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Mimosa pudica L., a High-Value Medicinal Plant as a Source of Bioactives for Pharmaceuticals

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Abstract: *Mimosa pudica* Linn. (Family: *Mimosaceae*) is used as an ornamental plant due to its thigmonastic and nyctinastic movements. *M. pudica* is also used to avoid or cure several disorders like cancer, diabetes, hepatitis, obesity, and urinary infections. *M. pudica* is famous for its anticancer alkaloid, mimosine, along with several valuable secondary metabolites like tannins, steroids, flavonoids, triterpenes, and glycosylflavones. A wide array of pharmacological properties like antioxidant, antibacterial, antifungal, anti-inflammatory, hepatoprotective, antinociceptive, anticonvulsant, antidepressant, antidiarrheal, hypolipidemic activities, diuretic, antiparasitic, antimalarial, and hypoglycemic have been attributed to different parts of *M. pudica*. Glucuronoxylan polysaccharide extruded from seeds of *M. pudica* is used for drug release formulations due to its high swelling index. This review covers a thorough examination of functional bioactives as well as pharmacological and phytomedicinal attributes of the plant with the purpose of exploring its pharmaceutical and nutraceutical potentials.

Keywords: bioactives, folk medicinal uses, *Mimosa pudica*, nutraceuticals, pharmaceutical attributes, phytochemicals

Introduction

Mimosa pudica is a famous ornamental plant commonly known as sleeping grass, sensitive plant, humble plant, shy plant, touch-me-not, chuimui, and lajwanti among other names. Its ornamental use can be attributed to its thigmonastic and seismonastic movements in which closure of leaves and hanging down of petioles takes place in response to certain stimuli like light, vibration, wounds, wind, touch, heat, and cold (Volkov and others 2010a,b; Soetedjo and others 2015). Besides its ornamental use, *M. pudica* is a popular plant among folk healers to treat several diseases.

Phytomedicines, due to their potential benefits, have remained in practice in all traditional systems of therapies, including Greco-Arab (Unani-Tibb), Ayurveda, and Chinese (Gilani and Atta-ur-Rahman 2005; Krishnaswamy 2008). *M. pudica* is known and valued for its analgesic, anti-inflammatory (Prasanna and others 2009), hypoglycemic (Amalraj and Ignacimuthu 2002), diuretic, astringent, antispasmodic, and blood-purifying activities (Ghani 2003). Therefore, it has been used to treat high blood pressure (Aalok 1997), menorrhagia, and leucorrhea (Hemadri and Rao 1983; Vaidya and Sheth 1986). Leaves and roots are used for curing hemorrhoids (Ghani 2003). Wounds and eczema can be treated by applying a paste of the whole plant and leaves, respectively (Singh and Singh 2009). Leaf paste is also applied externally as a psoriasis cure (Ignacimuthu and others 2008) and fresh leaf juice for impotence and spermatorrhea treatments (Behera and Misra 2005).

Various pharmacological attributes like anti-inflammatory (Vikram and others 2012), antinociceptive (Karthikeyan and Deepa 2010; Vikram and others 2012), hypolipidemic (Rajendran and Krishnakumar 2010; Sowmya and Ananthi 2011), hepatoprotective (Rajendran and others 2009), and diuretic (Sangma and others 2010) activities are ascribed to different parts of the plant. *M. pudica* is also admired for its antidiabetic (Sutar and others 2009), antimalarial (Tran and others 2003), anticonvulsant (Bum and others 2004), antidepressant (Molina and others 1999), antifertility (Valsala and Karpagagaanapathy 2002; Ganguly and others 2007), and antidiarrheal potentials (Balakrishnan and others 2006a). Antiparasitic (Marimuthu and others 2011), antimicrobial (Ambikapathy and others 2011; Mohan and others 2011; Tamilarasi and Anathi 2012), antioxidant (Rekha and others 2010; Arokiyaraj and others 2012), antivenomic (Ambikabothy and others 2011; Sia and others 2011), and wound-healing activities (Paul and others 2010) are credited to different parts of *M. pudica*. Regarding the secondary metabolite potential of *M. pudica*, it has been reported that it contains tannins, steroids, flavonoids, triterpenes, alkaloids, and glycosylflavones (Gandhiraja and others 2009). Seeds of *M. pudica* extrude a hydrogelable material, glucuronoxylan polysaccharide, that can be used for the delayed/sustained/targeted release of different drugs (Singh and others 2009; Kumar and Kumar 2011; Ahuja and others 2013).

A number of reports on medicinal and pharmaceutical applications of *M. pudica* has attracted us to compile a comprehensive review on its potential of bioactives and nutraceuticals. A comprehensive review is being presented here on a detailed range of bioactives and many biological and medicinal activities of *M. pudica*. This review focuses on the phytochemistry, folk

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Table 1–Phytochemicals isolated from different parts of *M. pudica*.

Plant part used	Phytochemicals isolated	References
Whole plant	Mimosine Jasmonic acid Isolation of *C*-glycosylflavones	Tsurumi and Asahi (1985); Yuan and others (2006, 2007a, b); Nair and others (2007); Champanerkar and others (2010)
Roots	2-Hydroxymethyl-chroman-4-one	Kang and others (2004)
Leaves	Phenolic ketone	Josewin and others (1999)
	7′,3′,4′-trihydroxy-3,8-dimethoxyflavone	Kirk and others (2003)
	Separation of tubulin protein	Pal and others (1990)
	L-malate, magnesium potassium trans-aconitate, dimethyl ammonium salt, potassium 5-*O*-β-D-glucupyranosylgentisate, mimupodine	Ueda and Yamamura (1999a,b,c)

medicinal uses, and pharmacological attributes of this multipurpose plant. The review will bridge the knowledge between medicinal chemists and pharmacologists about phytochemistry, bioactive potentials, and pharmaceutical applications of this versatile plant. It should also be of value to R&D scientists in food sciences.

Taxonomy and Distribution

M. pudica (Family: *Mimosaceae*) is a creeping annual or perennial shrub with compound leaves, spiny stipules, and globose pinkish flower heads. It is native to Brazil and has been naturalized throughout the world. *M. pudica* is an annual or perennial shrub with erect stems in young plants which modifies to creeping with age. It attains a height of 1 to 2 m with compound bipinnate leaves having 1 to 2 pinnae pairs and each pinna contains 15 to 25 leaflets. The plant has red-colored prickly petioles and pink filaments. A fruit has 2 to 8 pods, which are 3 mm broad and 1 to 1.5 cm long. Each pod has 2 to 5 segments in which brown seeds (2.5 mm long) are embedded (Wealth of India 1962; Howard 1988; Liogier 1988; Ghani 2003).

Phytochemistry

Medicinal plants are used to cure various ailments due to the presence of high-valued secondary metabolites. Literature-based phytochemical screenings have revealed that *M. pudica* is rich in medicinally important secondary metabolites, including carbohydrates, proteins, amino acids, tannins, phenolics, steroids, flavonoids, saponins, mucilage, alkaloids, and fixed oil (Pal and others 2015). Table 1 shows some of the important phytochemicals isolated from the plant.

Mimosine **[1]** (for this and subsequent numbers, see Figure 1) is extracted from the whole plant with acidified water (1% HCl), separated by liquid chromatography, and detected and quantified by mass spectrometry. Champanerkar and others (2010) developed an efficient and precise Liquid chromatography-Mass spectrometry and liquid chromatography-Tandem Mass spectrometry (LC-MS-MS) method for accurate determination of mimosine from *M. pudica*.

In another study, mimosine was isolated from a water extract of *M. pudica* using reverse-phase High Pressure Thin Layer Chromatography (HPTLC) method. The mimosine was successfully quantified by using a densitometric scanning (λ_{max} = 282 nm) in reflectance-absorbance mode. It was noted that the plant contained a significant amount of mimosine (20 mg/g; Nair and others 2007).

