Chapter 2
Important Trees with Antidiabetic Activities

Abstract This chapter explains antidiabetic activities of woody plants like *Achras sapota*, *Bombax ceiba*, *Barringtonia acutangula*, *Casuarina equisitifolia*, *Conocarpus lancifolius*, *Eriobotrya japonica*, *Euphorbia pulcherrima*, *Jasminum sambac*, *Kigelia pinnata*, *Lagerstroemia indica rosea*, *Hibiscus rosa sinensis*, *Morus alba*, *Murraya koenigii*, and *Roystonea regia*. More than 400 plants are reported to have antidiabetic activities due to their effects on lowering blood cholesterol, decreasing lipid peroxidation, and increasing the renewal of parietal cells in the pancreas and thereby stimulating the secretion of pancreatic insulin. The medicinal properties of many such trees are described in this section.

2.1 Introduction

Diabetes mellitus, a serious health problem which is caused due to increase in plasma glucose concentration resulting from insufficient insulin, results in many metabolic abnormalities and disturbed metabolism of proteins, carbohydrates, and lipids. Insulin is released by pancreatic β-cells and regulates glucose homeostasis. It stimulates hepatocytes, myocytes, and adipocytes to uptake glucose from the circulatory system which can be further catabolized for metabolic needs or stored as glycogen. When insulin cannot be utilized effectively by cells, it results in diabetes.

There are almost 150 million people worldwide suffering from diabetes (Moller and Filler 1991). However, type 2 diabetes (T2DM) is the most encountered form of diabetes, which accounts for more than 80% of total cases (Mlinar et al. 2007). Diabetes is also known to cause hyperlipidemia by disturbing metabolic pathways. Insulin deficiency stimulates lipolysis in adipose tissues and gives rise to hyperlipidemia.

Management of diabetes without any side effects is still a challenge for medical science, and research is being conducted on medicinal plants with antidiabetic activities in order to identify potential compounds and facilitate their therapeutic application. More than 800 plants are used in different ways to treat diabetes worldwide, particularly those which belong to the families Asteraceae, Cucurbitaceae, Euphorbiaceae, Leguminosae, Lamiaceae, Moraceae, and Rosaceae. Many of them have proved to be effective in lowering blood glucose level in alloxan-induced and streptozotocin-induced diabetic mice, Swiss rats, or Wistar rats. However, some

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plants medicate diabetic nephropathy by lowering blood cholesterol, decreasing lipid peroxidation, and increasing the renewal of parietal cells in the pancreas and thereby stimulating the secretion of pancreatic insulin.

Many saponins are antidiabetic compounds which stimulate insulin release (Keller et al. 2011), improve insulin sensitivity (Kwon et al. 2009), or promote glucose uptake (Wang and Zhang 2012). Plants with antihyperlipidemic activities also reduce blood glucose, improve lipid profile, increase insulin secretion from the pancreas, and inhibit intestinal absorption of glucose (Fig. 2.1a–e).

2.2 Important Trees with Antidiabetic Activities

Antidiabetic activity of important trees is discussed in the following section.

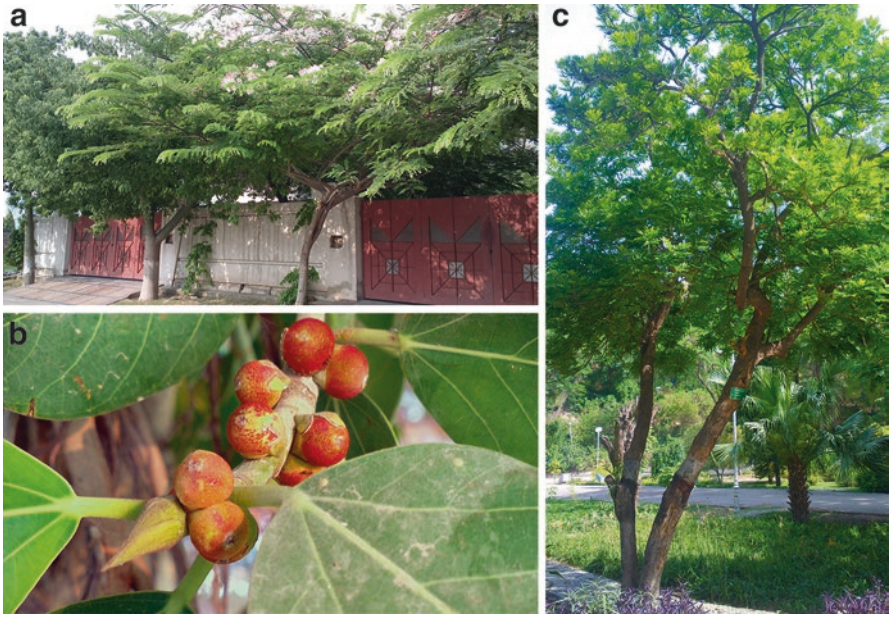

Fig. 2.1 (**a**–**e**) (**a**) *Cassia javanica* (pink shower) is an important tree with antidiabetic, anticancer and antifungal properties which are due to important phytochemicals like anthraquinones and sterols (**b**) Fruits (red) of *F. benghalensis* (Indian banyan) are source of leucopelargonins (an active antidiabetic constituent) (**c**) Hydrochloric acid extract of *Sapindus mukorossi* (Chinese soapberry) fruit possesses antihyperglycemic and antihyperlipidemic properties (**d**) *Sterculia alata* (Buddha coconut) seeds are used traditionally for treating diabetes (**e**) Seeds and leaves of *Roystonea regia* (Cuban royal palm) are used traditionally for treatment of diabetes

Fig. 2.1 (continued)

2.3 *Achras sapota* L. (Syn: *Manilkara zapota*)

Vernacular name: Sapodilla
Family: Sapotaceae

Ecological Distribution and Morphological Characteristics *A. sapota* is an evergreen, latex-producing tree which is native to tropical America but is also grown in many countries in Southeast Asia.

It can grow up to a height of 30 m. The glossy leaves are medium sized, alternately arranged, and elliptic to ovate in shape. The flowers are monoecious, white, and look like bells. The fruit is a berry, which is edible (Fig. 2.2a, b).

Important Phytochemicals and Medicinal Value The main constituents are alkaloids, steroids, flavonoids, saponins, tannins, amino acids, anthraquinone, deoxy sugars, and phenolic compounds. Important phytochemicals in seeds are saponin, sapotin, achrassaponin, and sapotinine. The juice is a rich source of sugars, proteins, ascorbic acid, phenolics, carotenoids, and minerals like iron, copper, zinc, calcium, and potassium. The radical-scavenging potential of *sapota* juice is due to its nutraceutical metabolites, like phenolics, carotenoids, and ascorbic acid (Monalisha et al. 2010).

