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Exploring the therapeutic potential of *Xanthium strumarium* L: A review of its phytoconstituents and pharmacological activities

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Abstract
Xanthium strumarium is an annual herb of family Asteraceae found in the temperate zone, subtropical and Mediterranean regions along the roadsides, riverbanks, plains, hills, garbage sites and agricultural land. It is used for the treatment of malaria, bacterial and fungal infections, tuberculosis, epilepsy, smallpox, cancer, leukoderma, excessive salivation, and rheumatism. In traditional Chinese Medicine system, dried fruit of the *Xanthium strumarium* is used treat rheumatism, bacterial infections, headaches, gastric ulcers, urticaria, rhinitis, nasal sinusitis, and arthritis. In Ayurveda, the leaves decoction is used to cure malaria and urinary tract problems whereas the decoctions of root is utilized to treat diarrhea, constipation, stomach issues and dysentery. The species is rich in various bioactive compounds like sesquiterpene lactones, flavonoids, steroids, phenylpropenoids, glycosides, coumarins, lignans, alkaloids, saponins. The major phytochemical constituents are xanthatin, xanthiumin, xanthinin, tometosin, β-sitosterol, stigmasterol, caffeic acid, ferulic acids, quercetin atractyloside and carboxyatractyloside.

Keywords: *Xanthium strumarium*, medicnal plant, phytoconstituents, pharmacological properties

Introduction
Xanthium strumarium is indigenous to North and South America and is predominantly found in temperate regions, although it also occurs in subtropical and Mediterranean climates. It is commonly distributed in countries such as Pakistan, Australia, India, South Africa, the United States, and Turkey, where it thrives in diverse habitats including agricultural lands, roadsides, riverbanks, grasslands, parks, and urban environments (Waheed *et al*., 2024) [29]. In India, it is recognized as a common weed with significant ecological and agricultural implications. The plant is known by various vernacular names, including cocklebur, clotbur, woodgarie bur, ogora, godrin, sankhanulla, ghagra, umattai, marulutige, chota dhatura, and muruluumatti (Chavan and Kulkarni, 2021) [3].

Various parts of *X. strumarium*, including leaves, roots, stems, and seeds are widely utilized in traditional medicine for the treatment of numerous ailments including rheumatism, arthritis, bacterial and fungal infections, gastric ulcers, urticaria, nasal sinusitis, headaches, diabetes, and inflammatory disorders (Khan *et al*., 2020) [10]. One of the most well-known herbal preparations derived from the fruit is Cang-Er-Zi, which has been used for centuries, particularly for treating headaches and rhinitis. In India, where it is commonly referred to as chotagokhru or chotadhatura, it is also used for treating biliousness, epilepsy, leucoderma, insect bites, and hemicrania (Fan *et al*., 2019; Nayak *et al*., 2026) [4, 15]. The fruit resembles a cow's toe, which is the basis for its vernacular name "chotagokhru." *X. struamrium* is used to cure rhinitis, chronic wounds, insect bite, skin injury, bacterial infections, diabetes, gastric ulcers, arthrisis, nasal sinusitis, headache, rheumatoid arthrisis (Zhao *et al*., 2025; Jiang *et al*., 2022) [7, 35]. The decoction of plant is used in Ayurveda for treatment of urinary tract disorders and malaria whereas fruit has been used to treat arthritis, headaches and nasal sinusitis, urogenital disorders, smallpox and hormonal disorders (Sultana *et al*., 2019 [24]; Xu *et al*., 2022). Despite its medicinal importance, *X. strumarium* contains a toxic compound, carboxyatractyloside (CAT), a sulphated diterpene glycoside that primarily affects the liver. This hepatotoxin is mainly present in seeds and cotyledonary seedlings and poses a significant risk to both humans and animals, particularly livestock such as cattle, pigs, sheep, and horses (Tolgyesi *et al*., 2025) [25].

Beyond its medicinal uses, the plant has shown potential in industrial and environmental applications. Extracts of *X. strumarium* have been explored as eco-friendly corrosion inhibitors for metals such as steel in acidic environments, including hydrochloric and sulfuric acid solutions commonly used in industrial processes (Khadom *et al*., 2025) [9]. Additionally, the non-edible oil extracted from its seeds has been utilized for biodiesel production using methods such as the Taguchi orthogonal array technique, making it a promising candidate for sustainable energy development without competing with food resources (Pawar *et al*., 2022) [16]. Furthermore, studies have demonstrated its role in phytoremediation, including the accumulation and translocation of heavy metals such as zinc, cadmium, copper, and lead, highlighting its potential in environmental cleanup strategies (Ullah *et al*., 2021) [27].