M. pudica is also a valuable source of jasmonic acid **[2]** and abscisic acid, which can be isolated and characterized by mass spectrometry, high-performance liquid chromatography, and thin-layer chromatography. Both of these valued bioactives significantly affect the auxin and light-induced pulvinule opening at 10^{-5} M concentration. One study has established that reduction in the transpiration of pinnae and inhibition of pulvinule movements was due to jasmonic and abscisic acids (Tsurumi and Asahi 1985). A valuable contribution for the isolation and identification of a number of flavonoids was from Yuan and others (2006). They thoroughly characterized the whole plant using advanced spectroscopic and chromatographic techniques and isolated various *C*-glycosylflavones, including 7, 8, 3′, 4′-tetrahydroxyl-6-*C*-[α-L-rhamnopyranosyl-(1→2)]-β-D-glucopyranosyl flavone; 5, 7, 4′-trihydroxyl-8-*C*-[α-L-rhamnopyranosyl-(→2)]-β-D-glucopyranosyl flavone; and 5, 7, 3′, 4′-tetrahydroxyl-6-*C*-[α-L-rhamnopyranosyl-(1→2)]-β-D-glucopyranosyl flavone (Yuan and others 2006). Yuan and others (2007a,b) also isolated more *C*-glycosylflavones from the whole plant which were identified by various analytical techniques as 5,7,3′,4′-tetrahydroxy-6-*C*-[β-D-apiose-(1→4)]-β-D-glucopyranosyl flavones; 5,7,4′-trihydroxyl-8-*C*-β-D-glucopyranosyl flavones; 5,7,3′,4′-teteahydroxy-6-*C*-[β-D-apiose-(1→4)]-β-D-glucopyranosyl flavones **[3]**; and 5,7,4′-trihydroxyl-8-*C*-β-D-glucopyranosyl flavones **[4]**.

The residue obtained from petroleum ether-extracted leaves of *M. pudica* was dissolved in ethyl acetate. An EtOAc-benzene (1:9) mixture yielded a phenolic ketone that was identified by different spectroscopic techniques as 4-(24′-methoxy-24′-methyl-1′-oxo-5′-n-propyl-tetracosanyl)- phenol **[5]** (Josewin and others 1999). In another study, *M. pudica* leaves were extracted with 96% ethanol and the residue obtained was fractionated into petroleum ether, ethyl acetate (EtOAc), and methanol–water systems. The EtOAc fraction was eluted by column chromatography to isolate 7′-3′-4′-trihydroxy-3,8-dimethoxyflavone **[6]** along with *p*-coumaric acid **[7]** (Kirk and others 2003).

Pal and others (1990) isolated an important protein, tubulin, from *M. pudica* leaves and pulvinar callus cells through an anion exchange resin, and then purified by DEAE-Sephadex A-50, ammonium sulfate fractionation, and Sephadex G-200 gel filtration. It was revealed by 2-D electrophoresis that tubulin has one main α-tubulin (pI 7.1) along with 3 β units ($_pI$ 6.70, 6.46, and 6.40). This α-tubulin is different from the one obtained from other sources because it increased radioimmuno assays and immunoblotting with the antibodies against α- and β-tubulins of *M. pudica*. Leaf movements of the plant are thought to be due to this protein, which is 5% to 6% of total extracted proteins (Pal and others 1990).

Ueda and Yamamura (1999a) isolated a compound, mimopudine **[8]**, which is responsible for leaf movements even at night. It was also investigated that mimopudine is responsible for *M. pudica* leaf opening, even at a very low concentration (2×10^{-5} M), which is not an effective concentration for leaf openings of other plants. Leaves opened by mimopudine are sensitive to touch (Ueda and Yamamura 1999a). Later on, a leaf-closing substance, potassium 5-*O*-β-D-glucupyranosylgentisate **[9]** was also identified from leaves of *M. pudica*. It was also concluded that this compound is responsible for slow movements of *M. pudica* leaves (Ueda and Yamamura 1999c). Different chemical substances, potassium L-malate **[10]**,

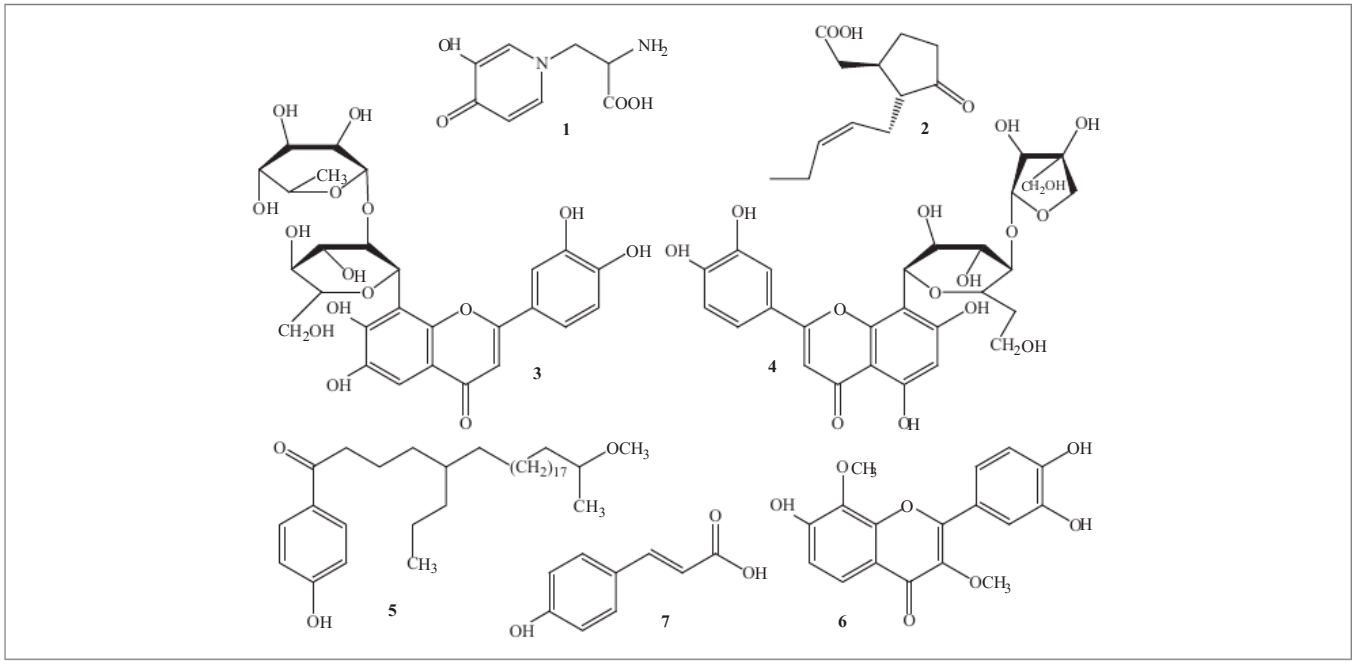

Figure 1–Structures of selected phytochemicals from *M. pudica*: Mimosine [1], jasmonic acid [2], 5,7,3′,4′-tetrahydroxy-6-*C*-[β-D-apiose-(1→4)]-β-D-glucopyranosyl flavones [3], 5,7,4′-trihydroxyl-8-*C*-β-D-glucopyranosyl flavones [4], 4-(24′-methoxy-24′-methyl-1′-oxo-5′-n-propyl-tetracosanyl)-phenol [5], 7′-3′-4′-trihydroxy-3,8-dimethoxyflavone [6], and *p*-coumaric acid [7].

