities of these bioactive compounds are mostly evaluated on model animals like rats, and many of the known compounds are still not applied on humans. Therefore, there is sufficient need to evaluate medicinal activities of plant-based phytochemicals on humans and to develop drugs which do not have any side effects like antibiotics.

1.2 Phytochemicals of Medicinal Importance of Woody Plants

Alkaloids are important medicinal compounds with nitrogen-containing molecules and their presence gives a bitter taste to plants. So far 12,000 alkaloids have been elucidated from plants which are part of the defensive system of plants. Due to their bitter taste, many herbivores and pests cannot consume them as they are difficult to digest. Many *Acacia* spp. are a source of important alkaloids of medicinal importance. Aztecs used alkaloid drugs for hallucination, divination, and magic-religious purposes. Alkaloid extracts from plants like *Hyoscyamus*, *Atropa*, and *Datura* were used as aphrodisiacs. Many alkaloids which have been known to be involved in execution cases throughout history are aconitine, atropine, colchicine, mescaline, morphine, and strychnine. Alkaloids like benzophenanthridine, protoberberine, psychotrines, and michellamine B have anti-HIV activities.

Terpenoids are another class of medicinal compounds which are carbon- and hydrogen-containing units also known as isoprenoid compounds. Over 40,000 terpenoids are reported from different parts of economically important plants. Many monoterpenoids make fragrances of plants which plants biosynthesize in their plastids in order to attract their pollinators, and many of these essential oils act as insect and mosquito repellents and also inhibit microbial growth and infections. Many of these essential oils, which are mostly monoterpenoids, have pleasant fragrances and are therefore used in food, most commonly as herbs due to their aroma and taste and also due to their antimicrobial properties. Essential oils like eucalyptol, menthol, linalool, nerolidol, limonene, eugenol, isoeugenol, myrcene, and pinene exhibit many antimicrobial properties against a wide range of microorganisms. Betulinic acid is a triterpenoid which is known to possess anti-HIV activities and to cause membrane disruption by lipophilic compounds. Terpenoids from the bark of the tree *Pteleopsis suberosa* in Mali are known to inhibit gastric ulcer. The stem bark of *Ekebergia capensis* contains a mixture of approximately ten triterpenoids which possess antimalarial activities.

Flavonoids are phenol-containing compounds which are important antioxidant, anticancer, cardioprotective, and neuroprotective compounds. Over 6000 flavonoids are reported in plants where they form colored pigments in plants, mostly in flowers and fruits, and provide protection against ultraviolet (UV) light. They are synthesized from phenylalanine and classified as chalcones, flavones, flavonols, flavandiols, anthocyanins, proanthocyanidins, and aurones. Many flavonoids like anthocyanins are antioxidants and are medicinally important compounds. Berries like bilberries, blueberries, cranberries, raspberries, mulberries, and strawberries and many citrus fruits are rich sources of flavonols of medicinal value including quercetin, which possesses anticarcinogenic and antiatherosclerosis activities. Their role as a natural modulator of cancer multidrug resistance is also important. Flavonoids like biochanin and daidzein and green tea polyphenols like epigallocatechin-3-gallate (EGCG) can inhibit multidrug resistance activities in many cancer cells by inhibiting P glycoprotein transporters.

Polyphenols of blueberries and teas provide protection against Parkinson's disease and Alzheimer's disease. Kaempferol and its derivatives are also found in many fruits which are also antioxidant, anti-inflammatory, and antiulcer agents. Many edible fruits which contain anthocyanins like edible berries have high nutritive value and their intake provides protection against many diseases. They are also commonly used in many nutraceutical products and their use is being recommended by physicians due to their antioxidant nature, nutritive value, and ability to stimulate some hormones. The role of flavonoids and their derivatives is also being explored as possible anti-HIV agents as they are reported to inhibit HIV-1 protease, integrase, and reverse transcriptase. Isoflavones can inhibit transcription by repressing HIV-1 promoter activity. Coumarins reported from more than 1300 species are phenolic compounds which possess anti-inflammatory, antimicrobial, and antiviral activities. Hydroxycinnamic acids and phytoalexins, which are coumarin derivatives, are also known to have antimicrobial and antifungal activities.

Glycosides are also important medicinal compounds which contain sugar molecules attached to a nonsugar group, while saponins are glycosides like glycosidic triterpenoids, which possess antimicrobial, insecticidal, and allelopathic activities. Cardioactive glycosides from plants like *Nerium oleander* are effective on heart muscles, while cyanogenic glycosides are found to occur in more than 2600 plants like almonds, peaches, and cherries and release hydrogen cyanide (HCN) due to the breakdown of cell walls.

Tannins are a group of polymeric astringent phenolic compounds commonly present in different parts of plants which can cause leather tanning and can precipitate gelatin. They are either hydrolyzed tannins, which are gallic acid derivatives, or condensed tannins, which are flavonoid derivatives. Many tannins present in plants used for making green teas and red wines are medicinally important compounds with antimicrobial, anticancer, and antioxidant properties. Condensed tannins are capable of binding with the cell wall of ruminal bacteria and prevent protease activities. Methanolic extracts from the bark of trees like *Terminalia alata* possess tannins responsible for antibiotic activities.

1.3 Solvents and Techniques for Extraction and Isolation of Medicinal Compounds

Various traditional techniques which are employed for extraction of medicinal compounds from plants include soaking or maceration of plant parts in suitable solvents or decoction, which is widely used in Chinese and Ayurvedic medicinal practices which involve heating or boiling of plant materials. Extraction of desired compounds is also achieved through percolation using methanol or ethanol or other solvents like acetone, petroleum ether, or hexane. Water is the best solvent to extract phytochemicals. Traditionally, the leaves of trees with known medicinal value are ingested as tea which is steeped in hot water or tinctures are prepared using alcohols, or steam containing boiling suspensions of leaves can also be inhaled. Poultices are also used traditionally, which are made from concentrated teas or tinctures. The dried parts of plants are also applied externally, possibly with the addition of a small amount of oil.