Morphology
Xanthium strumarium (fig. 1) is an erect herb that grows to a height of approximately 30-120 cm. The plant has a branched, sturdy, and fuzzy stem. The stem is round, slightly ribbed, and covered with short white hairs distributed over the surface. Its color ranges from green to brown or reddish-brown and often bears red or purple spots (Chavan *et al*., 2021) [3]. The leaves are light to bright green

in color and arranged alternately. They have long petioles and are triangular-ovate to suborbicular in shape, often appearing heart-shaped. The leaves are 5-15 cm long, usually with three lobes and prominent veins. Their margins are uneven with inconspicuous teeth. The plant is monoecious and flowers are arranged in heads forming short pedicellate axillary or terminal racemes (Chavan *et al*., 2021) [3]. Pistillate (female) flowers are found in the basal inflorescences, while staminate (male) flowers occur in the upper inflorescences (Zazharskiy *et al*., 2024) [33]. Male flower heads are spherical, located at the tips of branches, and consist of numerous tubular flowers with free stamens. Female flower heads contain two florets situated below the male heads. Each female floret consists of a pistil and lacks both calyx and corolla. These florets are enclosed within a spiny involucre, which later develops into the fruit (Ghannam *et al*., 2020) [5]. Olive-green flower heads occur in apical and axillary racemes; male heads are numerous, while female heads are spherical and covered with hooked bristles. The fruit (fig. 1) is an oblong bur, measuring about 1.3–3.5 mm, brown in color, and enclosed in a rigid involucre (Saluja *et al*., 2010) [19]. It contains two achenes and is characterized by hooked beaks and spiny hairs that facilitate dispersal by animals. The seeds are dark brown, oval, pointed at the tip, and about 1 cm long (Khan *et al*., 2020; Chavan *et al*., 2021) [10, 27]. Flowering generally occurs from July to August, while fruits ripen between September and October. In India, flowering typically starts from August to September. The discoid capitula are arranged in racemiform to spiciform patterns. Male capitula are oval-shaped and measure 3-5 mm in diameter, while female capitula are elliptic and measure 2–5 mm.