Antidiabetic activity of the seeds is due to the presence of saponins as significant hypoglycemic effects are reported in streptozotocin-induced diabetic rats at 400 mg of aqueous extract and 200 mg of ethanolic extract (Zheng et al. 2012; Ruchmani et al. 2014). The roots and leaves are also reported to have hypoglycemic activity (Muthadi et al. 2000; Fayek et al. 2012).

Fig. 2.2 (**a**, **b**) Antihyperglycemic activities of *Achras sapota,* sapodilla are due to the presence of sterols and triterpenoids.Significant hypoglycemic effects of seed extracts are reported in streptozotocin-induced diabetic rats at 400 mg of aqueous extract and 200 mg of ethanolic extract (**a**) Spiral leaves containing fruits (**b**) Fruit

Traditional Uses Bark of the plant is antibiotic, astringent, and febrifuge. The leaves are used to treat cold and cough. They have antimicrobial and antioxidant activities (Nair and Chanda 2008; Kaneria et al. 2009; Kaneria and Chanda 2012). The latex of *sapota* is used for filling tooth cavities. A paste of the seeds is applied to cure bites of poisonous animals. The fruit is edible, aromatic, astringent, and sweet (Balerdi and Shaw 1998).

2.4 *Bombax ceiba* L.

Vernacular names: Red cotton, Silk tree
Family*:* Bombacaceae

Ecological Distribution and Morphological Characteristics It is also known as the red cotton tree due to the color of the flowers. It is native to Pakistan, India, and Nepal. The leaves are large, petiolate, compound, divided into 5–7 leaflets, digitate,

and lanceolate. Large red flowers appear in early spring, and the fruit is a capsule having fibers like the cotton plant (Fig. 2.3a–h). The seeds are smooth, black, or gray embedded in long white wool.

Important Phytochemicals and Medicinal Value The roots are a rich source of terpenoids like cadinane sesquiterpenoids, which include bombamalones, lactone, bombaxquinone B, and lacinilene. They also contain β-D-glucoside of β-setosterol, free β-setosterol, hentriacontane, hentriacontanol, kaempferol, and quercetin along with traces of an essential oil. Phytochemical screening revealed that fresh petals of the flowers are a source of anthocyanidine glycoside (A and B), which are characterized as pelargonidin-5β-D (El-Hagrassi et al. 2011). The seeds of plants also contain important metabolites like n-hexacosanol, palmitic acid, octadecyl palmitate, tannic acid, 1-gallayl-β-glucose, ethyl gallate, and a mixture of α-, β-, and γ- tocopherol.

The leaves, fruits, and heartwood are reported to possess antidiabetic activity due to the presence of C-flavonol glucoside shamiminol (Saravanamuttu and Sudarsanam 2012). At a dose of 600 mg/kg/bw, bark extract caused significant hypoglycemic and hypolipidemic effects in streptozotocin-induced diabetic rats, which might be due to the presence of triterpenoid compounds in the extract (Bhavsar and Talele 2013). The flowers are known to possess cardioprotective activities (Patel et al. 2011).

Fig. 2.3 (**a**–**h**) (**a**) Leaves and fruits of *Bombax ceiba*, red cotton tree possess antidiabetic activity. Main antidiabetic compound is C-flavonol glucoside shamimin. Bark extract showed significant hypoglycemic and hypolipidemic effects in streptozotocin-induced diabetic rats at dose of 600 mg/kg/bw (**b**) Digitate leaves (**c**) Flowers (**d**) Buds (**e**) Branch containing fruits (**f**) Cotton from fruit which is a capsule is used for making pillows and quilts (**g**, **h**) Deciduous tree in winter

Fig. 2.3 (continued)

Traditional Uses The plant is used as a source of fuel, furniture, and carving wood. Cotton from seeds is used for pillows quilts and matchsticks (Sheikh 1993). The stem bark is considered as diuretic, inflammation, and astringent. The flowers are also astringent. The seeds are used traditionally in the treatment of chickenpox and smallpox (Jain 1996; Williamsons 2002).

2.5 *Barringtonia acutangula* (L.) Gaertn.

Vernacular names: Freshwater mangrove, Mango-Pine
Family: Lecythidaceae

Ecological Distribution and Morphological Characteristics It is an evergreen tree which grows up to a height of 15 m and is native to South Asian and northern Australia. The leaves are petiolate, oval, thick, and smooth, and inflorescence is a drooping raceme which bears white flowers. The fruits are oval (Fig. 2.4a–c).

Important Phytochemicals and Medicinal Value Methyl ether extract of dried seeds revealed the presence of three monodesmosidic glucuronide saponins of

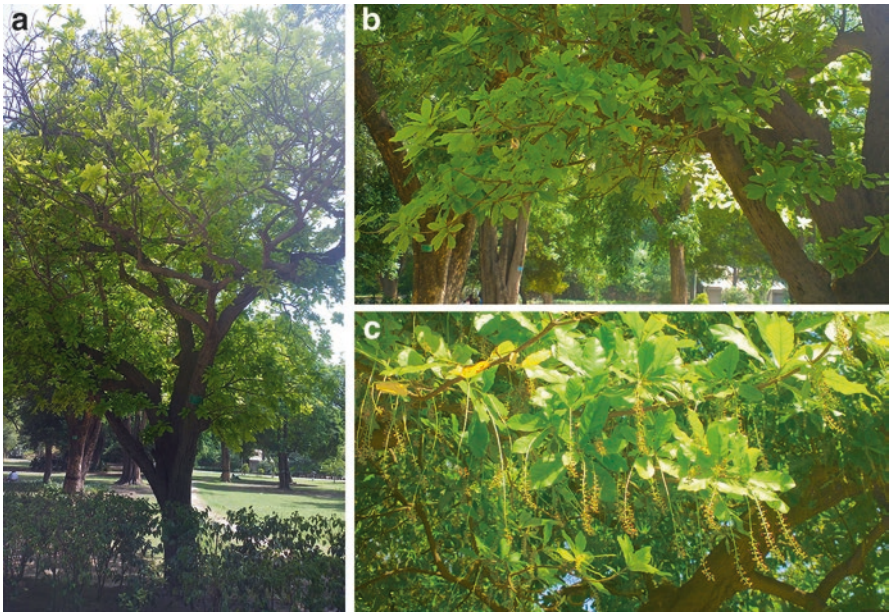

Fig. 2.4 (**a–c**) (**a**) *Barringtonia acutangula* (Indian oak) is a medicinally important tree with antidiabetic activities of leaves, roots and fruit. Aqueous extract of fruit at dose of 400 mg/kg/bw possesses significant hypoglycemic activities in streptozotocin-induced hyperglycemic rats and its activity is comparable to standard drug glibenclamide. Important phytochemicals are barringtosides, quercetin, syringic acid and vanillic acid (**b**) Petiolate leaves (**c**) Drooping raceme

barringtogenol C, i.e., barringtosides A, B, and C (Pal et al. 1994). Phytochemical analysis showed the presence of flavonols 3′, 4′-diOMe quercetin, gossypetin, 3′-OMe gossypetin, and quinones in leaves, whereas the bark showed 8-oxygenated flavonols, gossypetin, 3′-methyl ether, and quinone (Daniel and Robin 2011).