However, initial screening is achieved through alcoholic extraction followed by organic extraction including methanol, ethanol, dichloromethane, ether, or chloroform extraction. Alcoholic extractions include grinding the dried parts of plants, soaking in methanol or ethanol, followed by filtration and washing and then drying under reduced pressure or dissolving again in alcohol with determined concentration. However, extraction in water involves initial soaking of plants, drying, blending, and filtrate formation, which is then cleared through multiple centrifuges and screened for antimicrobial, antifungal, or antiviral activities in different assays.

Further chemical analysis is done through many techniques which include extraction and identification of medicinal phytochemicals including different chromatographic methods like high-performance liquid chromatography (HPLC), droplet counter-current chromatography (DCCC), capillary zone electrophoresis, bioautography, radioimmunoassays, fast atom bombardment mass spectroscopy (MS), Fourier transform infrared spectroscopy (FTIR), near infrared Fourier transform (NIR-FT), Raman microspectroscopic techniques, electrospray ionization mass spectrometry (ESI-MS), tandem mass spectroscopy, infrared, 1-D or 2-D (dimensional) nuclear magnetic resonance (NMR), ion exchange, silica gel column chromatography, and x-ray crystallography.

1.4 Important Medicinal Activities of Woody Plants

Although many trees have more than one medicinal activity, in this book they are characterized on the basis of their main and unique medicinal activities. With billions of medicinal trees in the world, it is not possible to include the medicinal properties of so many trees within one book, so only a few species are included at this stage. Important medicinal activities included are antidiabetic, anticancer, antipyretic, analgesic, anti-HIV, hepatoprotective, cardioprotective, aphrodisiac, and nutritive value of many legumes, figs, nuts, and edible fruits.

1.4.1 Antidiabetic Activity of Important Trees

Diabetes mellitus is one of the most rapidly increasing diseases, affecting approximately 2.8% of the global population, and is expected to increase to 5.4% by 2025. It is one of the most common endocrine disorders, which results in deficiency of insulin-causing high blood glucose level known as type 1 diabetes. In type 2 diabetes, the body does not produce enough insulin or does not use it properly.

Plants which can reduce the level of glucose in blood and stimulate the secretion of insulin by the pancreas have antidiabetic activities. Many trees are reported to have antidiabetic potential. More than 50% of plants with antidiabetic potential are distributed in Asia, and more than 35% of compounds for diabetic treatments are extracted from leaves. However, the fruits of many plants with antidiabetic potential can be consumed orally in the form of juices.

Many plants from families like Fabaceae, Lamiaceae, Liliaceae, Moraceae, and Rosaceae are known to possess phytochemicals like alkaloids, carotenoids, polyphenols, flavonoids, terpenoids, coumarins, and other metabolites which possess antidiabetic activities and can maintain glucose level in blood. Some of the important trees with antidiabetic activity which are discussed in this book include *Achras sapota*, *Aegle marmelos*, *Bauhinia variegata*, *Bombax ceiba*, *Hibiscus rosa sinensis*, *Eriobotrya japonica*, *Euphorbia pulcherrima*, *Ficus* spp., *Jasminum sambac*, *Kigelia pinnata*, *Lagerstroemia indica rosea*, *Murraya koenigii*, and *Roystonea regia* (Fig. 1.1a–c). Active constituents include aegeline from *Aegle marmelos*, vindoline and vleurosine from *Catharanthus roseus*, strictinin and isostrictinin from *Psidium guajava*, trigonelline from *Trigonella foenum-gracuem*, arboran and aleosin from *Aloe barbadensis*, nimbidin from *Azadirachta indica*, pinitol from *Bougainvillea spectabilis*, bengalinoside from *Ficus benghalensis*, moran A from *Morus alba*, bisindole alkaloid from *Murraya koenigii*, amygdallin from *Prunus persica*, and techomine from *Tecoma stans*.

1.4.2 Trees with Anticancer Activity

Many trees are known to have anticancer potential. Cancer is one of the important leading causes of death and is responsible for one in eight deaths worldwide. Chemotherapy is widely used for cancer treatment, but the use of chemotherapeutic drugs causes many toxic effects. Plant-based anticancer agents in the market include vinca alkaloids like vinblastine, vincristine, and vindesine, and epipodophyllotoxins (etoposide and teniposide), taxanes (paclitaxel and docetexal), and camptothecin derivatives like camptothecin and irinotecan. They interact with methyltransferases or histone deacetylases and inhibit their activities or act as DNA damage preventers or interrupt with mitotic activities of proliferating cells. Many sulforaphanes from vegetables like broccoli and cabbage, isoflavones from edible legumes, and pomiferins from Osage oranges are histone deacytylases inhibitors. Taxanes like paclitaxel drug from *Taxus* sp. can reduce the rate of replication of cancer cells by

