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Pharmacology and phytochemical profile of *Wattakaka volubilis* (L.f.) Stapf: A systematic review

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Abstract

Wattakaka volubilis (L.f.) Stapf, a substantial woody climber of the family Apocynaceae is widely employed in numerous Ayurvedic formulations to treat leucoderma, asthma, tumors, urinary tract infections, piles, and inflammations. Traditionally, its leaves and entire plant are utilized to alleviate cough, severe cold, fever, rheumatic pain, rabies, snakebites, boils, abscesses, and ocular afflictions. Diverse chemical constituents, encompassing alkaloids, terpenes, amino acids, tannins, pregnane glycosides, flavonoids, and polyphenols are present in the extracts from different plant parts such as bark, leaves, flowers, and fruits. These extracts exhibit a wide array of pharmacological properties, including anticancer, larvicidal, anti-leishmanial, chondroprotective, and anthelmintic activities. However, for thorough validation, well-designed in vivo and clinical trials are imperative to substantiate its immense medicinal potential. The current investigation aims to deliver a comprehensive review of the bioactive compounds and pharmacological attributes of this plant.

Keywords

bioactives; pharmacology; *Dregea volubilis*; Apocynaceae; climber; phytochemicals, phytochemistry

Introduction

Wattakaka volubilis (L.f.) Stapf, a large woody climber belonging to the family Apocynaceae is widely distributed in India, including the hotter tropical regions, Himalayas, north-west region to West Bengal, Assam, Eastern Ghats, the Deccan Peninsula, and the Western Ghats, encompassing the southern parts of India (1, 2). Additionally, it can be found in Sri Lanka, Pakistan, Malaysia, China, Thailand, Indonesia, Burma, and Java (1, 2). Synonyms of this species include *Wattakaka viridiflora* Hassk., *Dregea volubilis* (L.f.) Benth. ex Hook.f., *Dregea volubilis* var. *viridiflora* (Hassk.) Kuntze, *Asclepias volubilis* L.f., *Hoya viridiflora* R.Br., *Hoya volubilis* (L.f.) Griff., and *Marsdenia volubilis* (L. f.) Cooke. *Wattakaka volubilis* is well-recognized in India for its medicinal properties, and it is utilized as a substitute for the ayurvedic drug 'Murva' (*Marsdenia tenacissima*) with its leaves and roots serving as main ingredients in numerous Ayurvedic formulations (3). The plant possesses various vernacular names across India (Table 1). To highlight the plant's versatility in traditional medicine, this study aims to conduct a systematic review of its phytochemical constituents and pharmacological properties.

Table 1. Vernacular names of *W. volubilis*

S. No.	Vernacular Name	Language	Reference
1	Sneeze wort, Green milkweed climber, Green wax flower	English	(4)
2	Hemajivanti lata, Khamal lata	Assamese	(4, 46)
3	Hemapushpi, Hemavalli, Bahuparni, Svarnalata	Sanskrit	(4)
4	Kadavi dodi	Gujarati	(4)
5	Hegale balli, kaadu hale balli	Kannada	(4, 46)
6	Harandodi, Nakchikni	Marathi, Hindi	(4, 42)
7	Kodipalai	Tamil	(2)
8	Jukti	Bengali	(8)
9	Dudhipaala	Telugu	(44)

Methodology

The publications were obtained from various online databases, including Scopus, PubMed, Web of Science, Wiley Online Library, Google Scholar, and Science Direct. The search employed key terms such as *'Wattakaka volubilis'*, '*Dregea volubilis*', and their synonyms, combined with relevant phrases like 'uses', 'activity', 'phytochemicals', 'bioactives', 'compounds', 'phytochemistry', and 'pharmacology' in titles and other sections. A thorough review and summary were conducted on the literature concerning traditional uses, bioactive compounds, as well as *in-vitro* and *in-vivo* pharmacological activities. Among the 52 obtained publications, 39 articles published from 1969 to 2023 were included based on predefined criteria. The chemical structures of the compounds were drawn using chemdraw 14.0 software.