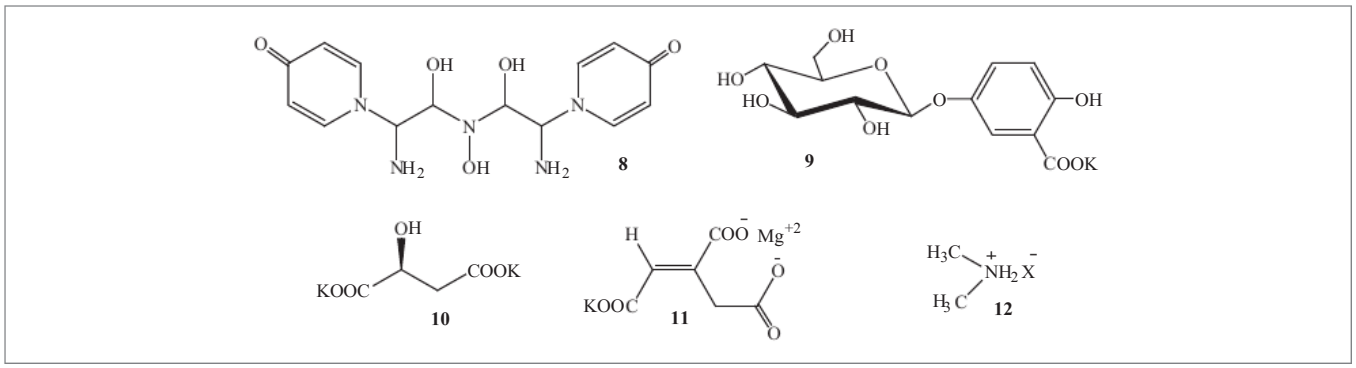

Figure 2–Structures of the compounds responsible for leaf movements of *M. pudica*.

magnesium potassium trans-aconitate [**11**], dimethyl ammonium salt **[12]**, potassium 5-*O*-β-D-glucupyranosylgentisate [**9**], and mimupodine [**8**] were isolated from *M. pudica* leaves (Fig. 2). These compounds were found responsible for sensitive rapid movements (stimulated by touch and heat) and periodic slow movements (nyctinastic movements; Ueda and Yamamura 1999b). These studies successfully solved more than 8 decades of mystery regarding *M. pudica* movements.

Roots of *M. pudica* contain endophytes, microorganisms that inhabit the plants forming a symbiotic relationship. Endophytes also produce secondary metabolites like terpenoids, steroids, alkaloids, phenols, and quinines, which defend plants from various pathogens (Strobel 2003; Baker and others 2012a,b). In this regard, a *Burkholderia* species, isolated from roots of *M. pudica*, was cultured and an antifungal compound, 2-hydroxymethyl-chroman-4-one was isolated. The culture was centrifuged (7000 rpm, 20 min) to isolate bacterial colonies. The supernatant was extracted with ethyl acetate and eluted through a silica packed column. The ethyl acetate-*n*-hexane fraction contains 2-hydroxymethyl-chroman-4-one [**13**], which was identified by spectroscopic techniques (Kang and others 2004). In another study, it was found that roots of *M. pudica* contained β-sitosterol [**14**], betulinic acid [**15**], stigmasterol [**16**], and 1 new sterolglucoside characterized as 24-dimethylcholest-7-en-3β-ol-3β-D-glucoside [**17**] (Dinda and others 2006). Some important compounds isolated from roots of *M. Pudica* are shown in figure 3.

Folk Medicinal Uses

Fruits, roots, and leaves of a number of plants are being widely used in folk medicinal systems to treat various ailments due to the presence of highly valued bioactive compounds (Gilani 1998; Gilani and Atta-ur-Rahman 2005; Rahmatullah and others 2010a,b; Ghanbari and others 2012). In a report by World Health Organization (WHO), it was stated that about 80% of the world population relies on phytomedicines to cure various diseases (WHO 2002). In folk medicines, various parts of *M. pudica* are used as an antidote to scorpion and snake bites. In particular, its roots have been used as an antivenomic material as reported by several studies (Bhalla and others 1982; Macmillan 1999; Pattanaik and others 2006; Thirumalai and others 2010; Kala 2015). Roots of *M. pudica* are chewed at the time of snakebite and its paste is combined with black pepper and then bandaged onto the

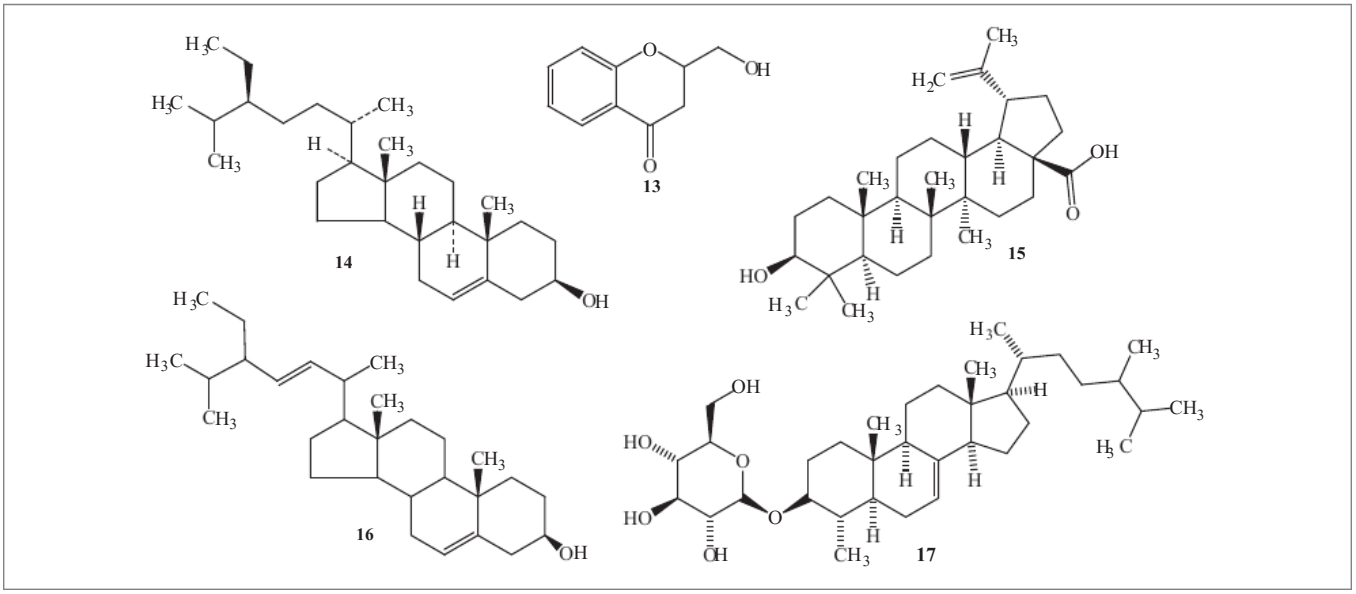

Figure 3–Some selected phytochemicals isolated from roots of *M. pudica*.

snakebite area. *M. pudica* has been known among snake charmers against cobra bites (Mahanta and Mukherjee 2001). The roots can also be used to cure menstrual problems and toothache (Pandey and others 2015). Stem and leaves of *M. pudica* have been found effective against scorpion stings (Patwari 1992). A paste of the whole plant is then applied onto the bite area as the cure (Samy and others 2008). Similarly, powdered roots (25 g each) of *M. pudica*, *Calotropris gigantia*, and *Trichosanthes palmata* is applied to a snakebite area (once a day) after removing the poison with Osta leaf (Lenka and Mohapatra 2015). However, the mechanism of action has not been explained yet.

The literature has revealed that roots of *M. pudica* are diuretic, constipating, bitter, febrifuge, antispasmodic, astringent, and emetic. They are also used in the treatment of dysentery, smallpox, fever, ulcer, jaundice, leucoderma, inflammation, asthma, hemorrhoids, and fistula (Vaidyaratanm 2001; Pande and Pathak 2010; Rahman 2015). Besides the roots, the leaves of *M. pudica* are also used to cure hydrocele, hemorrhages, fistula, conjunctivitis, hemorrhoids, and wounds. The whole plant of *M. pudica* is helpful to cure cancer, rheumatism, edema, and myalgia (Sharma and others 2001; Pande and Pathak 2010). An alkaloid, mimosine separated from *M. pudica* is used for the treatment of skin diseases, cancer, and has apoptotic effects (Restivo and others 2005). A decoction is a method that is widely adopted by folk healers to take bioactives effectively. Decoction of *M. pudica* leaves has also been reported to possess antibacterial (Balakrishnan and others 2006a) and anticonvulsant activities (Bum and others 2004) and is used for the treatment of cough and influenza (Painkra and others 2015). By using a decoction of *M. pudica* leaves and seeds, systemic infections and bowl disorders can be treated (Krishnaraju and others 2006). In India, people have used seeds of *M. pudica* to treat veneral diseases. For this purpose, a mixture of seeds of *M. pudica* (about 5 g) and sugar is taken orally for 3 d (Ahirwar 2015). Piloherb, an ointment consisting of extracts of Aloe vera, *M. pudica*, *Azadirachta indica* (Neem), Vitex negundo, Alpinia galangal, and Cissampelos pareira can be used for the treatment of hemorrhoids in India. The ointment will give relief from hemorrhage and itching. The Piloherb also has anti-inflammatory and antinociceptive effects (Gupta and Mitra 2015).