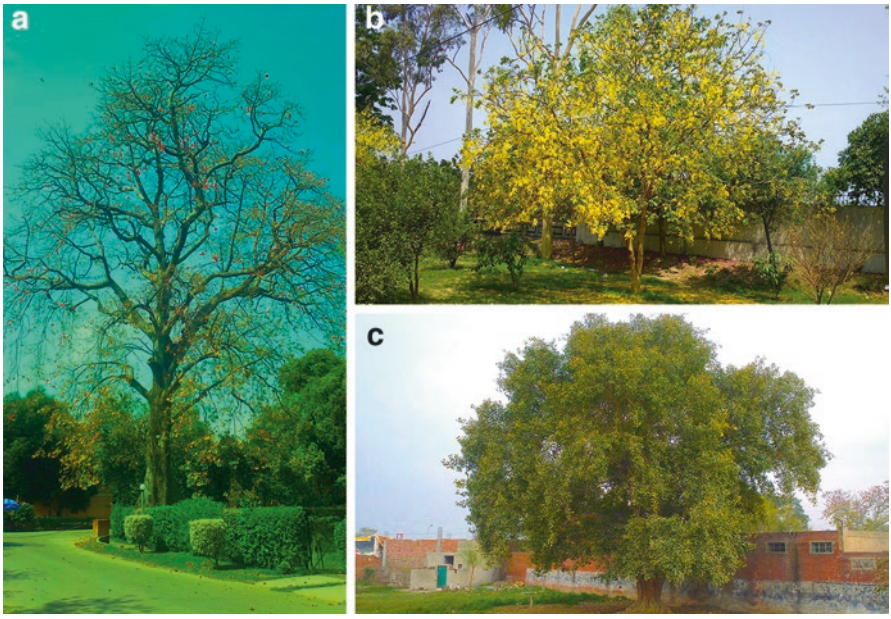

Fig. 1.1 (**a–c**) Trees with antidiabetic activities. (**a**) *Bombax ceiba* (red cotton tree) is an important medicinal tree with antidiabetic and antimicrobial activities due to the presence of compounds like shamimin (flavonol-C-glycoside). (**b**) Pods of *Cassia fistula* (golden shower tree) are used traditionally for the treatment of diabetes and for antiseptic purposes. (**c**) *Ficus* species are medicinally important figs. *F. religiosa* (sacred fig) is an important antidiabetic fig with β-sitosteryl glycoside as an active compound

stabilizing or polymerizing microtubules in the cells. Anticancer compounds in combination like *Taxus* diterpenes, *Podophyllum* lignans, and alkaloids from *Camptotheca* can be effectively used to reduce the growth of cancer cells.

The National Cancer Institute has cataloged approximately 35,000 plants species with potential anticancer activities. Over 50 plants are reported to have anticancer (tumor-inhibiting) properties due to the presence of their bioactive compounds (anticarcinogens). However, anticancer compounds are mostly antioxidants or they have antitumor activity like polyphenols, isoflavones, taxols, and brassinosteroids. Polyphenols include tannins, flavonoids, curcumin, resveratrol, and gallocatechins. They interfere with carcinogenic compounds through binding with proteins or through regulation of acetylation, methylation, or phosphorylation.

Curcumin is known to suppress expression of tumor necrosis factor through interaction with various stimuli. Flavonoids from many plants have shown anticancer activities against many cancer cell lines including hepatoma, cervical carcinoma, and breast cancer. Genistein, isoflavone from soy beans, is known to inhibit the growth of many cancer cell lines including leukemia, lymphoma, prostate, breast, and lung cancer. It is reported as a protein tyrosine kinases inhibitor. It is capable of arresting the G2/M cell cycle in breast cells, gastric adenocarcinoma cells, and human melanoma cells. Biochanin is another anticancer isoflavone from soy which

is cytotoxic on cell growth in the mammary carcinoma cell line MCF-7, myeloid leukemia, and pancreatic tumor cells. Flavonoids from plants like *Erythrina suberosa* have cytotoxic effects against human leukemia. Flavonoids from citrus fruits like tangeretin and nobiletin can inhibit human breast cancer cell lines by blocking the progression of G1 phase of the cell cycle.

Popular trees with anticancer activities include *Abrus precatorius*, *Albizia lebbeck*, *Dillenia indica*, *Delonix regia*, *Erythrina suberosa*, *Magnolia grandiflora*, *Podocarpus macrophyllus*, *Murraya koenigii*, *Nasturtium officinale*, *Prunus persica*, *Pterospermum acerifolium*, *Thuja occidentalis*, *Vinca rosea*, and *Ziziphus nummularia*. Important edible fruits with anticancer properties are *Achras sapota*, *Bauhinia variegata*, *Eriobotrya japonica*, *Mangifera indica*, *Prunus persica*, and *Syzygium cumini* (Fig. 1.2a–d).

Fig. 1.2 (**a–d**) Some trees with anticancer activities. (**a**) *Prunus persica* (peach) is an important tree with anticancer and antidiabetic activities (due to the presence of amygdallin, an active constituent). (**b**) *Thuja occidentalis* (white cedar) is an important medicinal and ornamental plant with antidiabetic and anticancer activities due to its bioactive compound, thujone. (**c**) *Erythrina suberosa* (red coral tree) is found to be effective against various cancer cell lines and also possesses antiplasmodial and anxiolytic activities. In some experiments, flavonoids extracted from stem bark (4′-Methoxy licoflavanone [MLF] and Alpinum isoflavone [AIF]) showed cytotoxic effects in HL-60 cells (human leukemia). Further, extract from all parts of the plant can treat chronic dysmenorrhea and can maintain menstrual flow by reducing abdominal fats. (**d**) *Murraya koenigii* (curry tree) is an important anticancer, antidiabetic, and antimicrobial tree

Fig. 1.2 (continued)

Brassinosteroids are naturally occurring compounds in plants which are significant against cancer and are known to bind with proteins and can inhibit initiation of hormone-sensitive and hormone- insensitive cancer cells. 28-Homocastasterone (28-homoCS) and 24-epibrassinolide (24-epiBL) are reported to be important anticancer molecules, including against breast cancer, prostate cancer, T-lymphoblastic leukemia Carboplatin, Etoposide Phosphate, Melphalan Hydrochloride (CEM), multiple myeloma Roswell Park Memorial Institute (RPMI) 8226, cervical carcinoma HeLa, lung carcinoma A-549, and human osteosarcoma (HOS) cell lines, which are effective even at micromolar concentrations against many cancer cell lines.