Results

Morphological characters of the plant

The plant is identified as a glabrescent, hoary woody vine, characterized by opposite, broadly ovate or lanceolate leaves (6-11 × 5-7 cm) with numerous glands at the base of the midrib on the upper surface and pubescence beneath. The leaves exhibit a rounded or cordate base and an apex that abruptly tapers to an acuminate point. The inflorescence forms dense lateral umbellate cymes, with fragrant, green to greenish-yellow flowers. The corolla displays a rotate structure with five oblong lobes, showing a ciliolate margin. The stamens, in a uniseriate arrangement are 5-lobed and adnate to the base of the staminal column. The fruit is a follicle, approximately 9 cm in length, divaricate, and tapers to a blunt point. It bears a brown tomentose surface. The seeds are smooth, shining, concave-elliptic, and possess sharp edges, crowned with extremely minute silky white hairs (1, 4).

Traditional uses

The Indian traditional culinary system incorporates various plant parts, such as leaves, flowers, and unripe fruit rind, as vegetables (5, 6). Additionally, the whole plant extract has been utilized in the traditional treatment of rabies, eye diseases, scorpion and snakebites (5, 7). In the southern region of India, locals have used the leaves to alleviate severe cold, fever, and rheumatic pain, while the leaf juice serves as a topical remedy for boils and abscesses (5, 8). Moreover, this plant plays a crucial role in numerous Ayurvedic formulations targeting ailments like tumors, leucoderma, asthma, urinary tract infections, neck pain, inflammations, and piles (6, 9). The tender twigs and roots possess purgative, expectorant, emetic, antimutagenic and anthelmintic properties (3). Furthermore, the consumption of bark paste with milk is believed to remedy urinary diseases, and leaf powder combined with milk is employed in diabetes treatment (7).

Phytoconstituents

Compound isolation from different extracts of *W. volubilis* bark led to the identification of β-sitosterol, kaempferol, and kaempferol 3-galactoside (10). Subsequently, novel glycosides (A01, Aa1, Ap1, A11, C11, Ka1, and Kp1) were isolated from the plant's stem and characterized based on chemical and spectral evidence (11). Analysis of the leaf extract yielded multiflor-7-en-12α-ol and a new triterpenoid, multiflor-7-en-12,13-ether (12). Moreover, the flower extract revealed three novel polyoxypregnane glycosides: volubiloside A, B, and C, whose structures were elucidated using NMR and MALDI-TOF-MS, and found to be drevogenin D-3-O-β-D-glucopyranosyl (1→4)-6-deoxy-3-O-methyl-β-D-allopyranosyl (1→4)-β-D-cymaropyranosyl (1→4)-β-D-cymaropyranoside, drevogenin D-3-O-β-D-glucopyranosyl (1→4)-6-deoxy-3-O-methyl-β-D-allopyranosyl (1→4)-β-D-cymaropyranosyl (1→4)-β-D-digitoxopyranoside, and drevogenin P-3-O-β-D-glucopyranosyl (1→4)-6-deoxy-3-O-methyl-β-D-allopyranosyl (1→4)-β-D-cymaropyranosyl (1→4)-β-D-cymaropyranoside, respectively (13).

Three novel polyhydroxy pregnanes named dregealol, volubilol, and volubilogenone were extracted from the flowers and their structures were determined using 2D-NMR and X-ray crystallography (14). Additionally, established pregnane derivatives, namely drevogenin D, iso-drevogenin P, and 17α-marsdenin, were also isolated (14). Furthermore a new acylated flavone C-glycoside, dregeanin was obtained from the flowers along with other compounds including apigenin, isoorientin, isovitexin, luteolin, quercetin, rutin, vicenin-2 and vitexin. Dregeanin structure was identified through spectroscopic studies as apigenin-{6-C-β-D-glucosyl 2″-O-feruloyl}8-C-β-D-glucopyranoside (15). Moreover, drevogenin D an active triterpenoid aglycone was isolated from the leaf extract (5), while taraxerol and kaempferol were obtained from the leaves, stem, and seed extracts, respectively (16).