Aqueous extract of the fruit at a dose of 400 mg/kg/bw possesses significant hypoglycemic activities in streptozotocin-induced hyperglycemic rats, and its activity is comparable to the standard drug glibenclamide (Khatib and Patil 2011). In another study, ethanolic extract of leaves significantly reduced (40–50%) blood sugar level in alloxan-induced diabetes in Wistar albino rats after treatment for 21 days at dose of 250 and 500 mg/kg/bw per day (Palanivel et al. 2013; Gregory et al. 2014). Aqueous ethanolic extract of roots is reported to cause significant improvement in glucose tolerance (Babre et al. 2010).

Petroleum ether extract of stem bark showed antimicrobial activities against *B. subtilis* and *A. niger* (Rahman et al. 2005). Flavonoids like myricetin and gossypetin can modify low-density lipoproteins and increase their uptake by macrophages. Many medicinal properties of the tree, like hepatoprotective, antiviral, antimicrobial, analgesic, anticarcinogenic, antidiabetic, and antimalarial activities, are due to compounds like quercetin, syringic acid, and vanillic acid (Miller 1996; Duke 1997).

Traditional Uses Aqueous extract of the bark is hypoglycemic and effective against pneumonia, diarrhea, and malaria, and is used as a contraceptive in China. The leaf juice is also used to treat diarrhea. The fruit is anthelmintic and an expectorant (Daniel and Robin 2011). The young leaves are edible and popular in Vietnamese cuisine. It is also recommended that consumption of tea made from any of the plant parts is helpful in the management of diabetes (Gregory et al. 2014).

2.6 *Casuarina equisitifolia* L.

Vernacular names: Australian pine tree, She-Oak
Family: Casuarinaceae

Ecological Distribution and Morphological Characteristics It is native to Myanmar, Vietnam and Southeast Asia to Australia. The plant is grown as an ornamental evergreen tree with drooping branches approximately 10–50 m high. Scale-like leaves are arranged in whorls of six to eight. Catkin flowers are monoecious(Fig. 2.5).

Important Phytochemicals and Medicinal Value Important compounds isolated from different parts are alicyclic acids (shikimic and quinic acids), lupeol, kaempferol, lupenone, quercetin, sitosterol, taraxerol (Rastogi and Mehrotra 1998), ellagic acid, trifolin, catechin, epicatechin, casuarine, gallicin, nictoflorin, and rutin.

Phytosterols from the leaves possess antibacterial, hypoglycemic, antimicrobial (Gumgumjee and Hajar 2012), antidiarrheal (Kumar 2011), and cytotoxic activities. Ethanolic extract of the bark reduced blood sugar, total cholesterol, LDL cholesterol, and VLDL cholesterol in streptozotocin-induced diabetic rats, which indicates its hypoglycemic and antihyperlipidemic effect (Sriram 2011).

Fig. 2.5 Bark of *Casuarina equisitifolia* (Australian pine tree) is antidiabetic and antihelmintic

Traditional Uses The plant is used as fuel and to control soil erosion. The bark is used traditionally as an astringent (Mhaskar et al. 2000) and for its antidiabetic (Prajapati et al. 2003) and antihelmintic activities (Aher et al. 2006, 2008). An infusion of the leaves is used to treat throat infections, menorrhagia, cough, asthma, and diabetes (Sriram 2011).

2.7 *Conocarpus lancifolius* Eng.

Vernacular name: Damas tree
Family: Combretaceae

Ecological Distribution and Morphological Characteristics It is a fast-growing tree that produces a large amount of biomass in summer which can be shaped into hedges. The plant is native to coastal and riverine regions of East Africa (Baroon

and Razzaque 2012) but is also cultivated in South Asia. It was introduced formerly into Kuwait, where it has been exposed to many environmental stresses including salinity, oil pollution, high temperature, and extreme climatic conditions.

The leaves are glossy, with trichomes, and lens shaped (Redha et al. 2011). Flowering takes place in early spring. The flowers are pentamerous and floral heads are globose and creamy white (Fig. 2.6a–f).

Important Phytochemicals and Medicinal Value Analysis of the leaf extracts indicated the presence of phenolics, terpenoids, alkaloids, and fatty acids. The plant

Fig. 2.6 (**a–f**) Methanolic extract of *Conocarpus lancifolius* (damas tree) is known to cause antidiabetic activity in alloxan-induced diabetic rabbits. Ethanolic extract of bark reduced blood sugar level in streptozotocin-induced diabetic rats (**a**) Young plant (**b**) Mature tree (**c**) Young flower (**d**, **e**) Developing flowers (**f**) Fruits

Fig. 2.6 (continued)

possesses prominent antidiabetic and cytotoxic activity against the MRC-5 cancer cell line and antiprotozoal and antibacterial activities (Al-Taweel et al. 2016). Total methanol-soluble extract is reported to have antibacterial and low antifungal activities (Saad et al. 2014).

Methanolic extract of the plant showed antidiabetic activity in alloxan-induced diabetic rabbits at a dose of 200 mg/kg/bw due to the presence of saponins (Saadullah et al. 2014).

Traditional Uses The plant is used as a source of fuel and fodder (Sheikh 1993). Leaf extracts of *C. lancifolius* showed allelopathic effects in corn and bean seeds and plants.

2.8 *Eriobotrya japonica* Lindl.

Vernacular names: Japanese plum, Loquat
Family: Rosaceae

Ecological Distribution and Morphological Characteristics *E. japonica* is an evergreen shrub or tree which is native to China. Its cultivation is known to be more than 2000 years old since the Han dynasty (100 BC) (Chen et al. 2008). It is widely planted as an edible fruit tree in China, Japan, Pakistan, and the Mediterranean region. Leaves are alternate, tough, leathery with serrate margins, and arranged in the form of whorls (Fig. 2.7a–d). Flowering starts in autumn.

Important Phytochemicals and Medicinal Value Important metabolites include many alcoholic groups like camphene, camphor, cymene, farnesol, hexenol, geraniol, linalool, trans-linalool oxide, nerolidol, nerol, myrcene, and pinene (Zheng et al. 1998). Many phenolic compounds are found in the fruit, which include 4-caffeoylquinic acid, 5-caffeoylquinic acid, hydroxybenzoic acid, 5-*p*-feruloylquinic acid, protocatechuic acid, epicatechin, *o*-coumaric acid, ferulic acid, and *p*-coumaric acid (Lim 2012). Amygdalin is found in the leaf and kernel in significant amounts (Zhuang 2002).