Infections, particularly when between toes or fingers can be healed by washing with warm water in which *M. pudica* leaves have been soaked. Infected areas are also soaked in warm water containing *M. pudica* leaves for 10 min 2 times daily for 4 to 5 d. If delivery is not effective, then a mixture of whole roots of *Heliotropium indicum* and *M. pudica* is applied to the toes for half an hour to expedite the effect (Haque and others 2011). Crushed roots of *M. pudica* are boiled with fruit pulp of *Aegle marmelos* L. and applied on the aching area to treat rheumatism. In Bangladesh, a paste of *Allium cepa* (onion, 12 g), *M. pudica* leaves (35 g), *Piper nigrum* (pepper, 25 g), *Allium sativum* (garlic, 12 g), and *Crocus sativus* (saffron, 6 g) is administered orally (twice a day) to barren cows for the treatment of fever (Al Mamun and others 2015). The fruit of *M. pudica* is utilized for dysentery, diarrhea, and as an emetic. Bone fractures can be cured by using extract of stem (Sala Uddin and others 2015). A paste of leaves is taken orally or applied topically to treat skin diseases and swelling (Xavier and others 2015).

Villagers grow *M. pudica* in front of their homes to keep away insects (Hasan and others 2012). A paste of *M. pudica* leaves is fed to animals with 1 to 2 chapattis twice a day to treat wounds caused by worms (Nigam and Sharma 2010). The whole plant (*M. pudica*) is useful for the treatment of epilepsy, plague, edema, allergy, asthma, ulcer, and elephantiasis (Rahmatullah and others 2010a,b; Yadav and others 2015). One formulation, Pilex (Himalaya Drug Co., India) containing *M. pudica* along with other components can be used for the treatment of hemorrhoids. Pilex tablets were given to patients for 4 wk and it was observed that Pilex therapy stopped bleeding in most of the patients and gave them relief. Sometimes it is useful to use Styplon, another herbal formulation used to treat hemorrhoids along with Pilex. Pilex ointment can also be applied externally after defecation (Rangnekar and Arora 1974). *M. pudica* roots, *Sida rhombifolia* roots, and *Hibiscus rosa-sinensis* leaves are boiled with coconut oil to treat psoriasis. The whole plant juice was 1st mixed with coconut oil and salt then it is used to treat asthma and inflammation, respectively (Silja and others 2008). Leaf juice is also used to treat hemorrhoids, hypertension, and menstrual problems. The paste of *M. pudica* leaves alone is applied on injuries and snakebite areas to cure them (Vijayakumar

Table 2–Folk medicinal uses of different parts of *M. pudica*.

Plant part used	Uses	References
Roots	Dysentery, small pox, fever, ulcer, jaundice, leucoderma, inflammations, asthma, hemorrhoids, and fistula	Vaidyaratanm (2001); Pande and Pathak (2010)
	Expedition of delivery	Haque and others (2011)
	Rheumatism	Hasan and others (2012)
Leaves	Treatment of hydrocele, hemorrhages, fistula, conjunctivitis, hemorrhoids, and wounds	Sharma and others (2001); Pande and Pathak (2010)
	Antibacterial	Balakrishnan and others (2006a)
	Anticonvulsant	Bum and others (2004)
	Infection between fingers	Haque and others (2011)
Whole plant	Treatment of cancer, rheumatism, edema, and myalgia	Sharma and others (2001); Pande and Pathak (2010)
	Insect repellant	Hasan and others (2012)
	Epilepsy, plague, edema, and elephantiasis	Rahmatullah and others (2010a,b)
Leaves and seeds decoction	Urinary tract infections and increased diuretic activity	Krishnaraju and others (2006)

and others 2015). In Bangladesh, an aqueous extract of whole plant is used to treat urinary infections. The paste of roots can be used to treat diarrhea and dysentery, and leaves can be applied to an insect bite area. A decoction of roots can be taken to cure hemorrhoids (Rahman and Debnath 2015), and sores and piles can be healed by rubbing with the decoction of leaves. The decoction of roots can be used as a blood purifier and is also used to treat hepatitis, toothache, pyrexia, piles, and leprosy. Stones from any part of the body can be removed by taking a decoction of roots. People have tied roots on the neck to get relief from coughing and cold (Singh 2015). Table 2 shows folk medicinal uses of the plant.

Pharmacological activities

M. pudica is known worldwide for its broad spectrum of pharmacological and biological attributes, which is due to the presence of a number of valuable bioactive compounds. Several literature reports have uncovered the successful utilization of *M. pudica* roots, fruits, leaves, and whole plant to treat various diseases (Table 3).

Wound-healing activity

Apart from other pharmacological and therapeutic properties, the literature has revealed that the *M. pudica* plant has reasonable wound-healing activity. Shoots and roots of *M. pudica* were extracted with methanol to study this activity. An ointment of extracts of *M. pudica* roots and shoots is prepared by mixing with emulsifying wax, white soft paraffin, and liquid paraffin separately. Both root and shoot extract ointment have healed wounds better than the standard drug gentamicin as studied with Wistar albino rats (Kannan and others 2009). Later on, *M. pudica* roots were extracted with chloroform and methanol to treat incision, excision, and burn wounds in rats by the dead space wound model. Two ointments of each extract prepared in carbopol (2.5% and 5%) were applied topically. Both methanol and chloroform extract showed significant healing of incision, excision, and burn wounds as compared to the Aloe vera control (Paul and others 2010).

Shade-dried leaves of *M. pudica* were extracted with diethyl ether, methanol, and chloroform to prepare the ointment (10%) in a water-miscible base. Wound-healing activity was determined by a wound excision model. Ointment of methanol extract (93.87%) showed better wound-healing tendency than the ointment of chloroform (80.72%) or diethyl ether (70.76%) extracts. Ointment of methanol extract exhibited almost similar potential to treat wounds as the positive control, nitrofurazone ointment (98.44%), in Wistar albino rats after 16 d. Phytochemical screening disclosed that wound healing is due to the presence of phytosterols, alkaloids, and glycosides (Vinothapooshan and Sundar 2010). The methanol and aqueous extracts of *M. pudica* roots were evaluated for wound-healing activity in rats by incision and excision models. An ointment (2% w/w) of each extract was prepared. It was investigated that the methanol extract had better wound-healing tendency than the aqueous extract. This wound-healing activity may be attributed to phenolic compounds that are generally present in methanol (17% w/w) and aqueous (11% w/w) extracts (Kokane and others 2009).

Anti-inflammatory and antinociceptive activity

Due to side effects and the high cost of nonsteroidal anti-inflammatory drugs, there is an utmost need to develop cheaper and safer drugs from plants to treat inflammations (Gilani and Atta-ur Rahman 2005; Hussain and others 2015). For this purpose, paw edema was induced by carrageenan in Wistar albino rats and mercury displacement technique was employed to study the anti-inflammatory effect of ethanol extract of *M. pudica* leaves. The percentage inhibition of paw edema by the extract at dose of 250 and 500 mg/kg was almost similar to that of the standard drug indomethacin (Vikram and others 2012). Furthermore, anti-inflammatory activity was studied by preparing different formulations of hydrogel of *M. pudica* with carbopol 940, carboxymethylcellulose, and hydroxypropylmethylcellulose as gelling agents. Carrageenan-paw edema was determined by mercury displacement technique in albino rats. Carbopol 940 (0.2% to 0.6% w/v) gel formulation with drug (1.5% w/w) inhibited paw edema significantly (Kumar and Kumar 2011).