Taraxerol, a pentacyclic triterpenoid, was isolated from the petroleum ether extract of fruits using column chromatography (8). Its structural elucidation as D-friedoolean-14-en, 3-ol was achieved through NMR, IR, and MS spectroscopic studies (8). From the same petroleum ether extract of fruits, another pentacyclic triterpenoid called taraxerone along with the bioactive constituent β-sitosterol were isolated using chromatographic techniques (17). An active compound, polyoxypregnane glycoside (PGG) was isolated from an active fraction of the ethyl acetate root extract (18). The methanol extract of leaves yielded ursolic and oleanolic acids (19). Additionally, three new pregnane glycoside derivatives, namely drevoluoside O, P and Q along with five known compounds (dreageoside A11, hoyacarnoside G, stavaroside H, volubiloside C and 17β-marsdenin) were also isolated from the same methanol leaf extract (20).

GC-MS analysis of various extracts (petroleum ether, chloroform, methanol, ethyl alcohol, hydroalcohol, and aqueous) of leaves revealed the presence of 67 compounds. Among these, prominent constituents included oleic acid, palmitic acid, 1,3,4,5-tetrahydroxy-cyclohexanecarboxylic acid, (E)-cinnamic acid, dichloroacetic acid, linoleic acid, squalene, octacosane, hexacosane, heptacosane, tridec-2-ynyl ester, and methyl tropate (2). Figure 2 displays the structures of some bioactive compounds from the plant.

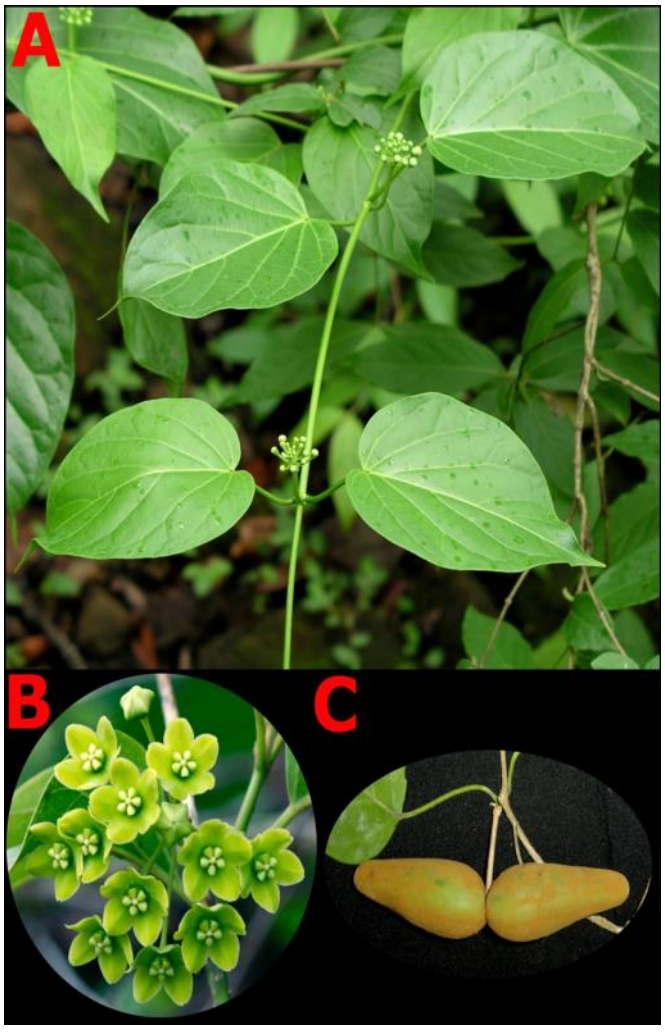

Fig 1. *Wattakaka volubilis* (L.f.) Stapf. Habit [A], Inflorescence [B], Fruit [C].