Oleanolic and ursolic acids are extracted from flower extract (Cheng et al. 2001). Other isolated sesquiterpenes include sesquiterpene, sohumbertiol as aglycones, and branched oligosaccharidic chains made up of -L-rhamnopyranosyl and -D-glucopyranosyl units (Chen et al. 2008).

Antidiabetic potential of the plant is attributed to the presence of compounds like flavonoids, tannins, corosolic acid, 3-epicorosolic acid methyl ester, 2-α hydroxy-3-oxo urs 12-en-28-oic acid, tormentic acid methyl ester, and ursolic acid isolated from leaf extract (Saravanamuttu and Sudarsanam 2012). Ethanolic extract of the seeds is reported not only to suppress the rise of blood glucose for 4 months but also to improve glucose tolerance in mice (Tanaka et al. 2008). Further, 50% ethanolic extract of the fruit reduced blood glucose level at a dose of 200 mg/kg/bw and improved lipid profile in alloxan-induced diabetic rats (Shafi and Tabasum 2013).

Antidiabetic activity of the leaves is reported due to the presence of sesquiterpene glycosides which have hypoglycemic effects (Chen et al. 2008) and due to their potential to inhibit 11ß-HSD1 and 11ß-HSD2 (Christel et al. 2009). Leaf extract is also used as an oral hypoglycemic agent for the treatment of diabetes in

Fig. 2.7 (**a**–**d**) Ethanolic extract of seeds *Eriobotrya japonica* (loquat) is reported to improve the glucose tolerance in mice and ethanolic extract of fruit reduced blood glucose level at dose of 200 mg/kg/bw in alloxan-induced diabetic rats (**a**) Leaves bearing young fruits (**b**) Flowers (**c**, **d**) Young fruits

Southeast Asia, China, Korea, and Japan (Ceylan-Isik et al. 2008). The presence of cinchonain Ib isolated from the plant is reported to increase insulin secretion in rats (Qa'dan et al. 2009).

Further, the plant is known to possess antioxidant (Hamada et al. 2004; Huang et al. 2006), cytotoxic (Ito et al. 2000), hepatoprotective (Nishioka et al. 2002), anti-inflammatory (Ju et al. 2003), and antiaging activities (Muramoto et al. 2011).

Traditional Uses Almost all parts of the plant are used in traditional Chinese medicine. The plant is used to relieve cough and to treat skin problems in Japanese folk medicine (Namba 1994). The dried leaves are used to cure diarrhea and depression. Edible fruit is rich in sugar, high in vitamin C and low in fat (Lim 2012). Fragrant flowers contain essential oils which are used in cosmetics and for treating cough and common cold.

2.9 *Euphorbia pulcherrima* Willd.

Vernacular names: Spurge, Poinsettia
Family: Euphorbiaceae

Ecological Distribution and Morphological Characteristics *Euphorbia* is a large genus of the family Euphorbiaceae and consists of over 2000 species. Poinsettia is a shrub or small tree native to Mexico and South America. The leaves are dentate, and the bracts are red and give an appearance of petals of flowers due to photoperiodism. The flowers are known as cyathia (Fig. 2.8a–c).

Important Phytochemicals and Medicinal Value Compounds of economic value comprise alkaloids, steroids, terpenoids, and saponins. Methanolic extract and ethyl acetate fraction showed antibacterial effect against *E. coli*, *S. aureus*, and *S. typhi* (Sharif et al. 2015).

It is an important medicinal plant due to anticancer, antidiabetic, antieczema, anti-inflammatory, and antitumor properties (Luo and Wang 2006; Valente et al. 2003; Eberle et al. 1999; Ferreira et al. 2006).

Traditional Uses The bracts are used for ornamental purpose and for obtaining dyes. Decoction of flowers is used as a galactagogue. The plant is used traditionally to treat gastrointestinal problems in African ethnopharmacopeia (Yakubu and Mukhtar 2011), for malaria, asthma, and eczema.

2.10 *Jasminum sambac* L.

Vernacular name: Arabian jasmine
Family Oleaceae

Ecological Distribution and Morphological Characteristics Jasmine is a large genus and comprises nearly 200 species. *J. sambac* grows as a small shrub and is

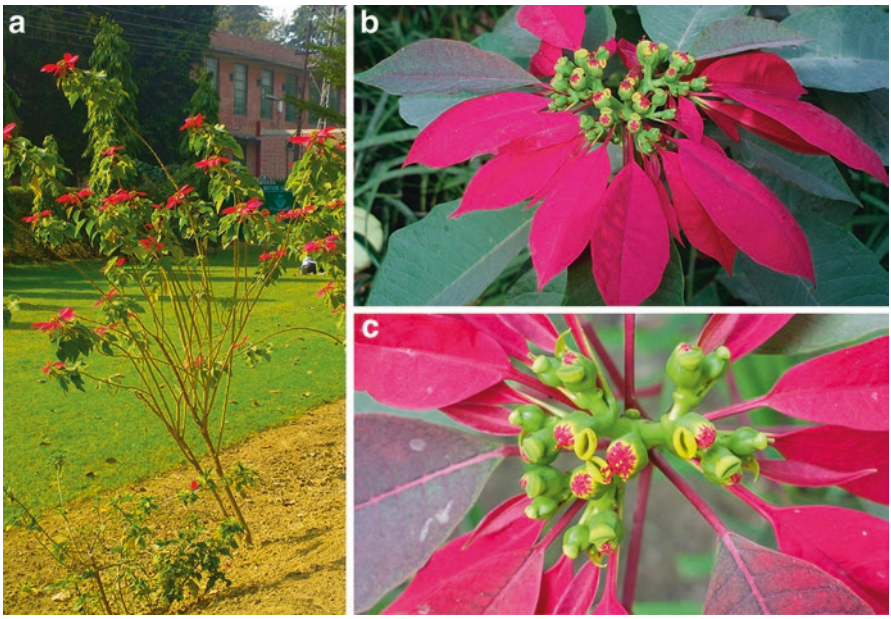

Fig. 2.8 (**a**–**c**) *Euphorbia pulcherrima,* poinsettia is an important ornamental and medicinal tree due to anticancer, antidiabetic and anti-eczemic properties (**a**) Young tree (**b**) Pink bracts bearing cyathia (**c**) Cyathia

Fig. 2.9 Aqueous extract of leaves of *Jasminum sambac* (Arabic Jasmine) caused reduction in blood glucose at dose of 300 mg/kg/bw in alloxan-induced diabetic rat. Ethanolic extract of flowers also showed antidiabetic activity in alloxan and streptozotocin-induced rats

native to Bhutan, Myanmar, Pakistan, India, and Sri Lanka. It is a popular ornamental plant and is cultivated for its fragrant flowers in many tropical and subtropical parts of the world. The leaves are broadly ovate or elliptic and opposite. The flowers are fragrant, white, and solitary (Fig. 2.9).