Azam and others (2015) recently studied the anti-inflammatory effect of ethanolic extract of *M. pudica* leaves in rats in which paw edema was induced by carrageenan. The extract (300 mg/kg) showed significant inhibition (43.48%) in paw edema after 4 h of carrageenan injection. Results (50.31%) were similar to the reference drug diclofenac sodium. The extract (800 mg/kg) also exhibited prominent inhibition (33.64%) in inflammation as studied by the cottonwool-induced granuloma test (Azam and others 2015).

Phytomedicines are more economical and safer than commercial analgesic drugs to relieve pain, which are used worldwide (Elisabetsky and others 1995; Almeida and others 2001; Muhammad and others 2014). *M. pudica* (whole plant) was boiled with water for 30 min and the decoction obtained was centrifuged and filtered. The residue obtained was fed to Swiss albino mice at doses of 200 and 400 mg/kg body weight after inducing writhing with acetic acid. Prominent reduction in writhing was noted at doses of 200 (46.24%) and 400 (56%) mg/kg body weight as compared to the standard drug aspirin (71.36%). Similarly, the response of mice to thermal stimuli was noted by hot plate method. Significant decrease in latency was noted and percent protection was found to be 50.86% (200 mg/kg) and 70.06% (400 mg/kg) as compared to standard drug pentazocine (89.23%) at a dose of 10 mg/kg of body weight (Karthikeyan and Deepa 2010).

Likewise, antinociceptive activity of leaves of *M. pudica* (ethanolic extract) was evaluated by hot plate method, tail flick test, and acetic acid-induced writhing. In tail flick and hot plate tests, ethanol extract exhibited significant cut in latency in rats. In

Table 3–Pharmacological activities of different parts of *M. pudica.*

Pharmacological activity	Plant part used	References
Wound-healing	Root and shoot ointment	Kannan and others (2009)
	Roots extract ointment	Paul and others (2010)
	Leaf extract ointment	Vinothapooshan and Sundar (2010)
	Roots extract ointment	Kokane and others (2009)
Anti-inflammatory	*M. pudica* hydrogel	Kumar and Kumar (2011)
	Leaves extract	Vikram and others (2012)
Antinociceptive	Plant decoction	Karthikeyan and Deepa (2010)
	Leaves extract	Vikram and others (2012)
Hypolipidemic	Leaves extract	Rajendran and Krishnakumar (2010)
	Plant extract	Sowmya and Ananthi (2011)
Hepatoprotective	Leaves extract	Rajendran and others (2009)
Diuretic	Leaves extract	Sangma and others (2010)
Antidiabetic	Leaves extract	Sutar and others (2009)
Antimalarial	Plant extract	Tran and others (2003)
Anticonvulsant	Leaves decoction	Bum and others (2004)
Phytoabsorption	Root nodules	Chen and others (2008)
Antidepressant	Leaves extract	Molina and others (1999)
Antifertility	Roots extract	Valsala and Karpagagaanapathy (2002); Ganguly and others (2007)
Antidiarrheal	Roots extract	Balakrishnan and others (2006b)
Antiparasitic	Nanoparticles	Marimuthu and others (2011)
Antimicrobial	Leaves, roots, aerial parts, and whole plant extracts	Vijaya and others (2004) Vadlapudi and Naidu (2010) Tamilarasi and Anathi (2012) Sukanya and others (2009) Mohan and others (2011) Marimuthu and others (2011) Gandhiraja and others (2009) Genest and others (2008) Chowdhury and others (2008) Ambikapathy and others (2011)
Antioxidant	Aerial parts, leaves, and whole plant	Genest and others (2008); Chowdhury and others (2008); Haripyaree and others (2010); Rekha and others (2010); Arokiyaraj and others (2012)
Antivenomic	Roots, leaves aerial parts, and whole plant	Thirumalai and others (2010) Girish and others (2004); Vejayan and others (2007); Ibrahim and others (2007); Fattepur and Gawade (2007); Samy and others (2008); Meenatchisundaram and others (2009); Ambikabothy and others (2011); Sia and others (2011)

acetic acid-induced writhing, there was a significant reduction in writhing at doses of 250 (25.84%) and 500 mg/kg (43.18%) similar to the standard drug aspirin (48.75%). Studies concluded that the ethanol extract showed reasonable anti-inflammatory activity that can be further utilized as a bioactive for pharmaceuticals (Vikram and others 2012).

Hypolipidemic activity

High Low density lipoproteins-cholesterol, plasma cholesterol, and triglyceride level in the blood result in coronary heart diseases (Koba and others 2006). To study antihyperlipidemic activity, hyperlipidemia was induced in Wistar albino rats with an atherogenic diet for the determination of hypolipidemic activity of *M. pudica* leaves (chloroform extract). It was concluded that hyperlipidemia can be treated with chloroform extract because it decreased triglyceride, low density lipoproteins (LDL), Very low density lipoproteins (VLDL), serum cholesterol, and increased High density lipoproteins (HDL) level comparable with the standard drug atorvastatin. It was also concluded that hypolipidemic activity was due to such phytochemicals as steroids, flavonoids, glycosides, alkaloids, and phenolic compounds present in the chloroform extract, as confirmed by high-performance thin-layer chromatography (Rajendran and Krishnakumar 2010; Gunawardhanaa and others 2015). Similarly, the ethanolic extract of whole plant was evaluated for its hypolipidemic activity in rats in which hyperlipidemia was induced by butter. At the end of study, it was found that ethanol extract lessened serum cholesterol, Triglycerides (TG), LDL, VLDL, and enhanced the HDL level in rats. Results were similar to the positive control (lovastatin). Phytochemical screening of *M. pudica* ensured the presence of steroids, flavonoids, alkaloids, phenolic compounds, and glycosides in its ethanolic extracts (Sowmya and Ananthi 2011).

Diuretic activity

In folk medicine, roots of *M. pudica* are used for diuretic activity and the treatment of many other complications (Vaidyaratanm 2001; Pande and Pathak 2010). Urinary tract infections are treated by a decoction of leaves and seeds of *M. pudica* (Krishnaraju and others 2006). Evaluation of this practice on a scientific basis was carried out by Sangma and others (2010). They extracted *M. pudica* leaves with water and the aqueous extract was fed to Wistar albino rats at doses of 100, 200, and 400 mg/kg. They studied diuretic activity by the Lipschitz test and results were compared with the standard drug furosemide. Colorimetry was used for biochemical analysis of urine collected from rats kept in metabolic cages. There was a prominent increase in urine containing electrolytes (Na^+, K^+, and Cl^-) at 100 mg/kg body weight. Results were good, although, diuretic activity was less than with the standard drug furosemide. It was also investigated that an increased dose of extract did not affect diuretic activity, and no mortality was observed in a 14-d study. Phytochemical screening revealed the presence of alkaloids, tannins, and saponins in the aqueous extract of *M. pudica* leaves (Sangma and others 2010).

Antidiabetic activity

Phytomedicines are more inexpensive and safer than synthetic drugs to treat the most widespread and most rapidly growing

disease, diabetes (Wild and others 2004; Jung and others 2006). Therefore, there is dire need to evaluate more plants to treat diabetes. Antidiabetic potential of *M. pudica* leaves was studied by Sutar and others (2009). They extracted *M. pudica* leaves with ethanol and petroleum ether. Alloxan at a dose of 150 mg/kg body weight was used to induce diabetes. Serum glucose level was reduced from 292.67 ± 2.91 to 198.96 ± 3.26 for the petroleum ether extract (600 mg/kg) and 274.36 ± 5.22 to 136.21 ± 1.69 for the ethanol extract (600 mg/kg) in 7 d, while serum glucose level was decreased from 280.12 ± 2.80 to 105.21 ± 5.32 by the standard metformin (500 mg/kg) as tested by the glucose oxidase/peroxidase method. The studies concluded that ethanol extract significantly exhibited hypoglycemic activity. This antidiabetic activity might be due to flavonoids, tannins, and alkaloids in the ethanol extract of leaves (Sutar and others 2009).