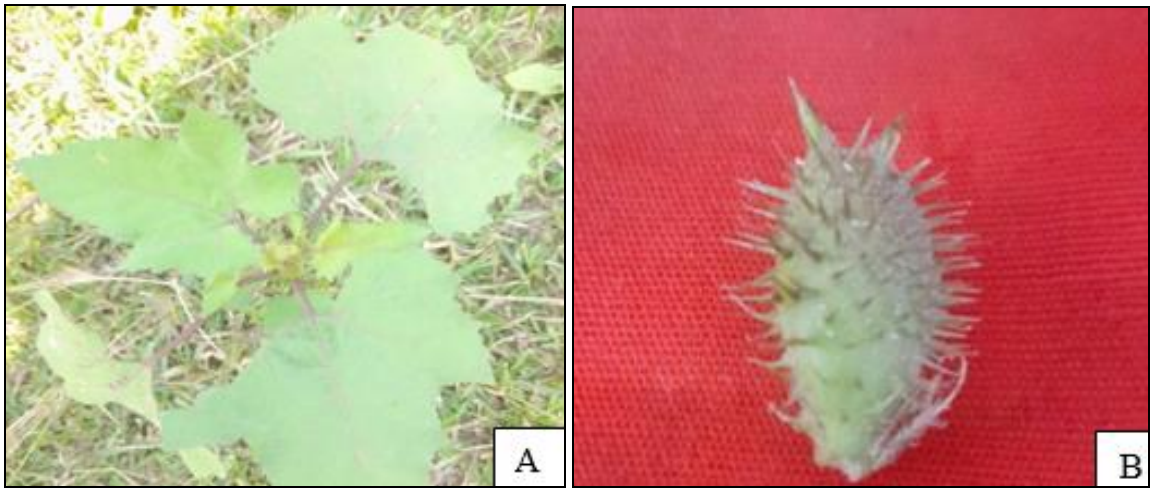


Fig 1: A. *Xanthium strumarium*, **B**. Fruit

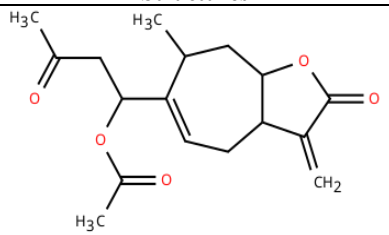
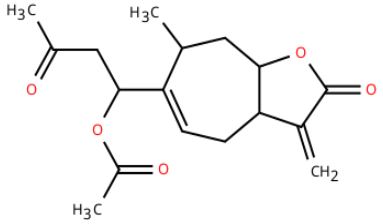
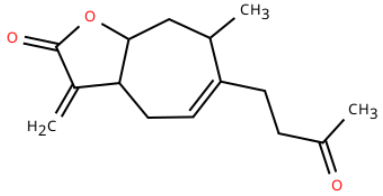
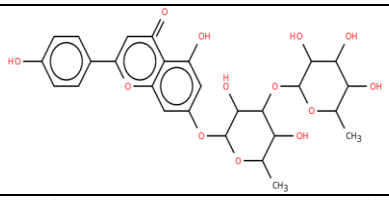
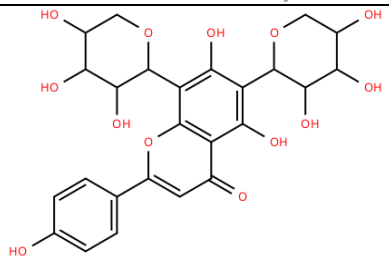
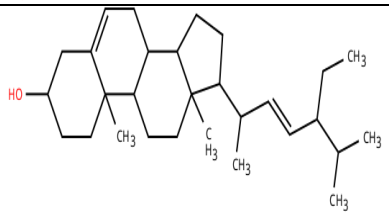
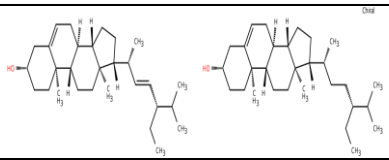
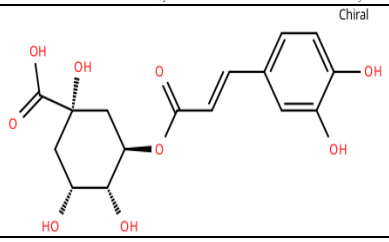
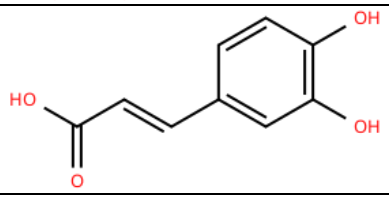
Table 1: Morphological features of *X. strumarium*

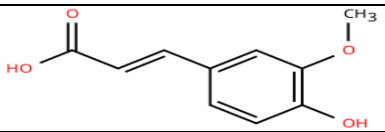
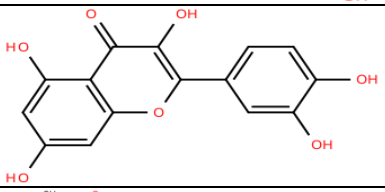
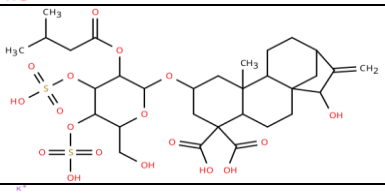
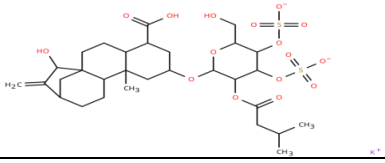
Part of plant	Morphology
Habitat	Warmer environment, along road sides, riverbanks, garbage sites and canal banks
Height	30 to 120 cm
Stem	Branched and sturdy, bears red spots and short hairs over the surface. Round and ribbed
Leaves	Green in colour, 5 to 15cm long, heart shaped and alternate phyllotaxy
Flower	Monoecious
Fruits	1.3 to 3.5 mm long, called bur, brown, and enclosed by hardened sac
Seeds	Dark brown, oval, 1cm long