Important Phytochemicals and Medicinal Value Important phytochemicals in the leaves include alkaloids, saponins, flavonoids, terpenoids, and iridoid glycosides like sambacin, jasminine, sambacoside A, sambacolingoside, and flavonoids like quercetin, isoquercetin, rutin, kaempferol, luteolin, and secoiridoids (Yu et al. 1995; Shen et al. 2000). The flowers contain 3-hexenol, 2-vinylpyridine, myrcene, linalool, geranyl linalool, alpha terpenol, benzyl alcohol, nerolidol, phytol, isophytol, cis-jasmone, 8,9-dihydrojasminine, and 9-deoxyjasminigenin (Inagaki et al. 1995).

The plant is used as an emmenagogue and analgesic as well as antidiabetic (Jensena et al. 2002). The leaves are used to control blood sugar level. Aqueous extract of leaves showed reduction in blood glucose at a dose of 300 mg/kg/bw in alloxan-induced diabetic rats for 21 days (Upaganlawar et al. 2009). The flowers also possess antidiabetic activity as blood glucose level was significantly reduced in alloxan- and streptozotocin-induced rats treated with ethanolic extract (Rambabu and Patnaik 2014). Many species of jasmine are also being used in research on its anticarcinogenic properties (Nadkarni and Basu 1996; Khare 2004).

Traditional Uses The flowers are used in making jasmine tea and are commonly used in Buddhist ceremonies (Roberts 2000). They are considered to be antidepressant and a relaxing herb by aromatherapists. Decoction of dried flowers is used in conjunctivitis, dermatitis, opthalmopathy, leprosy, and dementia, as well as for menstrual flow (Rath et al. 2008; Joy and Raja 2008; Talib and Mahasneh 2010). The aroma of jasmine flower is antidepressant, and essential oils are widely used in aromatherapy and in making perfumes. Jasmine oil is used in vapor therapy and can be used to relieve stress. Flowers are also used to make garlands.

2.11 *Kigelia pinnata* Jacq. (Syn: *Bignonia africana*)

Vernacular name: Sausage tree
Family: Bignoniaceae

Ecological Distribution and Morphological Characteristics *K. pinnata* is popularly called the sausage tree due to its huge fruit which is almost 4 kg in weight. It is native to East Africa.

The leaves are ovate to oblong in shape, alternate, and pinnately compound. It is a spreading tree which bears long, pendulous racemes of bell-shaped, mottled dark flowers which appear in spring or summer. The fruits are long and woody, sausage-like in appearance with long cord-like stalks (Fig. 2.10a–e).

Important Phytochemicals and Medicinal Value Phytochemical screening studies revealed the presence of many flavonoids, iridoids, glycosides, steroids, naphthoquinones, pinnatal, and isopinnatal (Saini et al. 2009). Some of these phytoconstituents may be responsible for anthelmintic activity. Phytochemicals extracted from the roots include kigelinone, isopinnatal, dehydro-a-lapachone, lapachol, coumaric acid, and ferulic acid. The fruits contain many antibacterial and antifungal compounds, such as kigelinone and caffeic acid (Binutu et al. 1996).

Fig. 2.10 (**a**–**e**) *Kigelia pinnata* (sausage tree) has many medicinal properties due to the presence of many phytochemicals like iridoids, flavonoids, and naphthoquinones. Methanolic extract of flowers are reported to have significant antidiabetic and hypolipidemic activity in streptozotocin-induced diabetic Wistar rats at dose of 500 mg/kg/bw for 21 days (**a**) Tree (**b**) Bark (**c**) Leaves (**d**) Branch bearing leaves (**e**) Pods

The plant has many medicinal properties due to the presence of numerous iridoids, flavonoids, and naphthoquinones (Gormann et al. 2004; Asekun et al. 2011). Methanolic extract of flowers is reported to have significant antidiabetic and hypolipidemic activity in streptozotocin-induced diabetic Wistar rats at a dose of 500 mg/kg/bw for 21 days (Kumar et al. 2012). Extract from the leaves is also reported to have antidiabetic activity, which is compared with acarbose standard (Dhriti et al. 2014). Oral administration of leaf extract showed significant reduction in blood glucose level at a dose of 200 mg/kg/bw in alloxan-induced diabetic rats (Raju and Hemamilini 2012).

The fruit and stem bark are known to possess antibacterial activity (Grace et al. 2002). Root extract is known to have antimalarial activity due to the presence of laphachol (Saini et al. 2009). The plant is also known to have many antioxidant (Olalye and Rocha 2008) and antidiabetic activities (Nyarko, et al. 2005). Furthermore, ethanolic stem bark extract of the plant acts as a stimulant on the CNS(central nervous system) and is being explored for therapeutic advantage to treat sedation and dizziness (Owolabi et al. 2008).

Traditional Uses The fruit is reported to be purgative, is known to induce abortion, and is also used in criminal poisoning (Quattrocchi 2012). The plant is used traditionally for treatment of malaria, asthma, cancer, gynecological disorders, renal ailments, epilepsy, and rheumatism, and as a detoxifier. The fruit is used as therapy for ulcers in Africa. It is also pickled in jam and used as an appetizer.

2.12 *Lagerstroemia indica rosea*

Vernacular name: Crepe myrtle
Family: Lythraceae

Ecological Distribution and Morphological Characteristics Approximately 50 species of *Lagerstroemia* are known in the family Lythraceae. *L. indica* is native to China and has a long history of cultivation of 1800 years (Zhang 1991). It is a deciduous tree and raised as an ornamental plant in many parts of Southeast Asia including the Philippines, Vietnam, Malaysia, and southern China. The leaves are small and oval shaped. The flowers are formed in panicles and are pinkish purple in color (Fig. 2.11a–f).

Important Phytochemicals and Medicinal Value Phytochemical screening showed the presence of alkaloids, cardiac glycosides, anthraquinones, saponins, essential oils, tannins, and flavonoids (Wani et al. 2012; Ghannadi et al. 2012), which makes the plant important for commercial purposes. Many microsatellite markers are being developed from crepe myrtle to analyze genetic diversity within *Lagerstroemia* cultivars and related species (Liu et al. 2013).