However, many medicines prepared from herbs are hardly absorbed due to their complex structure and large size, so research is being conducted through nanobiotechnology which is aimed at reducing the particle size and increasing the dissolution rate of bioactive compounds. Bromelain is an anticancer compound isolated from *Ananas comosus* and more effective when formulated with nanoparticles by triggering the apoptosis of benign cells. Gold nanoparticles of *Antigonon leptopus* and *Acalypha indica* have shown anticancer activities against breast cancer cell lines. Quercetin is applied through superparamagnetic magnetite against breast cancer cell lines.

1.4.3 An Account of Antimicrobial Activity of Important Woody Plants

Antimicrobial properties of many trees are associated with alkaloids, tannins, terpenoids, polyamines, isothiocyanates, thiosulfinates, glucosides, and polyacetylenes. Flavonoids and acetylene compounds are also effective against malaria and liver

disorders. Many herbs also contain compounds with antimicrobial activities against a wide range of microorganisms and fungal spores including quinones, catechols, catechins, eugenols, isoeugenol, capsaicin, curcumin, piperine, hypericin, chrysin, coumarin, menthol, berberine, warfarin, and harmane.

Flavonoids like robinetin, myricetin, apigenin, rutin, galangin, 2,4,2′-trihydroxy-5′-methylchalcone, and lonchocarpol A also possess antimicrobial activities. Their antimicrobial activity is related to the position and number of hydroxyl groups attached to the ring, as higher toxicity is reported against many microorganisms with increase in number of hydroxyl groups. Catechol and pyrogallol are hydroxyl-containing flavonoids and contain toxic effects against many microorganisms. Many catechins present in teas are antimicrobial against many bacteria like *Vibrio cholerae*, *Streptococcus mutans*, and *Shigella*.

Trees like *Pterocarpus santalinus* possess a broad spectrum of antimicrobial activities due to isoflavone glycosides. Many antimicrobial compounds are being extracted from plants to be used for therapeutic purposes due to problems such as increase in antibiotics resistance (Fig. 1.3a–e). Antimicrobial activities of tannins are associated with their potential to inhibit microbial adhesion, enzymes, and cell envelope transport proteins. They also possess many insecticidal, antiviral, and antifungal activities.

Fungicidal activities of approximately 1281 species are reported from 184 families. Members of the families Anacardiaceae, Compositae, Cruciferae (Brassicaceae), Labiatae (Lamiaceae), Liliaceae, Ranunculaceae, Rosaceae, and Solanaceae exhibit antifungal activities.

Antimicrobial activities are screened commonly through either broth dilution assays and disk or agar well diffusion assay. Inoculated plates are also exposed to UV light to check for the presence of light-sensitizing phytochemicals. Antifungal activities are measured through spore germination assays in which phytochemicals are added to fungal spores and then observed microscopically to check spore germination and then check for antibiotic effects.

1.4.4 Antiviral and Possible Anti-HIV Activity of Important Woody Plants

Acquired immunodeficiency syndrome (AIDS) is an immunosuppressive disease caused by the human immunodeficiency virus (HIV) which causes life-threatening opportunistic infections. It is one of the leading causes of death in Africa and the number of people infected with HIV is increasing worldwide.

Many trees are reported to be effective against viruses and for the treatment of AIDS due to their possible anti-HIV potential. Crude extract of balsam from many trees, which is also known as bee glue, is a mixture of complex terpenoids, flavonoids, benzoic acids, esters, and phenolic acids. It is effective against herpes simplex virus (HSV-1), adenovirus type 2, vesicular stomatitis virus, and poliovirus (Fig. 1.4a–c).