Pharmacological properties

Antioxidant activity

in vitro analysis of six distinct leaf extracts was conducted to evaluate their antioxidant activity using various analytical methods. The methanol extract demonstrated superior scavenging activities against nitric oxide, superoxide, and DPPH radicals, with IC_{50} values of 13.06 ± 1.40, 13.71 ± 6.99, and 39.24 ± 2.56 µg/mL, respectively (2). Conversely, the hydroethanolic extract exhibited higher free radical scavenging potential for hydroxyl (46.92 ± 14.30 µg/mL), ABTS (51.23 ± 8.36 µg/mL), metal chelating (49.61 ± 0.96 mg/g), and total antioxidant (16.81 ± 1.60 mg/g) activities (2).

Drevogenin D, when assessed against DPPH and superoxide free radicals, displayed notable antioxidant capacity with IC_{50} values of 43 and 200.6 µg/mL, respectively (5). Significant antioxidant activities were reported for petroleum ether, chloroform, and methanol extracts of the fruit, including lipid peroxidation, nitric oxide, reducing power, and superoxide anion scavenging activities (21). Furthermore, the hydroalcoholic flower extract demonstrated substantial free radical scavenging activities against DPPH (IC_{50}: 237.86 ± 1.05 µg/mL), hydroxyl (IC_{50}: 170.67 ± 0.98 µg/mL), superoxide (IC_{50}: 219.07 ± 1.25 µg/mL), FRAP (IC_{50}: 176.47 ± 3.18 µmol/g), and nitric oxide (IC_{50}: 196.38 ± 1.49 µg/mL) (22).

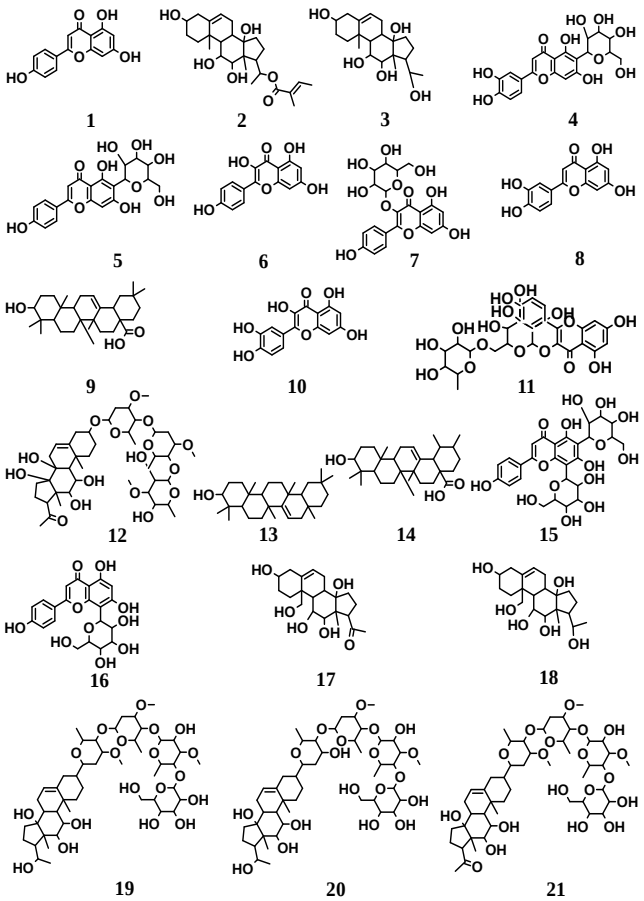

Fig. 2. Structures of important chemical constituents. Apigenin [1], Dregealol [2], Drevogenin D [3], Isoorientin [4], Isovitexin [5], Kaempferol [6], Kaempferol 3-galactoside [7], Luteolin [8], Oleanolic acid [9], Quercetin [10], Rutin [11], Stavaroside H [12], Taraxerol [13], Ursolic acid [14], Vicenin-2 [15], Vitexin [16], Volubilogenone [17], Volubilol [18], Volubiloside A [19], Volubiloside B [20], Volubiloside C [21].