Phytoconstituents

The phytochemical studies show the existence of phytochemicals (table 2) such as sesquiterpene lactones, alkaloids, flavonoids, steroids, tannins, phenylpropenoids, and glycosides (Shi *et al*., 2025) [22]. Sesquiterpenes includes xanthanin, xanthanol acetate, xanthumin, xanthnaol, isoxanthanol, xanthumanol deacetoxylxanthumin, xanthinosin and tomentosin obtained from the leaves and 11α, 13 dihydro-8-eoi-xanthatin isolated from the fruit (Zhang *et al*., 2022) [34]. The plant contains phytosterols such as stigmasterol and β-sitosterol (Fan *et al*., 2019) [4]. *X. strumarium* produce two novel triterpenoids are Methoxy-3β-O-(trans-p-coumaroyl)-lupane-28-oate and 3β-(3-furancarbonyloxy)-lupane-20-ol-betulinic acid and six recogonized triterpenoids were found to be 3β-O-trans coumaroylbetulinic acid, lupenyl acetate, hederagenin c, amaldulenic acid, crategolic acid, and methyl crategolate (Xu *et al*., 2022). 5,7,3′,4′-tetrahydroxyisoflavone, formononetin-7-O-β-D-glucopyranoside, kushenol O, 3-caffeoylquinic acid, and 6-hydroxykaempferol 3-glucoside, (3–7) yield two novel flavonoid glycosides which are 6-hydroxy-3-methoxy-apigenin 7-O-α-L-rhamnopyranoside and 3-hydroxyl-apigenin 8-C-β-D-xylopyranoside by mass spectrometery and Nuclear Magnetic Resonance. High performance liquid chromatography and diode array detection (HPLC-DAD) reveals the phenolic constituents, such as chlorogenic acid, epigallocatechin gallate, ferulic acid, naringenin, p-coumaric acid, rosamarinic acid, luteolin, kaempferol, rutin, caffeic acid, vanillic acid, protocatechuic acid and resveratrol (Yang *et al*., 2023) [32]. The other phytochemicals include isoprenoids such strumasterol and β-sitosterol, as well as phenolic substances such as ferulic acid, thiazolidinediones, caffeic acid, chlorogenic acids, 1,3,5-tri-O-caffeoyl quinic acid, 1,5-di-O-caffeoyl quinic acid, triterpenoid saponins, xanthanolide sesquiterpene lactones, monoterpene and sesquiterpene hydrocarbons which are bicyclic sesquiterpene lactones having a five-membered γ-butyrolactone ring attached to heptatomic carbocycle (Sharifi *et al*., 2015).

Table 2: Phytochemicals reported from *Xanthium strumarium*

Name of the compounds	Structures	Part of plant	References
Xanthatin		Leaves	Yang *et al*., 2023 [32]
Xanthinin		Leaves	Yang *et al*., 2023 [32]
Tomentosin		Leaves	Yang *et al*., 2023 [32]
6-hydroxy-3-methoxy-apigenin 7-O-α-L-rhamnopyranoside		Leaves	Jiang *et al*., 2022 [7]
3-hydroxyl-apigenin 8-C-β-D-xylopyranoside.		Leaves	Jiang *et al*., 2022 [7]
Stigmasterol		Roots	Fan *et al*., 2019 [4]
β-sitosterol		Roots	Fan *et al*., 2019 [4]
Chlorogenic acids		Leaves	Fan *et al*., 2019 [4]
Caffeic acid		Leaves	Fan *et al*., 2019 [4]

Ferulic acids		Leaves	Fan *et al*., 2019 [4]
Quercetin		Leaves	Lalhlenmawia, 2022
Carboxyatractyloside		Seed	Tolgyesi *et al*., 2025, Van Kiem *et al*., 2020
Atractyloside		Seed	Van Kiem *et al*., 2020.

Pharmacological Profile

X. strumarium is biologically significant medicinal plant and several studies have reported the pharmacological properties such as antifungal, antibacterial, antioxidant, antimalarial *etc*.