Hypoglycemic effects are due to crosolic acid, ellagitannins, and galactotannins. Crosolic acid is reported to reduce blood glucose level within 60 min and possesses antihyperlipidemic and antioxidant activities (Miura et al. 2012). Tannins like

Fig. 2.11 (**a**–**f**) *Lajerstroemia indica* (crape myrtle) is known to have antidiabetic activity. Main antidiabetic compound is gallotanin penta-o-galloyl-glucopyranose (PGG) which is isolated from leaves (**a**) Tree (**b**) Tree in autumn (**c**) Leaves in autumn appear red (**d**) Pink panicle (**e**) Flowers (**f**) Young fruits (**g**) Ripen fruits

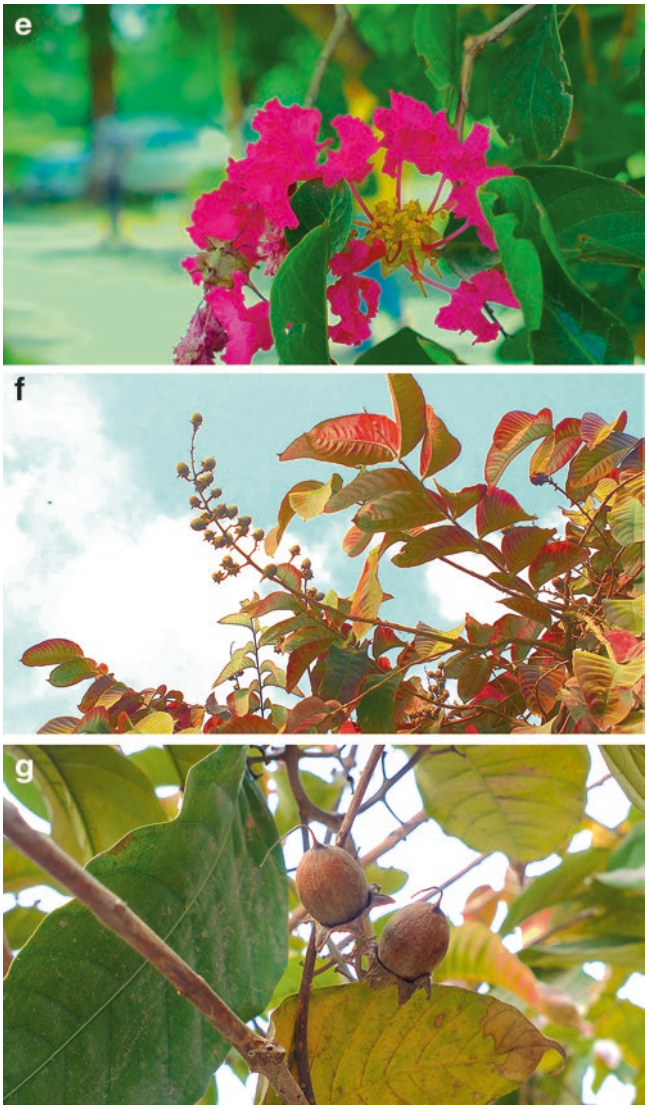

Fig. 2.11 (continued)

gallotanin penta-o-galloyl-glucopyranose (PGG) isolated from leaves are reported to have antidiabetic activity (Saravanamuttu and Sudarsanam 2012). Ellagitannins like lagerstroemin are also considered to be effective against diabetes (Klein et al. 2007). A significant decrease (16.6%) in blood glucose level is observed in individuals with fasting glucose level greater than 110 mg/dL (Miura et al. 2012).

Traditional Uses The leaves are traditionally consumed in the Philippines for treatment of diabetes and for kidney diseases. The insulin-like hypoglycemic effect of the leaves was published as early as 1940 (Garcia 1940). It is also being used in health-promoting tea products in Japan, the Philippines, South Korea, and the United States.

2.13 *Hibiscus rosa sinensis* L.

Vernacular names: Chinese rose, Shoe flower
Family: Malvaceae

Ecological Distribution and Morphological Characteristics It is an evergreen shrub which is native to East Asia. The leaves are glossy and solitary, the margins are serrate, and the flowers are complete, solitary, and red in color. The stamens are fused in the form of a cylinder, which surrounds the style (Fig.2.12a–c). Many cultivars of the plant in yellow, orange, and pink shades are being used in floriculture.

Fig. 2.12 (**a**–**c**) Ethanolic extract of flowers of *Hibiscus rosa sinensis* (shoe flower) reduced blood glucose level at dose of 250 mg/kg/bw and at 500 mg/kg/bw in alloxan-induced diabetic rats and also reduced glucose level in streptozotocin-induced rats (**a**, **b**) Bush bearing red flowers (**c**) Flower

Important Phytochemicals and Medicinal Value The leaves and stems comprise important phytochemicals like β-sitosterol, stigmasterol, and taraxeryl acetate. The flowers are reported to have many glucosides and flavonoids like cyanidin diglucoside, thiamine, riboflavin, niacin, and ascorbic acid. In addition, other glucosides extracted from yellow flowers include cyanidin- 3,5-diglucoside, 3,7-diglucoside, cyanidin-3-sophoroside-5- glucoside, and quercetin-3-diglucoside.

Antidiabetic activity of *Hibiscus* is considered to be due to secondary metabolites like alkaloids, flavonoids, saponins, glycosides, and polyphenols as many alkaloids can regenerate β-cells of the pancreas, and polyphenols can decrease blood glucose level.

The antidiabetic activity of the plant in hyperglycemic rats is also reported (Sachdewa et al. 2001; Sachdeva and Khemani 2003a, b). Ethanolic extract of the flowers reduced blood glucose level at a dose of 250 mg/kg/bw and at 500 mg/kg/bw in alloxan-induced diabetic rats (Venkatesh et al. 2008) and also reduced glucose level in streptozotocin-induced rats (Sachdewa and Khemani 2003a, b). Aqueous extract of the flowers exhibited significant hypoglycemic and hypolipidemic activities at a dose of 500 mg/kg/day in streptozotocin-induced diabetic rats (Bhaskar and Vidhya 2012). Oral administration of root extract at a dose of 500 mg/kg/bw also caused significant decrease in blood glucose and plasma lipids after 15 days in alloxan-induced diabetic rats, indicating the role of the plant in treating diabetic dyslipidemia and related complications (Kumar et al. 2013). Ethanolic extract of the leaves also reduced blood glucose level and improved lipid profile in alloxan-induced diabetic dyslipidemia in rats after four weeks (Mamun et al. 2013). Insulin-secreting activity of leaf extract is reported in diabetic Wistar rats (Vimala et al. 2008).

The plant is also reported to have anticancer potential in a study conducted on mice exposed to ultraviolet radiation (Sharma et al. 2004). Current research is being targeted to explore its antiaging potential and use in the treatment of scopolamine-induced amnesia, which suggests its further role against cognitive disorders (Nade et al. 2011).

Traditional Uses It is used in traditional medicine to induce abortion, to ease menstrual cramps, to facilitate childbirth, and to relieve fever, headache, and inflammation (Arullappan et al. 2009). It is considered a laxative and is used for treatment of stomach ulcer, as an aphrodisiac and emmenagogue, and as a reliable oral contraceptive. The petals are used as a remedy for treating chronic constipation. It is also used as a tonic for hair health and in psychiatric ailments. In order to induce periods, crushed petals are consumed early in the morning before the expected date of the period.

2.14 *Morus alba* L.

Vernacular name: White mulberry
Family: Moraceae

Ecological Distribution and Morphological Characteristics *M. alba* is a medium-sized deciduous tree that can reach up to 3–10 m in height. It is native to China and Pakistan.