Hexane and chloroform extracts displayed potent antioxidant potential in ABTS assays, with IC_{50} values ranging from 13.26 to 24.36 µg/mL (23). The methanolic leaf extract exhibited the highest inhibition percentage of DPPH radicals (83.44%) at a concentration of 200 mg/mL, while inhibition percentages of 80.04%, 70.54%, and 86.96% were observed against superoxide, nitric oxide, and hydroxyl radicals, respectively at the same concentration (24). Among the tested extracts, the leaf aqueous extract demonstrated the highest free radical scavenging activity, with a scavenging rate of 87.72% against DPPH radicals, followed by the acetone extract with a scavenging rate of 33.33% (25). Additionally, biofabricated silver nanoparticles synthesized from aqueous flower extracts displayed effective antioxidant activity against DPPH (IC_{50}: 40.45 ± 5.06 µg/mL) and ABTS (IC_{50}: 78.49 ± 1.41 µg/mL) radicals, along with a total antioxidant activity of 148.83 ± 2.99 mg GAE/g (6).

Antidiabetic activity

Antidiabetic activity of hydroalcoholic and methanolic extracts of leaves displayed strong inhibition of α-glucosidase and α-amylase enzymes with the IC_{50} values of 38.58 ± 0.56 and 60.51 ± 2.78 µg/mL, respectively (2). Further, hydro alcoholic flower extract revealed remarkable inhibitory effects on α-glucosidase (IC_{50}, 3780.09 ± 21.19 µg/mL) and α-amylase (IC_{50}, 360.68 ± 1.26 µg/mL) enzymes (22).

The protective effect of leaf petroleum ether extract was studied in STZ-induced diabetic rats (9). The extract reduced ALT levels significantly on days 7, 14 and 21 at 50-mg/kg (4.12, 10.23 and 13.47 U/L) and 100-mg/kg (10.79, 17.73 and 23.46 U/L) doses. The antidiabetic activity of root 95% ethanol extract was evaluated in STZ-induced rats (3,7). Treatment with 100 and 200mg/kg doses significantly reduced blood serum glucose levels to 169.83 ± 2.11 and 131.37 ± 2.07 mg/dL on day 21 respectively. The efficacy of active fractions of leaf extracts on blood serum glucose and lipid contents was evaluated in healthy and diabetic rats (26). The ethanol extract's active fraction significantly decreased fasting blood glucose (161.2 ± 7.1 mg/dL), cholesterol (87.6 ± 2.6 mg/dL), triglyceride (64.6 ± 7.5 mg/dL), and increased high-density lipoprotein (46.7 ± 2.3 mg/dL) levels on day 21 in diabetic rats. Hot aqueous leaf extract also showed notable antidiabetic activity (25). Biofabricated silver nanoparticles from aqueous flower extracts inhibited α-amylase and α-glucosidase enzymes significantly (IC_{50}:10.62 ± 0.22 and 6.49 ± 0.03 µg/mL, respectively) (6). Zinc nanoparticles synthesized from leaf extract significantly decreased glucose level (138mg/dL) at 100mg concentration (27).

Antimicrobial activity

The antibacterial efficacy of leaf extracts using ethyl acetate, hydroalcoholic, and aqueous solvents was investigated against pathogenic bacteria (2). At concentrations of 750 µg/mL, the extracts exhibited significant inhibition of *Escherichia Coli* (27.8 ± 0.83 mm), *Bacillus Subtilis* (22.6 ± 0.54 mm), and *Proteus Vulgaris* (21.0 ± 1.01 mm). Moreover, a separate study revealed that the methanolic extract from flowers effectively inhibited *E. Coli* (11.2 ± 0.141 mm) and *Staphylococcus Aureus* (12.15 ± 0.106 mm) at 500 mg/mL doses (28).