In another study, antidiabetic activity of an ethanolic extract (70%) of roots and stem of *M. pudica* was evaluated in Wistar rats. Alloxan-induced diabetic rats were fed with ethanolic extract (600 mg/kg/d) of stem and roots for 11 d. Blood samples were collected on the 4th and 11th d and it was found that both the extracts decreased blood glucose levels and had a hypoglycemic effect (Sutrisna and others 2015).

In a recent study, *M. pudica* leaves were extracted with methanol and the crude extract was used to evaluate its hypoglycemic effect in rats. Rats were fed with fructose, which increased their weight and glucose level. Then these hyperglycemic rats were fed with the extract, which normalized their body weight and glucose level. After that the rats were sacrificed and histopathological studies revealed that the extract had recovered the damaged liver and improved the insulin level (Sundaresan and Radhiga 2015). Also recently, methanolic extract of aerial parts of *M. pudica* and its various fractions (ethyl acetate, acetone, and methanol) were found to inhibit the activity of diabetic enzymes like α-amylase and α-glucosidase. The extract and its fractions also showed free radical-scavenging activity as determined by 1,1-diphenyl-2-picrylhydrazyl-hydrate (DPPH), total flavonoid content, and total phenolic content assays. The study revealed that *M. pudica* is a potential candidate to treat diabetes (Tunna and others 2014, 2015).

Antiparasitic activity

The tropical disease malaria is common in 100 countries and about 2400 million people are susceptible. Out of 100 million cases from South Asia, 70% are from India (Kager 2002; WHO 2004). The whole plant of *M. pudica* was extracted with methanol, water, and a methanol–water system and extracts were evaluated against *Plasmodium falciparum* strain FCR-3, which is resistant to chloroquine. Studies ended with the conclusion that methanol, water, and water–methanol extracts inhibited the growth of *P. falciparum* significantly with EC_{50} values of 3.8, 4.4, and 6.2, respectively, and could be used to treat malaria (Tran and others 2003). For the determination of antiparasitic activity, silver nanoparticles were prepared by mixing an aqueous decoction of *M. pudica* leaves with silver nitrate solution for 10 min at room temperature. The synthesized nanoparticles significantly killed (LC_{50} 8.98) larvae of *R. microplus* (Marimuthu and others 2011).

In another study, 26 stocker cattle were grazed on wheat forage along with *M. pudica* tannins in one group and commercial tannins in another group for 35 d. It was concluded that gain in body weight was greater with *M. pudica* tannins than commercial tannins. It might be due to a reduction in fecal parasitic infections (Min and others 2015).

Anticonvulsant and antidepressant activity

In folk medicine, *M. pudica* is used for its anticonvulsant activity. Bum and others (2004) prepared a decoction of *M. pudica* leaves at doses of 1000 to 4000 mg/kg, which was used to recover seizures induced by pentylentetrazol and strychnine in mice. Similarly, *N*-methyl-D-aspartate-induced turning behavior was also antagonized by a *M. pudica* leaf decoction. On the other hand, decoctions cannot heal seizures induced by picrotoxin (Bum and others 2004).Various concentrations of aqueous extract of *M. pudica* leaves were tested to relieve depression in rats. Rats were given 2, 4, 6, and 8 mg/kg *M. pudica* leaf extracts for 30 d to study the forced swimming test and differential reinforcement test of low response rates at 72 (DRL-72s). It was noted that *M. pudica* extract increased mobility in the forced swimming test and reinforced the rate in DRL-72s like the standard drugs clomipramine and desipramine. The extract cannot increase open arms exploration time in the elevated plus maze test like diazepam. Studies concluded that *M. pudica* can produce antidepressant action (Molina and others 1999).

Currently, elevated plus maze, open field, stress-induced hyperthermia, and hole board parameters were employed to study anxiolytic properties of *M. pudica* whole plant powder. It was noted that *M. pudica* powder could be used in mice to treat anxiety at a dose of 30 mg/kg. It can also act as a muscle relaxant and sedative as tested by horizontal wire and rota-rod tests (Mbomo and others 2015).

Antifertility activity

Antifertility activity was observed in Swiss albino mice by administering methanol extract of *M. pudica* roots for 21 d and studying reproductive hormones (LH, FSH, prolactin, estradiol, and progesterone), estrous cycles, and number of litters produced. *M. pudica* root extracts delayed the estrous cycle at a dose of 300 mg/kg body weight and enhanced the period of the diestrous phase. Numbers of litters were also reduced. A study of the hormones (FSH, LH, estradiol, prolactin, and progesterone) of estrous cycle showed that *M. pudica* root extracts changed the secretion of gonadotropin and estradiol. It was concluded that *M. pudica* root extracts has an antifertility effect due to delaying the estrous cycle and disturbing the hormones secretion (Valsala and Karpagagaanapathy 2002; Ganguly and others 2007).

Antidiarrheal activity

Diarrhea causes around 1.5 to 2 million deaths in the developing countries and is very common in children (Liebelt 1998, Kosek and others 2003; WHO 2009; Shafi and others 2014). Antidiarrheal effects were studied by extracting *M. pudica* roots with water and ethanol. One study disclosed that both extracts showed significant potential to treat diarrhea and reduce gastrointestinal motility (Balakrishnan and others 2006b).

Antimicrobial activity

Antibiotics inhibit the growth of pathogenic microorganisms. However, several microorganisms have developed resistance against these synthetic drugs, which are also expensive and have side effects (Shariff 2001). Furthermore, fungi destroy food by producing mycotoxins and cause diseases (Calado and others 2014; Hymery and others 2014). Consequently, researchers are focusing on plant extracts for isolation of bioactives that can be used as herbal substitutes (Rios and Recio 2005). In a very recent study, shade-dried leaves, roots, and stem bark of *M. pudica* were extracted with ethanol and petroleum ether, separately, and the extracts were

tested against microorganisms like the mold *A. niger* and the bacterium *S. aureus*. The study ended with the conclusion that both extracts inhibited their growth (Ighodaro and others 2015). Dried leaves of *M. pudica* were extracted with water and methanol to determine antimicrobial activity by the broth dilution and agar disk diffusion methods. It was found that methanol extract inhibited growth of *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumonia*, *Proteus vulgaris*, *Pseudomonous aeruginosa*, and the mold *Candida albicans*. Growth of *S. aureus*, *B. subtilis*, *P. aeruginosa*, and *P. vulgaris* was also inhibited by the aqueous extract (Mohan and others 2011).

In the most recent study, air-dried *M. pudica* leaves were ground to powder and extracted with water and also with ethanol plus water (1:1). Both the aqueous and ethanolic extracts inhibited the growth of 2 fungi (*Trichophyton verrucosum* and *T. soudanense*) significantly. The extracts also showed moderate antifungal activity against *Microsporum ferrugineum* and *T. schoenleinii* (Muhammad and others 2015). Bacteriostatic activity of *n*-hexane, methanol, and dichloromethane (DCM) extracts of *M. pudica* was carried out by the resazurin microtiter plate-based assay. It was revealed that the methanol and DCM extracts showed greater antibacterial activity against *B. subtilis*, *Bacillus cereus*, *E. coli*, ampicillin-resistant *S. aureus*, *E. coli*, and *Pseudomonas aeruginosa* with minimum inhibitory concentration ranging from 0.625 to 2.50 mg/mL, while *n*-hexane extract exhibited no bacteriostatic effect (Genest and others 2008). In another study, sterilized and disease-free leaves of *M. pudica* were extracted with *n*-butanol, methanol, and water to study their antifungal activity against *Pythium debaryanum* (a pathogenic mold) by agar-well diffusion assay. The study revealed that the methanol extract showed 20-mm zones of inhibition, while aqueous and *n*-butanol extracts showed no antifungal activity (Ambikapathy and others 2011). Chowdhury and others (2008) extracted aerial and underground parts of *M. pudica* with petroleum ether, chloroform, and methanol separately, and tested against various microorganisms by the disc diffusion method. All extracts showed very poor inhibition or no inhibition of growth of *B. cereus*, *B. subtilis*, *Bacillus megaterium*, *Sarcina lutea*, *S. aureus*, *P. aeruginosa*, *Salmonella paratyphi*, *E. coli*, *Salmonella typhi*, *Shigella dysenteriae*, *Shigella boydii*, *Vibrio mimicus*, *V. parahemolyticus*, *C. albicans*, *Aspergillus niger*, and *Sacharomyces cereviseae* (Chowdhury and others 2008). In another study, finely ground *M. pudica* leaves were extracted with methanol to evaluate antimicrobial activity against 2 bacteria, *Citrobacter divergens* and *Klebsiella pneumoniae* and also a mold species, *A. fumigatus*, by well diffusion assay. The extract inhibited the growth of *A. fumigates* and *K. pneumoniae* but had no effect on the growth of *C. divergens* (Gandhiraja and others 2009).