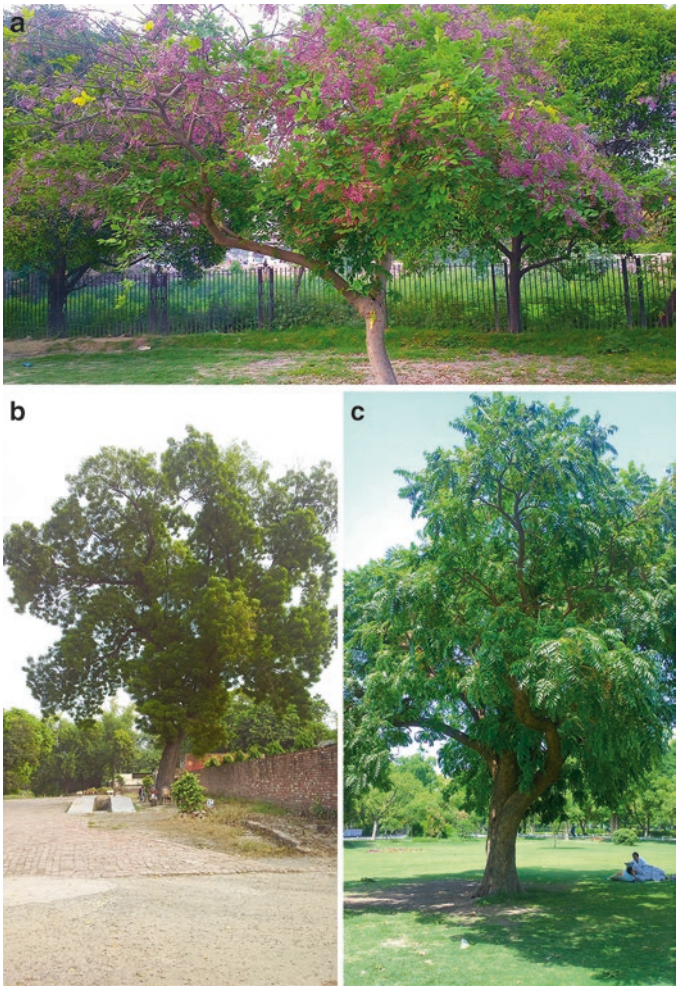

Fig. 1.3 (**a**–**e**) Antimicrobial properties of trees are due to alkaloids, glycosides, and other phenolic compounds. (**a**) *Millettia ovalifolia* (rosewood tree) possesses flavonoids and rotenone which are known to have antibacterial and anticancer activities. (**b**) *Melia azedarach* (white cedar) is well known due to its antimicrobial and other medicinal properties. Azadirachtin, nimbin, and nimbidin have antiviral and antifungal properties. (**c**) Ethyl acetate extract of *Toona ciliata* (red cedar) is reported to have antibacterial activity against *Salmonella typhi* and *Staphylococcus epidermidis*, while methanolic extract is significant against *Klebsiella pneumoniae*, *S. typhi*, *Staphylococcus aureus*, and *S. epidermidis*. (**d**) Spreading crown of *Kigelia pinnata* (sausage tree) is an important medicinal plant with antimalarial compound (lapachol) and antibacterial compound (kigelinone). (**e**) Essential oil of *Pinus roxburghii* (chir pine) is antimicrobial and possesses insecticidal properties

Fig. 1.3 (continued)

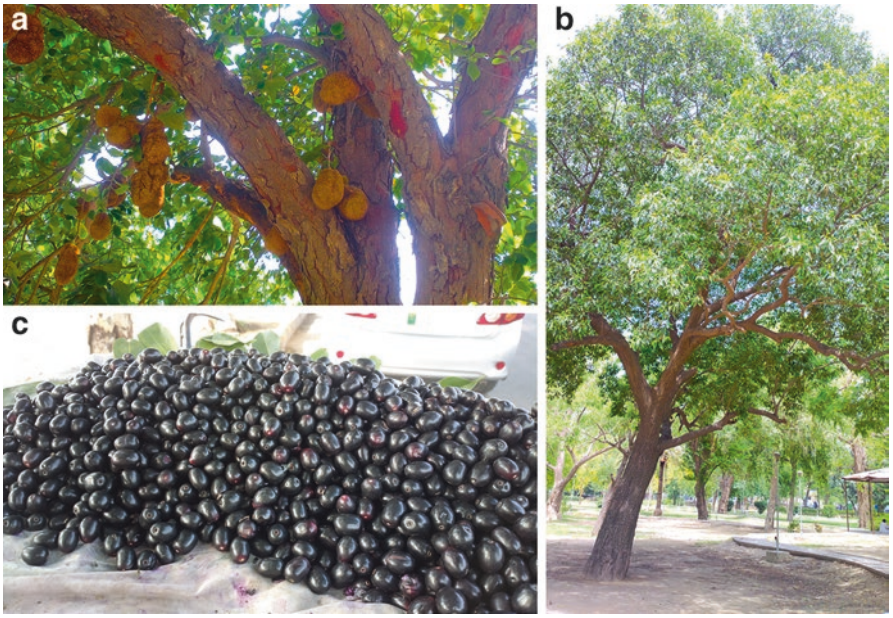

Fig. 1.4 (**a**–**c**) Trees with antiviral properties. (**a**) *Artocarpus integrifolia* (jackfruit) is an important plant with antibacterial, antidiabetic, and possible anti-HIV potential due to the presence of lectins like jacalin which interact with the lymphocyte cell-surface-molecule CD4, a receptor of HIV-1. (**b**) Fruits and seeds of *Mimusops elengi* (bullet wood tree) are a rich source of triterpenoid saponins like mimusopsides A and B, mimusopins and mimusopsins, and mimusopic acids which have possible anti-HIV potential. (**c**) Fruit and seeds of *Syzygium cumini* (jambul) are rich in antioxidants with anticancer and anti-HIV properties

Many flavonoid compounds exhibit antiviral activities against multiple viruses which include swertifrancheside, glycyrrhizin, and chryrsin, which can inhibit HIV replication. Ellagitannins, hydroxymaprounic acid, betulinic acid, catechins, quercetins, flavones, cornusins, ursolic acids, and lectins are associated with anti-HIV properties.

Polyphenols in tea like epigallocatechin-3-gallate (EGCG) are reported to interfere with the envelope protein of HIV-1. Scutellarin can inhibit many stages of HIV replication by inhibiting HIV-1 reverse transcriptase activity, HIV-1 particle attachment, or cell fusion. Chrysin is also known to be a potent inhibitor of HIV-1 transcription in infected cells, and calanolide isolated from *Calophyllum lanigerum* has the potential to be used for drug development against HIV.

Alkaloids like papaverine from *Papaver somniferum*, buchapine from *Evodia roxburghiana*, nitidine from *Toddalia asiatica*, piperidine from *Buchenavia capitata*, and harmine from *Symplocos setchuensis* have anti-HIV potential.

Phenolic compounds like lithospermic acid isolated from *Salvia miltiorrhiza*; punicalagin, gallic acid, and chebulagic acid from *Terminalia chebula*; repandusinic acid from *Phyllanthus niruri*; and mallatojaponin from *Mallotus japonicus* are also reported to have anti-HIV activities.

1.4.5 Cardioprotective and Hepatoprotective Activities

Flavonoids and polyphenols found in many trees are known to possess cardioprotective activities, as consumption of edible fruit containing flavonoids reduces oxidative stress which causes change in lipid peroxidation in arterial macrophage and in lipoproteins and is therefore beneficial for reducing cardiovascular disorders. Hypochlorite scavenging activity of some flavonoids is also reported, which can cause atherosclerosis. Many flavonoids in tea possess lipid-lowering activities, while polyphenols like diverin can reduce low-density lipoprotein (LDL) while increasing high-density lipoprotein (HDL) in coronary heart disease patients.