The chloroform extract demonstrated potent antimicrobial activity at a dose of 66.66 µg/mL against *Pseudomonas aeruginosa* and *S. aureus* (23). The antimicrobial potential of methanol, acetone, chloroform, and acetonitrile extracts from the whole plant was assessed against various bacterial strains. Among them, the acetone extract exhibited maximum inhibitory effect (100%) on *S. aureus* (29). In a separate study, antimicrobial activity was observed for bio-fabricated silver nanoparticles using aqueous flower extracts, with inhibition zones of 10.67 ± 0.44 mm (*P. aeruginosa*), 9.33 ± 0.44 mm (*E. coli*), 14.67 ± 0.60 mm (*B. subtilis*), and 15.67 ± 0.60 mm (*S. aureus*) (6). Similarly, silver and zinc oxide nanoparticles synthesized from leaf extracts demonstrated similar effects against *P. aeruginosa, S. aureus, S. epidermis, E. coli,* and *Enterobacter aeurogens* (27, 30).

Analgesic activity

Taraxerol, isolated from the petroleum ether extract of fruits, was evaluated for its analgesic activity in Swiss mice using the acetic acid writhing model (8). At a dose of 5 mg/kg, the compound exhibited a noteworthy inhibition of writhing (45.42%), which was statistically significant ($P<0.001$). In comparison, the standard aspirin demonstrated a higher inhibition of writhing (66.57%) but at a concentration of 300 mg/kg.

Anti-inflammatory activity

Taraxerol isolated from petroleum ether extract of fruits was evaluated for anti-inflammatory activity through acute paw edema model in Wistar rats. The compound at 5 mg/kg dose significantly reduced the paw volume (82.52%), which was comparable to the standard indomethacin (88.83%) (17).

The methanolic leaf extract and its fractions were assessed for anti-inflammatory efficacy in the carrageenan -induced acute inflammation model. The petroleum ether and chloroform fractions demonstrated 60% and 66% inhibition respectively at a 100 mg/kg dose, while the positive control indomethacin exhibited 73% inhibition at 10.0 mg/kg (31). Similarly, the methanol extract of the entire plant significantly reduced paw edema, showing 71.7% and 55% inhibition at 300 and 150 mg/kg doses, respectively, compared to the standard indomethacin, which resulted in 80.6% inhibition at 10 mg/kg (32). Another study evaluating the anti-inflammatory activity of leaf aqueous and acetone extracts found higher activity with writhing inhibition of 54.27% and 49.88%, respectively (25).

Anticancer activity

The *in vitro* cytotoxic activity of the 95% methanol extract of leaves was evaluated against Michigan Cancer Foundation-7 (MCF-7) and Henrietta Lacks (HeLa) cell lines within a concentration range of 62.5 to 1000 µg/mL (33). The extract demonstrated a CTC50 of 210 µg/mL against HeLa cells, indicating moderate cytotoxicity against MCF-7 cells (CTC50 below 1000 µg/mL). Moreover, a separate study revealed a remarkable toxicity of the leaf methanol

extract against Ehrlich Ascites Carcinoma (EAC) cells (IC50 of 85.51 ± 4.07 µg/mL), resulting in a significant reduction in packed cell volume, viable cell count, and tumor volume, along with an increase in non-viable cell counts in EAC-induced mice (34).

Antiulcer activity

Antiulcer activity of *W. volubilis* and *Tabebuia rosea* leaf extracts using aspirin and ethanol-induced gastric ulcer models in Wistar rats was assessed. The methanol extract of *W. volubilis* exhibited significant reduction in ulcer index (3.38 ± 0.03 and 5.09 ± 0.04) and increased percent protection (70.58% and 61.26%) at an oral dose of 500 mg/kg (35).

Bone and cartilage tissue engineering

The phytochemicals, hexadecanoic acid, octadecanoic acid, and N,N-diisopropyl (2,2,3,3,3-pentafluoropropyl) amine, derived from leaf extract were incorporated into polycaprolactone nanofibres (36). Both meniscus and osteoblast cells exhibited a proliferation rate of over 90% with increased incubation time. The DNA content of cells in both cases increased by 152% and 148%, respectively, indicating their potential as scaffolds for bone and cartilage engineering applications.