Kang and others (2004) screened different bacterial strains from *M. pudica* roots. They identified *Burkholderia* species by carbohydrate intake, biochemical and physiological tests, and 16S rDNA sequence. Moreover, an antifungal compound, 2-hydroxymethyl-chroman-4-one was isolated from the screened culture, which inhibited the growth of plant pathogenic fungi like *Pythium ultimum*, *Phytophthora capsici*, and *Sclerotinia sclerotiorum* (Kang and others 2004). The antimicrobial activity of ethanolic extract of *M. pudica* leaves was studied by disc diffusion method against *S. aureus*, *E. coli*, *P. aeruginosa*, and *C. albicans*. The results obtained were comparable to standard drugs, fluconazole and ampicillin (Kaur and others 2011). Marimuthu and others (2011) revealed that silver nanoparticles prepared from *M. pudica* leaves possessed significant antimicrobial activity against *A. niger*, *E. coli*, *and P. aeruginosa* (Marimuthu and others 2011). In another study, fresh leaves of *M. pudica* were extracted with water, methanol, ethanol, chloroform, and ethyl acetate, separately, and evaluated for their antimicrobial activity by the disc diffusion method. Aqueous extracts showed low activity against *E. coli* and *S. aureus*. Ethyl acetate extract inhibited the growth of *Xanthomonas vesicatoria*. All other extracts had no activity against *E. coli*, *S. aureus*, *X. vesicatoria*, and *Ralstonia solanacearum* (Sukanya and others 2009). Likewise, ethanolic extract of *M. pudica* leaves was investigated for antimicrobial activity and it was established that it inhibited the growth of *B. subtilis*, *P. aeruginosa*, *Aspergillus flavus*, *K. pneumonia*, and *Trycophyton rubrum* at a 100-μL concentration. It was also noted that inhibition in growth increased with an increase in extract concentration from 25 to 100 μL. Preliminary screening of *M. pudica* extracts revealed the presence of saponins, tannins, steroids, carbohydrates, and flavonoids (Tamilarasi and Anathi 2012).

A decade back, Vijaya and others (2004) employed the agar well diffusion method to determine antimicrobial activity of *M. pudica* methanolic extract against various microorganisms. Methanolic extract inhibited the growth of *A. niger* and *Macrophomina phaseolina* at a concentration of 500 mg/mL. Inhibition of growth became more significant with an increase in concentration. The extract showed no activity against *Alternaria alternate* and *Rhizoctonia solani* (Vadlapudi and Naidu 2010). *M. pudica* leaves, roots, and pods extracted with chloroform, ethyl acetate, and methanol displayed antimicrobial activity. Chloroform extract displayed great potential to inhibit the growth of different Gram-positive and Gram-negative bacteria, while ethyl acetate extract expressed reasonable antifungal activity (Vijaya and others 2004).

Antioxidant and hepatoprotective activity

Due to side effects of synthetic antioxidants, herbal medicines are considered safer and cost-effective to capture free radicals and treat cancer, hepatitis, and vascular complications (Stanner and others 2004; Kalim and others 2010; Maqsood and others 2014; Kumar and others 2015). The aerial parts of *M. pudica* were extracted with methanol to study the antioxidant activity of extract using the DPPH free radical scavenging assay. The study indicated that the extract possessed good antioxidant activity (IC_{50} 296.92 μg/mL) as compared to the standard antioxidant ascorbic acid (IC_{50}131.29 μg/mL; Chowdhury and others 2008). Methanol, DCM, and *n*-hexane extracts of stem of *M. pudica* were also evaluated for their antioxidant activity by the DPPH assay and results showed that methanol extract (RC_{50} 2.10×10^{-2}) had significant antioxidant activity and *n*-hexane showed the least (Genest and others 2008). Further studies by Arokiyaraj and others (2012) also claimed that methanol extract of *M. pudica* leaves possesses moderate antioxidant activity as determined by the thiocyanate method and DPPH assay. Phytochemical screening of *M. pudica* extracts recognized the presence of tannins, alkaloids, flavanoids, terpenoids, and glycosides in methanol extract of *M. pudica* leaves (Arokiyaraj and others 2012).

Antioxidant activity of *M. pudica* leaves (chloroform extract) was evaluated by super oxide dismutase, nitric oxide, DPPH, and reducing power ability and was found to possess great free radical scavenging activity when compared with the standard antioxidant ascorbic acid. The antioxidant property of an extract depends on concentration and is due to the presence of phenolic compounds. Different chromatographic techniques have confirmed the presence of steroids, flavonoids, glycosides, alkaloids, and phenolic compounds in chloroform extracts (Rekha and others 2010). In the same year, Haripyaree and others (2010) investigated

that methanol extract of *M. pudica* possessed sulfur-free radical reactivity, with curcumin as the standard. Depletion of curcumin by reacting with free radicals, generated by irradiating glutathione with gamma-radiation, was observed by spectrophotometer. Consumption of curcumin was decreased by adding methanolic extract showing that extract had the potential to capture sulfur-free radicals (Haripyaree and others 2010). The whole plant of *M. pudica* was shade-dried and extracted with ethanol to study its antioxidant activity by hydrogen peroxide scavenging (HPS) and super oxide scavenging (SOS) assays. The extract captured free radicals efficiently with IC_{50} values of 19 mcg/mL as compared to standard ascorbic acid (5.2 mcg/mL) in the HPS assay. The extract also showed IC_{50} value of 80.4 mcg/mL as compared to standard gallic acid (50.2 mcg/mL) in the SOS assay. It was also noted that the ethanolic extract decreased stress and protected Wistar rats from Alzheimer's disease at a dose of 500 mg/kg for 21 d (Ittiyavirah and Pullochal 2014).

Ethanolic extract of *M. pudica* leaves showed considerable antioxidant activity and an IC_{50} value of 24.55 μg/mL, when studied by DPPH fee radical scavenging activity. Free radical capturing activity is dose-dependent and maximum antioxidant activity was found at a dose of 800 μg/mL. This antioxidant activity might be due to flavonoids (Azam and others 2015).

Recently, whole *M. pudica* plant was ground to a powder to treat liver problems. Hepatitis was induced in rats by CCl_4. Rats were administered with the powder for 10 d. Blood was taken from the rats, and after that they were sacrificed. The study revealed that the powdered plant brought the total bilirubin, acid phosphatase, aspartate transaminase, alanine transaminase, alkaline phosphatase, and lipid peroxide to normal levels (Kumaresan and others 2015). In another study, the methanol extract of *M. pudica* leaves was administered to Wistar albino rats at a dose of 200 mg/kg body weight for 14 d to study its hepatoprotective effect (Rajendran and others 2009). Liver damage in rats was induced by CCl_4. The study concluded that methanolic extract reduced serum glutamic pyruvates transaminase (SGPT), serum glutamic oxaloacetate transaminase (SGOT), total bilirubin, total cholesterol, alkaline phosphatase, and increased total protein and albumin similar to the positive control, silymarin. Histopathological studies also support these results. This hepatoprotective effect is due to presence of such bioactives as flavonoids, glycosides, and alkaloids in the methanolic extract.