Chrysin, curcumin, catechins, chrysoeriol, eugenol, frederine, gingerol, diosgenin, hesperidin, hydroxytyrosol (from *Olea europaea*), kaempferol, lycopene, resveratrol, sesamin, mangiferin, and periplogenin from *Aegle marmelos* are reported to have cardioprotective activities against doxorubicin (DOX). Arjunolic acid is a triterpenoid saponin from *Terminalia arjuna* that possesses cardioprotective properties and reduces the effects of cytotoxic antibiotics like doxorubicin and reduces myocardial toxicity when administrated in rats (Fig. 1.5a–c).

Natural products from plants possess healing properties for recovery of intoxicated liver. A number of plants are known to have antihepatitis and anticirrhosis activities. Flavonoids like naringenin from *Citrus* spp. are useful in the treatment of hepatic fibrosis, while naringin promotes the hepatic antioxidant defense system. Proanthocyanidins and anthocyanins, which are widely present in blueberries, protect hepatocytes from oxidative stress and maintain normal functions of the liver. Extracts from cladode of *Opuntia ficus-indica* are known to protect liver health by scavenging free radical species and by enhancing antioxidant activities. They also reduce hepatic toxicity of organophosphorus insecticide chlorpyrifos.

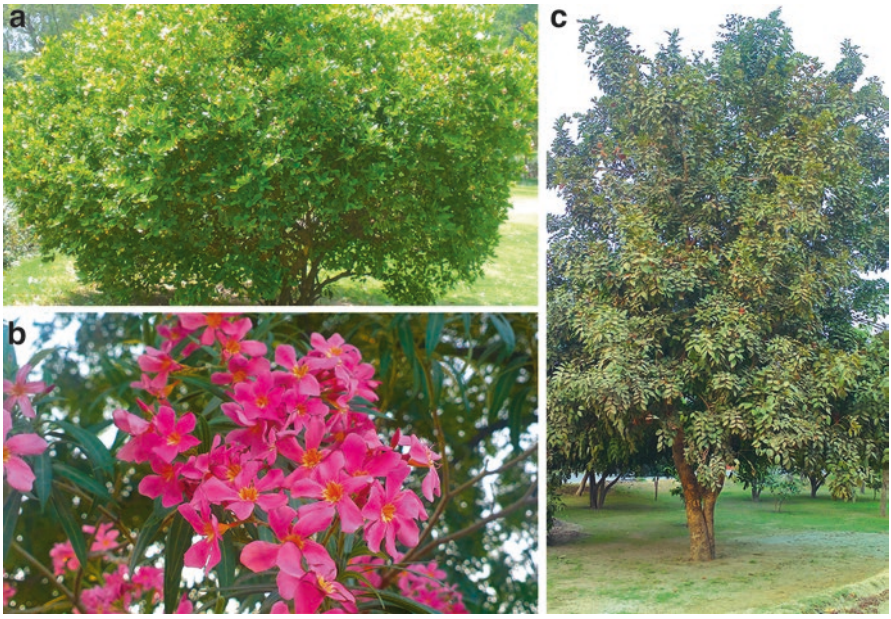

Fig. 1.5 (**a–c**) Trees with cardioactive and hepatoprotective properties. (**a**) Fruit and leaf extracts of *Carissa carandas* (Bengal currant) possess cardioprotective and hepatoprotective properties. (**b**) Cardioactive properties of *Nerium oleander* (rose-bay) are due to cardioactive glycosides which are extracted from leaves including gentiobiosyl-oleandrin, gentiobiosyl-nerigoside and gentiobiosyl-beaumontoside and also due to alkaloids like neriin and oleandrin. Oleandrin and its aglycone oleandrigenin are shown to have anticancer properties. (**c**) *Terminalia arjuna* (arjun tree) possesses cardioprotective properties against chronic stable angina, endothelial dysfunction, heart failure, and ischemic mitral regurgitation

1.4.6 Analgesic and Antipyretic Activities

Many trees are known to inhibit the activities of pyrogens (disease-causing agents) and are therefore known as "antipyretic." They inhibit the activity of prostaglandin synthase with low selectivity without causing any side effects. Many plants with antipyretic activities also relieve pain which is mostly due to fever and therefore also possess analgesic effects, i.e., pain-relieving activities. Therefore, there is a need to search for plants with antipyretic activities which can be used as a substitute for paracetamol and other synthetic drugs.

More than 500 species of *Salix*, commonly known as willows, are reported worldwide and have analgesic and antipyretic activities (Fig. 1.6a–b). They are used traditionally and in drugs due to their pain- and fever-relieving properties. The main active compound is salicin from tree bark along with phenolic glycosides like salicortin, fragilin, and tremulacin. Aspirin is one of the nonsteroidal anti-inflammatory drugs from willow leaves which has long been used due to its analgesic and antipyretic effects due to its inhibitory effects on cyclooxygenases, which can form prostanoids. However, discovery of cyclooxygenases-2 has increased the demands of plant phytochemicals with anti-inflammatory activities.