Fig. 2.13 *Morus alba* (white mulberry) is antidiabetic and anticancer tree. Leaf extract showed antidiabetic effects at a dose of 600 mg/kg/bw in streptozotocin-induced Wistar rats

Long leaves are petiolate, cordate, and acuminate near the tips. The bark is gray and thick, with many irregular longitudinal cracks. The plant produces ovate buds in winter which are reddish brown and bears bud scales which are covered with hairs resembling those on the twig surface. The flowers are unisexual catkins on the same or different plants (Fig.2.13). Green unisexual catkins appear with leaves in April to May and bloom axillarily.

Important Phytochemicals and Medicinal Value The plant is a very good source of ascorbic acid and carotene. It contains many natural antioxidants like vitamin B1, folic acid, folinic acid, isoquercetin, quercetin, tannins, flavonoids, and saponins. The leaves are rich in lupeol, sterols, bioflavonoids (rutin, moracetin, quercetin-3-triglucoside, and isoquercitrin), coumarins, volatile oil, alkaloids, amino acids, and organic acids.

The leaves contain rutin, quercetin, and apigenin as bioactive constituents (Doi et al. 2001). One of the major constituents is 1-deoxynojirimycin (Chu et al. 2006). Many flavones were isolated from the root bark as active principles. Other important biochemical compounds isolated from the plant include moranoline, albafuran, albanol, morusin, kuwanol, and calystegin. Mulberroside F isolated from mulberry leaves is used as a skin-whitening agent (Sang et al. 2002).

Extract of the plant is reported to reduce blood glucose level through regeneration of β-cells (Jamshid and Prakash 2013). Methanolic and aqueous extract of leaves showed significant antidiabetic activity, i.e., 18.88% and 9.1% respectively in streptozotocin-induced diabetic rats at a dose of 200 mg/kg/bw after 15 days (Chaurasia et al. 2011). Leaf extract of mulberry is also reported to have antidiabetic effects at a dose of 600 mg/kg/bw in streptozotocin-induced Wistar rats (Mohammadi and Naik 2008). Antidiabetic activity of mulberry leaves is due to the presence of compounds like trigonelline bases, moran A (Burman 1985), and moranoline (Yoshikuni 1988).

The fruits have radical-scavenging activity, which indicates their role as important antioxidants (Chon et al. 2009; Shahid et al. 2012). The leaves have adaptogenic and

anxiolytic activities (Yadav et al. 2008), which indicates its possible role as an antistress agent (Vandana et al. 2009) and in the management of psychiatric disorders (Adhikrao and Vandana 2008).

Traditional Uses It is a source of silkworm food, fodder, and plywood furniture, and it is one of the ideal trees for reforestation projects. Major use of the plant is as an antidiabetic, immunomodulatory, antimicrobial, antioxidant, and anticancer agent (Chon et al. 2009). Leaves are used as diuretic, expectorant, and antidiabetic in traditional Chinese medicine (Chen et al. 1995).

2.15 *Murraya koenigii* L.

Vernacular name Curry tree
Family: Rutaceae

Ecological Distribution and Morphological Characteristics *M. koenigii* is native to India, Sri Lanka, and other South Asian countries.

The plant grows as a deciduous shrub or tree having a short trunk with a dense shady crown. The leaves are bipinnately compound, with 11–25 leaflets which are arranged alternately on rachis. The flowers are small, aromatic, white, bisexual, and funnel shaped, borne on terminal cyme, comprising 60–90 flowers. The fruit is ovoid, subglobose, and purplish black in color upon maturity (Figs. 2.14a–e and 2.15).

Important Phytochemicals and Medicinal Value Phytochemicals such as alkaloids, sterols, tannins, volatile oils, saponins, anthroquinone glycosides, and flavanoids are reported from different parts of the plant (Handral et al. 2010). The leaves are aromatic and contain carotene, nicotinic acid, and vitamin C. The leaves contain high amounts of oxalic acid, crystalline glycosides, carbazole alkaloids, koenigin, and resin. The fresh leaves contain volatile oil which is rich in vitamin A, calcium, girinimbin, iso-mahanimbin, koenine, koenigine, koenidine, and koenimbine.

Other compounds isolated from leaves include mahanimbicine, bicyclomahanimbicine, phebalosin, coumarine, murrayastine, murrayaline, and pypayafolinecarbazole alkaloids. The bark comprises carbazole alkaloids as murrayacine, murrayazolidine, murrayazoline, mahanimbine, girinimbine, koenioline, and xynthyletin.

The roots and leaves are antihelmintic, analgesic, and effective against leucoderma and blood disorders. They are also known to control blood cholesterol, are antidiabetic (Saravanamuttu and Sudarsanam 2012; Quattrocchi 2012), and have memory-enhancing activities (Xie et al. 2006; Tembhurne and Sakarkar 2010). The leaves have antioxidant activity due to mahanimbine and koenigine alkaloids (Rao et al. 2006).

There has been significant research conducted on the antidiabetic potential of *Murrya* leaves which reported that feeding different doses of leaves to alloxan-induced diabetic rats can control mild to moderate diabetes (Yadav et al. 2002; Sarji et al. 2016). Oral administration of chloroform extract of *Murraya* leaves in

alloxan-induced diabetic albino rats caused significant reduction in blood glucose level at doses of 250 mg/kg/bw and 500 mg/kg/bw possibly by increasing insulin secretion and enhancement of glycogenesis, decreasing oxidative stress, and preserving pancreatic cell integrity (Vijayanand 2015). Oral administration of aqueous extract of leaves showed 75% reduction in urine sugar in normal and streptozotocin-induced diabetic rats (Kesari et al. 2007). Further, oral administration of aqueous extract (600 mg/kg/bw) and methanolic extract (200 mg/kg/bw) of *Murraya* leaves in alloxan-induced diabetic rats caused reduction in blood glucose level and plasma insulin level (Vinuthan et al. 2004). Aqueous extract of roots also showed reduction in blood glucose level of almost 57.6% at a dose of 400 mg/kg/bw in alloxan-induced diabetic rats (Singh et al. 2012).

Traditional Uses The leaves are the most important part of the plant due to their medicinal value. They are used as a herb and ingredient in Asian cuisine to promote appetite and digestion. Tree branches are used for strengthening of teeth and gums. Recently, it has been reported that formulation of a cream comprising essential oil of the leaf is found to have sun protection factor (Patil et al. 2010).

2.16 *Opuntia ficus-indica* L.