Larvicidal activity

The methanolic leaf extracts of *Bombax malabaricum* and *W. volubilis* were evaluated for their larvicidal activity against different instars larvae of *Culex quinquefasciatus*. Both plant leaf powders, at concentrations ranging from 0.1% to 0.5%, demonstrated significant larval mortality at 24, 48 and 72 hours post-treatment (37). However, the methanolic extract of *B. malabaricum* exhibited higher larvicidal activity (LC_{50} 48.85 ppm) compared to *W. volubilis* (LC_{50} 56.97 ppm) after 24 hours of exposure (37).

Anthelmintic activity

Anthelmintic activity of methanolic leaf extract was performed against the parasitic trematode *Paramphistomum explanatum*. The extract at 100 mg/mL significantly ($P < 0.001$) paralyzed and killed the trematodes at 8.83 ± 0.54 and 10.67 ± 0.61 min respectively. Authors could observe the absence of grooves and losing the sharpness of mouth with disrupted texture of tegument (38).

Chondroprotective activity

The Polyoxypregnane glycoside (PPG), an active compound derived from *W. volubilis* extract was found to effectively attenuate IL-1β-induced activation of human articular chondrocytes and mitigate damage to the extracellular matrix (39). At doses ranging from 6.25–25 µM, PPG demonstrated a reduction in chondrocyte hyaluronan release in response to Interleukin-1β (IL-1β), while also inhibiting Nuclear factor kappa B (NF-κB) activation, MMPs gene, and protein expression in these cells (39). In a separate study, the chondroprotective effect of PPG obtained from the active ethyl acetate extract of *W. Volubilis* roots was investigated (18). Remarkably, PPG led to a 1.06-fold decrease in S-GAG release from chondrocytes, and this effect was completely prevented at a dose of 25 µg/mL (18).

Neuroprotective activity

The neuroprotective effect of a mixture of PPG and sapogenin glycosides (WVSM) isolated from roots was investigated (40). The results demonstrated that pretreatment with PPG (5 and 10 mg/kg) and WVSM (50 mg/kg) significantly reduced cerebral infarction volume and brain edema. Moreover, the PPG-treated group exhibited increased superoxide dismutase activity, nitric oxide, and methylenedioxyamphetamine content in serum and the ischemic section. In another study, the nootropic potentiality of the alcoholic leaf extract (250 and 500 mg/kg doses) was screened in normal and stressed rats (41). The administration of different concentrations (250 and 500 mg/kg) of the extract in normal rats dose-dependently enhanced the cognition rate.

Anti-asthmatic and expectorant potential

The methanol extract from aerial parts was assessed for its anti-asthmatic and expectorant activity through *in vivo* broncho-protective experiments (42). The results revealed a considerable inhibition percentage of contraction (39.41±0.38%; $P < 0.01$) at the 100 µg/mL dose. During the *in vivo* anti-asthmatic study, the extract exhibited latency scores of 120.48 ± 3.8 and 140.50 ± 5.5 seconds at 200 and 400 mg/kg doses, respectively. Notably, the activity of the extract at the 400 mg/kg dose showed even more significance in tracheal phenol red output, which is related to the broncho-protective test.

Anti-leishmanial activity

The compound taraxerone isolated from petroleum ether extract of dried fruits was analysed against promastigotes of *Leishmania donovani*. The compound inhibited the growth of *Leishmania promastigotes* (51.34% to 90.8% lysis) with the dose range from 3-30 µg/mL, with the corresponding IC_{50} of 3.18 µg/mL (43).

Anti-leukemic activity

In vitro anti-leukemic activity of aqueous (WVA), ethyl acetate (WVE) and n-butanol (WVB) fractions from crude methanol extract of leaves were investigated against U-937, K-562 and HL-60 cell-lines (44). Among all, WVB and its isolated compound Kaempferol-3-O-[α-L-rhamnopyranosyl-(1-4)-O-α-L-rhamnopyranosyl-(1-6)-O]-β-D-glucopyranoside (WVP) showed remarkable anti-leukamic activity with IC_{50} of 10.8, 13.2 and 13.5 µg/mL respectively.