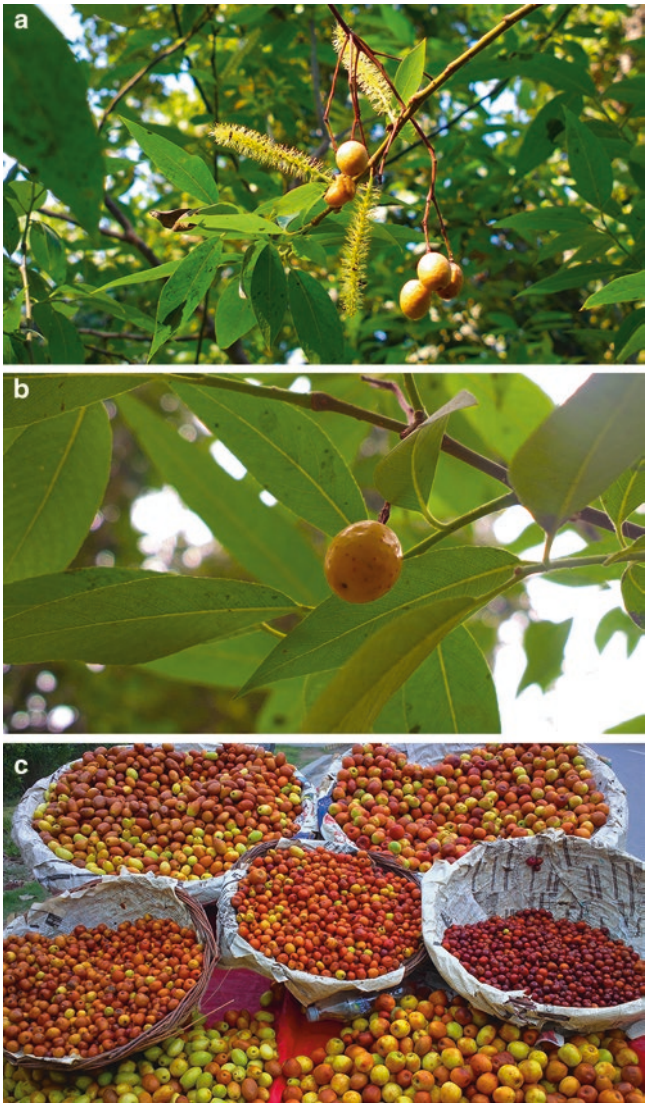

Fig. 1.6 (**a**–**b**) Antipyretic, anti-inflammatory, and analgesic properties of many *Salix* spp. (Indian willow) are due to the main compound salicin. (**c**) Analgesic, antimicrobial, anticancer, antiplasmodial, and antidiabetic activities of *Ziziphus mauritiana* (jujube) are due to cyclopeptides and jujubosides

1.4.7 Trees with Aphrodisiac and Antifertile Activities

Plants and plant-based products have long been usedto improve sexual behavior. Aphrodisiac properties of many trees are reported due to the presence of compounds which can maintain levels of the sex hormone testosterone and can also improve blood flow. Many aphrodisiacs work by improving the testosterone level or by controlling the central nervous system, or by crossing the blood-brain barrier and stimulating the area of sexual arousal or through giving nutrients required for sexual health.

Aphrodisiac properties of plants like *Moringa oleifera* are due to saponins and due to their high nutritive value. Other plants with aphrodisiac activities are discussed in Chap. 8 (Fig. 1.7a–d). Date palm pollens contain estradiol and flavonoids, which are reported to improve the reproductive system of adult male rats. Administration of 50% ethanolic extract of nutmeg, clove, and penegra improved mating behavior of mice.

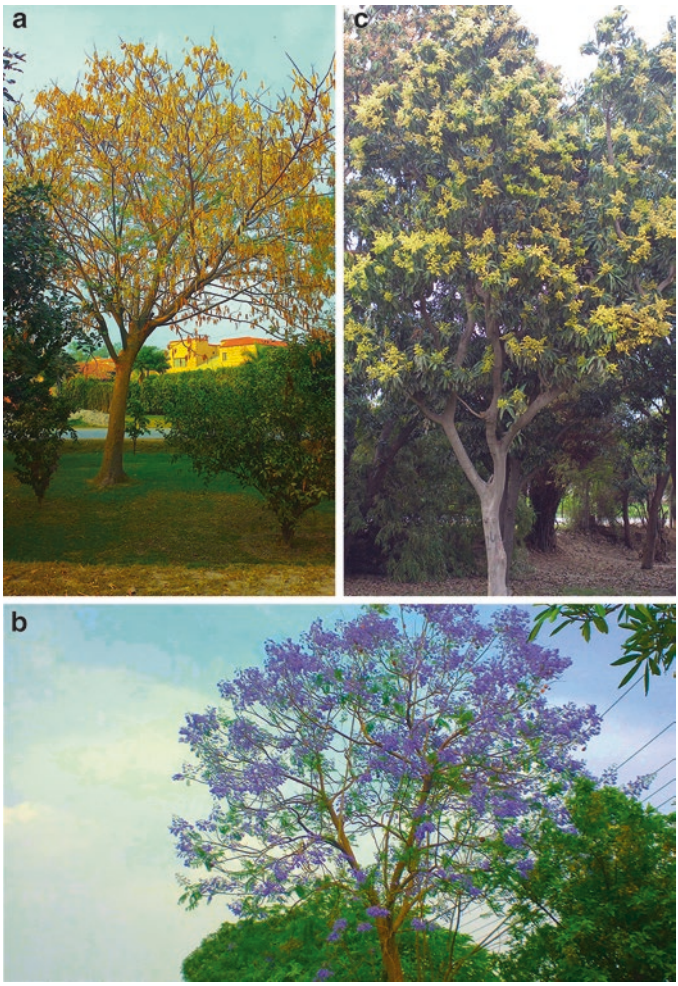

Fig. 1.7 (**a**–**d**) Some trees and shrubs with aphrodisiac and abortifacient activities. (**a**) Methanolic extract of *Albizia lebbeck* (flea tree) pods possesses antifertile activities. (**b**) Tea prepared from *Jacaranda mimosifolia* (fern tree) leaves and bark decoction is aphrodisiac and is used to regulate fertility and lactation. (**c**) *Mangifera indica* (mango) is an important edible tree in many Asian countries which possesses aphrodisiac, anticancer, and antidiabetic activities. (**d**) Seed extract of *Ricinus communis* (castor oil plant), commonly known as castor oil plant, possesses anticonceptive activity due to the presence of ricinoleic acid which has spermicidal effects. (**e**) *Dombeya rotundifolia* (wild pear) possesses abortifacient activity