Vernacular names: Cactus pear, Prickly pear
Family Cactaceae

Ecological Distribution and Morphological Characteristics Cacti are unique ornamental plants and are also useful in health and medicine. The cactus family comprises more than 350 families, and the plants are commonly known as desert plants,

Fig. 2.14 (**a**–**e**) Leaves and roots of *Murraya koenigii* (curry tree) are known to control blood cholesterol and possess antidiabetic and memory-enhancing activities due to mahanimbine and koenigine alkaloids. Antidiabetic activity of leaf extract is well reported in alloxan-induced and streptozotocin-induced diabetic rats (**a**) Tree (**b**) Leaflets on rachis (**c**) Terminal raceme of white flowers (**d**) Young globose fruits (**e**) Ripening of fruits

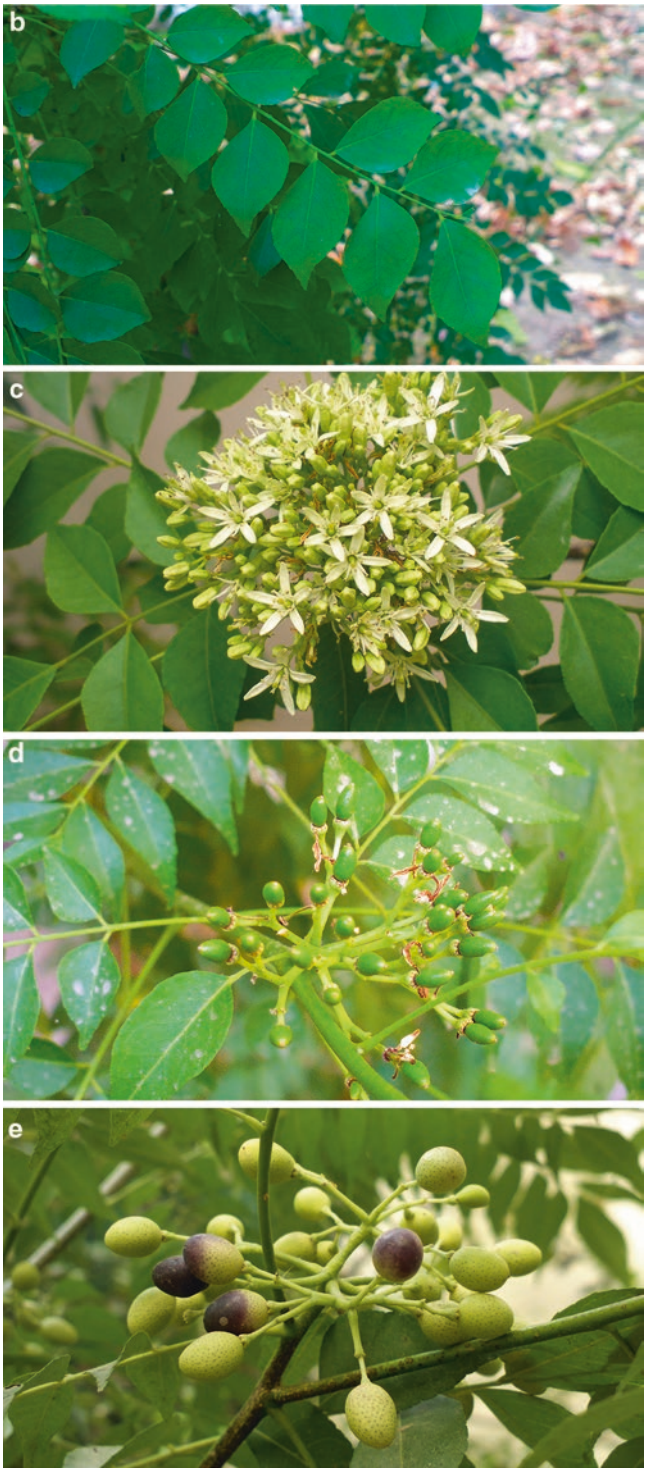

Fig. 2.14 (continued)

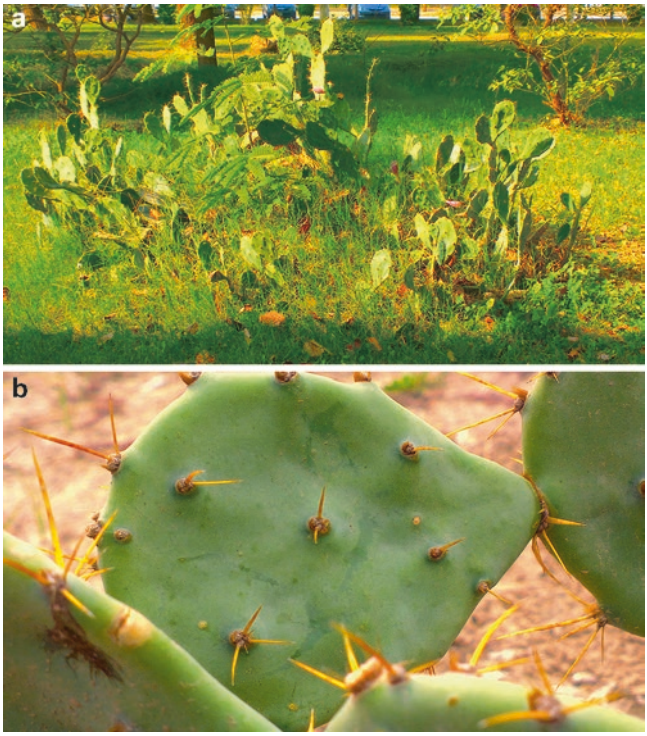

Fig. 2.15 (**a–b**) Leaves of Opuntia (prickly pear) are used to treat type 2 diabetes and hyperlipidemias

spiny plants, or succulents due to their ability to store water. Their leaves are reduced to form thorns or modified spines to reduce the rate of evaporation. The highly reduced stem of cacti is known as areoles, which form tubular flowers. These adaptations help cacti to survive in extreme weather. The joints of prickly pear swell when water is in abundance; however, they shrink in periods of drought, releasing excess water.

Important Phytochemicals and Medicinal Value Cactus plants have antitumor, antiulcer, and antirheumatic properties due to many phytochemicals in their leaves and flowers. Flavonoids are widely present in pear cactus. The pads (stem joints) of prickly pear are rich in vitamins, minerals, amino acids, potassium, magnesium, calcium, and iron. When the pads of pear cactus are sliced, they release sticky mucilage, which contains soluble dietary fibers and many polysaccharides. Prickly pear cacti are a rich source of vitamin C, carotenoids, thiamin, riboflavin, and niacin (Dominguez-Lopez 1995; Tous and Ferguson 1996).

Traditional Uses The fruit of prickly pear is pleasant in taste, with small black seeds. Tea is also made commercially from cactus flowers and sold in tea bags. Prickly pear is one of those exceptional plants which are vegetables, fruits, and flowers all in one and work both as food and medicine. Prickly pear is being used to treat

type 2 diabetes and hyperlipidemias. It is under investigation for antiviral diseases and as a potential cancer prevention agent (Knishinsky 2004). The fruit of opuntia is reported to have antidiabetic activity (Saravanamuttu and Sudarsanam 2012).

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