Discussion

W. volubilis is considered an important component in Indian traditional systems of medicine, particularly Ayurveda and folk medicines for treating various diseases. This review detailed its different uses, phytochemical constituents, and pharmacological properties in the past 50 years. Several studies have reported diverse chemical constituents from different plant parts, including terpenes, pregnane glycosides, polyhydroxy pregnanes, flavonoids, and polyphenols. Compounds such as β-sitosterol, kaempferol, dregealol, dregeanin, apigenin, luteolin, quercetin, rutin, taraxerol, ursolic acid, oleanolic acids, and volubiloside A, B

and C were found in varying concentrations in different extracts. The available *in vitro* and *in vivo* experimental evidence suggests that the plant has a wide range of pharmacological properties. These include antimicrobial, antioxidant, antidiabetic, analgesic, anti-inflammatory, anticancer, anthelmintic, and antiasthmatic activities, making it applicable in pharmaceutical, food, and agriculture industries. Furthermore, toxicity studies have analyzed the safety levels of various plant extracts intended for use in these industries (3, 9, 45). Synergistic effects of phenolic and flavonoid constituents in different extracts were observed in antioxidant and free radical scavenging activities (6, 22). These extracts decrease nitric oxide (NO) production, inhibiting the synthesis of prostaglandins and other mediators that cause inflammations (31), which may explain their effective anti-inflammatory actions. The molecular mechanisms of bioactive compounds and nanoparticles synthesized from various plant parts are widely studied to determine their validity in traditional medicine. The reverse enzymatic activities of superoxide dismutase, catalase, glutathione peroxidase, and glutathione reductase were studied to prove the anticataractogenic activity of the triterpenoid aglycone compound, drevogenin D, using a selenite-induced cataractous model (5). Similarly, the analgesic and anti-inflammatory activity of the compound teraxerol, isolated from the fruit's petroleum ether extract was assessed by inducing writhing reflex with acetic acid and acute carageenan-induced paw edema, respectively (8). Furthermore, the therapeutic potential of *W. volubilis* flowers as a natural antioxidant and antidiabetic agent containing gallic acid, ferulic acid, rutin, ellagic acid, quercetin, and cinnamic acid was studied to understand their possible role in controlling postprandial hyperglycemia (22). The mechanism of the antileukemic activity of the compound kaempferol 3-O-[α-L-rhamnopyranosyl-(1-4)-O-α-L-rhamnopyranosyl-(1-6)-O]-β-D-glucopyranoside, isolated from the methanolic leaf extract, was analyzed through flow-cytometric analysis, which showed the anti-leukemic effect with IC_{50} values of 10.8, 13.2 and 13.5 (mg/mL in K562, HL-60, and U937 cells, respectively (44). However, detailed pharmacological activities and molecular mechanistic studies of other important compounds such as dregealol, volubilol, volubilogenone, dreageoside A11, hoyacarnoside G, stavaroside H, volubiloside C, 17β-marsdenin, drevoluoside O, P and Q are still lacking. The combinational effects of multiple chemical constituents on various cell signaling pathways need to be explored to better understand the traditional uses and modern pharmacological applications of herbal medicine.

Conclusion

W. volubilis has been an important medicinal plant in Indian traditional medicine for a long time. While synthetic drugs exist for treating diseases, there is growing interest in natural drugs and their mechanisms of action due to their synergistic effects and diverse pharmacological activities. The plant contains promising compounds like dregeanin, drevogenin D, iso-drevogenin P, dreageoside A11, hoyacarnoside G, 17α-marsdenin, taraxerol, kaempferol, stavaroside H, 17β-marsdenin, and volubiloside A, B and C. It has shown potential as a larvicidal, anthelmintic, chondroprotective, and antibacterial/antifungal agent. However, quality control parameters and clinical trials are crucial to ensure its therapeutic efficacy.

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Authors' contributions

PB and SJ conceptualized the work plan, compiled the data and wrote the manuscript. SGG and HVH carried out the research analysis, reviewed and approved the manuscript.

Compliance with ethical standards

Conflict of interest: Authors declare no competing interests.

Ethical issues: None.

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