Fig. 1.7 (continued)

Terminalia catappa seeds at a dose of 1500 mg/kg exhibited improvement of aphrodisiac activities in rats for 7 days but a higher dose of 3000 mg/kg inhibited sexual behavior. Fruit, leaves, and bark extracts of *Ficus religiosa* are traditionally cooked with milk and sugar and used as an aphrodisiac. Yohimbe acts as a stimulant for pelvic nerve ganglia and also boosts adrenaline supply to nerve endings, which improves sexual sensation. Some herbal aphrodisiac products available in the market include VigRX Oil™, Maxoderm™, Virility Pills, ProEnhance™, Virility Patch, and RX™.

Many plants are known to induce abortion or to have antifertile activities and are used as emmenagogues. They have been used traditionally worldwide for inducing abortion. Extracts of such plants can inhibit fertility,cause abortion, or stimulate uterine contractions. They are either directly swallowed as abortifacients or a drink or tea is made from these plants' parts. Many of them cause disruption and desynchronizing of preovulatory and preimplanting events. Antifertile agents which prevent ovulation or fertilization are known as contraceptives while those which affect after implantation are known as abortifacients. Oral contraceptives like Depo-Provera and Norplant© have been used successfully in many areas of the Pacific.

Plants like *Albizia lebbeck*, *Carica papaya*, *Crocus sativus*, *Dombeya rotundifolia*, *Ricinus communis*, *Myristica fragrans*, *Tamarindus indica*, and *Trichosanthes kirilowii* are known to have anticonceptive activities. Interestingly, many plants which act as aphrodisiacs are also known to be abortifacients; the actual difference is due to the concentration of extract of plants, which can either promote fertility or can cause infertility.

However, the majority of these plants and their aphrodisiac and abortifacient efficacy are tested on rats, which showed improvement in sexual behavior through administration of aqueous, ethanolic, methanolic, chloroform, hexane, and petroleum ether extracts of different parts of these plants, and this has not yet been tested experimentally on humans and their mechanism of action on human tissues is still unknown and needs to be investigated further.

1.4.8 Medicinal Properties of Important Leguminous Trees

Edible legumes make up an important part of seed vegetables and are a rich source of proteins. They include lentils, peas, and chickpeas and beans like fava beans, kidney beans, pinto beans, and soybeans. Soymilk, tofu (bean curd), and miso are important products of soybeans. Soymilk is rich in many phytoestrogens which reduce osteoporosis, with a nutritive value equal to cow's milk. Many trees of the legume family are a source of food, fodder, and fuel and are medicinally important because they possess important plants with antibacterial, antifungal, antimicrobial, antiallergic, antidiabetic, and anticancer activities due to the presence of flavonoids (isoflavones), furanocoumarins, terpenoids, quinones, and xanthones.

Many trees of the legume family also serve as a source of biofuel, which can be derived from recently dead organic or biological material, whereas fossil fuel is derived from long dead material. Many plants are being evaluated to explore their potential to be used as biofuel. Some trees are a source of timber, fuel, cordage, and paper making. Well-known plants are *Acacia* and *Albizia* spp., *Butea monosperma*, *Dalbergia sissoo*, *Delonix regia*, and *Erythrina suberosa* (Fig. 1.8a–d).

Fig. 1.8 (**a**–**c**) Medicinally important legumes. (**a**) *B. variegata* (orchid tree) is a leguminous tree with a wide range of medicinal activities like anticancer, antimicrobial, anti-inflammatory, nephroprotective, and hepatoprotective properties which are attributed to many flavonoids, kaempferols, and cytokines present in leaves. (**b**) *Delonix regia* (royal poinciana) also known as flame of forest is an important medicinal leguminous tree due to the presence of many flavonoids many of which are antioxidants with anticancer and radioprotective properties. (**c**) *Saraca indica* (asoka) is a legume with antibacterial, anticancer, and antitumor potential

1.4.9 Medicinally Important Figs, Nuts, and Edible Fruits

Figs belong to the *Ficus* species, which is a large genus comprising over 800 medicinally important species distributed worldwide. However, some of the important species are discussed in Chap. 10 with their important phytochemicals and medicinal value. Although many species of *Ficus* are not edible, they possess many antidiabetic, anticancer, and antimicrobial activities (Fig. 1.9a, b).

Edible fruits, figs, and nuts are rich sources of micronutrients, fibers, vitamins, and minerals and are also important as they possess numerous medicinal activities. Thousands of different types of fruits are grown around the world and are also collected from wild plants. Various citrus fruits, pome fruits, stone fruits, dried fruits with hard shells like almonds, cashew nuts, walnut, pecans, macadamia, Brazil nuts, hazelnuts, pistachios, and pine nuts, and fruits growing in the tropics like bananas, papayas, mangoes, and pineapples are widely consumed due to their nutritive and medicinal value (Fig. 1.10a–e). Many edible dried fruits maintain cardiovascular health and provide protection against coronary heart diseases.

Fig. 1.9 (**a**) Figs like *Ficus benghalensis* (banyan) are antidiabetic due to the presence of leucoanthocyanidins. (**b**) *Ficus macrophylla* (strangler fig) is commonly known as strangler fig and possesses important antimicrobial and antidiabetic properties