In the same fashion, ethanolic extract (70%) of the stem of *M. pudica* reduced SGOT and SGPT in Wistar rats, in which diabetes was also induced by alloxan. For 11 d, rats were given the ethanolic extract (600 mg/kg body weight) once in a day. At the end of the study, it was found that ethanolic extract had a hepatoprotective effect (Sutrisna and others 2015). In another study, livers of mice were damaged with CCl_4 and then they were fed with flavonoids extracted from *M. pudica*. It was observed that total flavonoids from *M. pudica* can decrease the activity of Alanine transaminase (ALT) and Aspartate transminase (AST). Findings of the study showed that *M. pudica* can treat hepatitis and improve liver condition (Zhen-Qin and others 2015).

Antivenomic activity

In folk medicinal systems, people utilize various parts of *M. pudica* against snakebite of *Cobra*, *Naja naja*, *Naja kaouthia*, *Bangarus caeruleus*, and other species of snakes (Bhalla and others 1982; Macmillan 1999; Mahanta and Mukherjee 2001; Pattanaik and others 2006; Thirumalai and others 2010). Further confirmation of the antivenom effect was supplied by Ambikabothy and others (2011) by applying a tannin fraction from *M. pudica* roots. It was concluded that the fraction exhibited 100% protein-binding capacity *in vitro* by Bradford dye-protein binding assay against *N. kaouthia* venom. However, an isolate was not found to be effective *in vivo* when tested in mice (Ambikabothy and others 2011).

In another study, alcoholic extract of *M. pudica* showed antivenomic effect (Fattepur and Gawade 2007). Aqueous extract of *M. pudica* roots neutralized the lethal effect of *N. naja* and *B. caeruleus* venoms and inhibited myotoxicity (Mahanta and Mukherjee 2001; Girish and others 2004; Ibrahim and others 2007; Vejayan and others 2007; Meenatchisundaram and others 2009). Similarly, roots of *M. pudica* were ground to a fine powder and then extracted with water. It was concentrated and then redissolved in water to separate tannins, using Sephadex (LH-20) chromatography. *N. kaouthia* venom injected into mice caused 100% mortality without the tannin fraction. When *M. pudica* tannins were injected immediately after the *N. kaouthia* venom, the extract protected mice better than commercially available antivenom tannins, and there was no mortality. Two-dimensional electrophoresis of treated mouse serum showed that, due to downregulation, 2 protein spots are missing in snake venom. Therefore, snake venom lethality can be avoided by using *M. pudica* tannins (Sia and others 2011).

Role of *M. pudica* Hydrogel in Drug Release Formulations

Water-swellable polysaccharides like guar gum, psyllium, xanthan gum, and tragacanth are sensitive to pH and temperature and were extensively evaluated for successful target-specific sustained release of several drugs (Qiu and Park 2001; Chourasia and Jain 2003, 2004; Desai and others 2007; Tang and others 2008). Polysaccharide material from seeds of *M. pudica* is composed of D-xylose and D-glucuronic acid (Farooqi and others 1977; Saraswat and Pokharkar 2012) and is generally named glucuronoxylan. This polysaccharide (glucuronoxylan) was evaluated for sustained release of the antifungal drug fluconazole. The direct compression method was chosen for preparing buccal discs of fluconazole using *M. pudica* mucilage. Concentrations of mucilage, drug, and lactose were optimized and a quadratic model with backward elimination showed bucoadhesive (85%) release of the drug in 10 h. The studies concluded that the polymer/lactose concentration has a major effect on drug release, and thus *M. pudica* mucilage is a potential candidate for mucoadhesive drug deliveries (Ahuja and others 2010). *M. pudica* seed mucilage was also evaluated as a disintegrant by compressing tablets of hydrochlorothiazide with mucilage (1% to 10%). Results indicated that seed mucilage is a good disintegrant. Similarly, mucilage was used as binder in paracetamol tablets and it was found that at 10% concentration, tablets have reasonable hardness and friability. Studies revealed that *M. pudica* seed mucilage is a very good tablet binder and disintegrant (Ahuja and others 2013).

In another study, mucilage from *M. pudica* seeds was evaluated for sustained release of diclofenac sodium (Singh and others 2009). Diclofenac sodium tablets were studied for drug release using 0.1 N HCl for 2 h then the tablets were transferred to another chamber of dissolution apparatus containing phosphate buffer and release of drug was noted for 24 h at 37 °C. It was found that with an increase in the hydrogel ratio, there was a corresponding decrease in drug release, and erosion and increase in percent swelling. Results obtained were comparable with the standard formulation of diclofenac sodium. Recently, different formulations of *M. pudica*

hydrogel were prepared by using carbopol 940, carboxymethylcellulose, and hydroxypropylmethylcellulose, which were used as gelling agents (Kumar and Kumar 2011). The study showed that carbopol 940 (0.2% to 0.6% w/v) gel formulation with drug (1.5% w/w) was the best formulation.

M. pudica Mediated Synthesis of Nanoparticles

For the preparation of silver nanoparticles, dried powder of *M. pudica* leaves was boiled with water for 5 min and the filtrate was incubated with 1 mM $AgNO_3$ solution for 10 min at room temperature (Marimuthu and others 2011). Nanoparticles were isolated and characterized by UV-visible, FTIR, SEM, TEM, and powder XRD. The nanoparticles prepared by reduction of silver nitrate using *M. pudica* leaves extract were found to be significantly active against a number of parasites.

Silver nanoparticles of different sizes and shapes have also been prepared from aqueous extracts of *M. pudica* leaves. This biocompatible and green method of silver nanoparticle formation and progress of reaction were studied using UV-visible spectroscopy. Further confirmation was done by using advanced techniques like SEM, TEM, and XRD. It was found that *M. pudica* leaf extracts could act as stabilizing and reducing agents (Ganaie and others 2015). In another study, gold nanoparticles of different sizes (average size 16 nm) were prepared from an aqueous extract of *M. pudica* leaves. The formation was monitored by UV-visible spectroscopy. Moreover, these nanoparticles were used as catalyst to degrade organic pollutants. It was concluded that degradation of pollutants becomes very fast in the presence of gold nanoparticles (Devi and others 2015).

Conclusions and Future Prospects

Among the plants of the family *Mimosaceae*, the versatile uncultivated species *M. pudica* has captivating much attention because of its intensive folk medicinal uses and pharmaceutical attributes. *M. pudica* is esteemed by folk healers for the treatment of cancer, diabetes, snakebite, diarrhea, asthma, inflammations, ulcers, fever, and wounds. Antidepressant, antinociceptive, anti-inflammatory, antioxidant, hepatoprotective, antimicrobial, hypolipidemic, and hypoglycemic activities of *M. pudica* are now also considered admirable. Therefore, there is a dire need to isolate functional bioactives responsible for these attributes from the different parts of the plant. Various studies have concluded that the plant is rich in the alkaloid, mimosine, which has anticancer properties. Further efforts are required to elaborate the anticarcinogenic nature of mimosine and its isolation on a commercial scale for therapeutic applications in human beings.

A large number of studies have been done for its antivenomic activity. Some studies concluded that the antivenomic potential of the plant is due to tannins. However, tannins responsible for its antivenomic activity have still not been isolated in pure form. Lives could be saved by the separation of antivenomic phytochemicals from *M. pudica* to develop therapeutic formulation after evaluation. Extracts of various parts of the plant have exhibited significant antidiabetic, anti-inflammatory, and hypolipidemic activities, indicating the presence of functional secondary metabolites. Therefore, researchers must screen these compounds for the development of new and economical drugs. *M. pudica* has been extensively studied for its antimicrobial activities. Hence, efforts should be made to develop new antibiotics by isolating compounds from different parts of plant. The hydrogel glucuronoxylan from the seed coat of *M. pudica* has been evaluated for drug release. Further investigations are now demanding to study the cytotoxic effects of glucuronoxylan polysaccharide from *M. pudica* seeds for utilization in drug release studies.

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