Antioxidant

The ferric-reducing capacity and 2,2-diphenyl-1-picrylhydrazyl (DPPH) rassay of leaves and stem bark extracts of *X. strumarium* exhibited radical scavenging activity ranging from 18.06 ± 0.3 to 85.67 ± 11.54% and 9.13 ± 0.54 to 84.18 ± 0.92%, at concentrations between 200 and 3000 µg/ml. In the same concentration range, the ascorbic acid showed radical scavenging activity ranging from 56.64 ± 1.26 to 88.98 ± 0.31%. The study further reported that at concentrations above 3000 µg/ml, the hexane, chloroform, and methanol leaf extracts along with the chloroform stem bark extract shows higher radical scavenging activity (Pillai *et al*. 2023) [17]. The acetone extract exhibited the strongest antioxidant activity, with DPPH, 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS), and Ferric reducing/antioxidant power (FRAP) values of 442.81 ± 5.21, 234.34 ± 5.25, and 337.70 ± 6.14 mg Trolox/g, respectively whereas the methanol and ethanol extracts showed less antioxidant activity. Higher total phenolic and flavonoid content was associated with stronger antioxidant activity, indicating the important role of these phytochemicals reducing oxidative stress (Beyatli, 2025). Nayak and Pattnaik (2024) [2, 14] evaluated the antioxidant activity of *X. strumarium* different bioactive fractions (F1, F2, F3 and F4) separated after flash chromatography by DPPH, ABTS, Hydrogen Peroxide (H_2O_2), and Nitric Oxide (NO_2) scavenging assays. Fractions F2 and F3 exhibited the strongest antioxidant activity having IC50 values of 2.59 ± 0.07 and 1.85 ± 0.05 µg/mL against DPPH, 1.84 ± 0.04 and 2.16 ± 0.025 µg/mL against ABTS, 2.31 ± 0.05 and 1.66 ± 0.04 µg/mL against H_2O_2 and 4.62 ± 0.042 and 3.80 ± 0.04 µg/mL against NO_2. The antioxidant activity by DPPH assay of methanolic extract exhibited strong free radical scavenging potential with an IC50 value of 55.37 ± 0.61 µg mL^{-1} whereas ethanolic leaf extract has antioxidant activity ranging from moderate to significant. The findings suggested that the antioxidant potential is due to the bioactive phytochemicals capable of decreasing oxidative stress (Singh *et al*. 2022). Ly *et al*. (2021) [3, 23] evaluated the antioxidant activity of aerial part of *X. strumarium* by DPPH assay and the IC50 value was 184.13 µg/mL. Similarly, Kanthal *et al*. (2022) [8] study reported that the aerial part extract exhibited significant antioxidant activity by DPPH having an IC50 value of 17.88 µg/mL, whereas the ascorbic acid showed an IC50 value of 7.12 µg/mL.

Antidiabetic

Shaheen *et al*., (2023) [20] investigated the antidiabetic activity of *X. strumarium* leaves in different solvent such as water, ethyl acetate, ethanol and petroleum ether. Swiss albino mice were utilized for antidiabetic treatment and injection of alloxan monohydrate were given to cause diabetes at a level of 120 mg/kg body weight. The study reported that by giving the extract fractions directly to diabetic mice for 18 days at an amount of 400 mg/dl body weight decreased the blood glucose level. The findings suggest that ethyl acetate fraction shows the greater antidiabetic activity. The blood glucose level reduced 38 % from 353 ± 10.6 mg/dl on day 1 to 220 ± 25.5 mg/dl on day 18 when the ethyl acetate fraction was given to diabetic mice whereas the ethanol fraction reduced the blood glucose level to 266 ± 15.6 mg/dl followed by petroleum ether and water. The ethyl acetate extract exhibited the maximum antidiabetic activity by decreasing the blood glucose level. The α-glucosidase inhibition of *X. strumarium* fruit extract shows an IC_{50} value of 15.25 µg/ml. α-glucosidase activity reduce the absorption of glucose and the digestion of the carbohydrates whereas the high phenolic and flavonoid content was associated with high α-glucosidase activity inhibition action (Ingawale *et al*., 2018). Mouhamad *et al*., (2022) [6, 13] examined that the aerial portion extract when given to diabetic rats, decreases the blood glucose level and suggesting a dose-dependent hypoglycemic effect. Caffeic acid derivatives, phenols and flavonoids improve insulin action, increase glucose utilization and decreases oxidative stress linked to diabetes which helps in antihyperglycemic effect.

Anticancer

The anticancer potential of the aerial parts of *X. strumarium* was evaluated against human liver cancer cell line (HepG2). *X. strumarium* shows significant antiproliferative activity against HepG2 cells, with an IC_{50} value of 81.69 µg/mL. The cytotoxic effect was determined using the Sulforhodamine B (SRB) assay, a widely accepted method for assessing cell growth inhibition in cancer research (Ly *et al*., 2021). Tong *et al*. (2020) [26] indentified the phytochemical compounds from the fruits of *X. strumarium* and evaluated there antitumor activity against four human cancer cell lines. The compounds isolated were (7S,8R)-threo-1′- [3′-hydroxy-7-(4-hydroxy-3,5-dimethoxyphenyl)-8-hydroxymethyl-7,8 dihydrobenzofuran] acrylaldehyde (compound 1), rel-(2α,3β)-7-O-methylcedrusin, erythro-guaiacylglycerol-β-coniferyl, erythro-guaiacylglycerol-8-O-4′-(coniferyl alcohol) ether, cirsilineol, and isoorientin. Compound 1, a newly discovered neolignan, exhibited the highest cytotoxicity with an IC_{50} value of 10.2 ± 1.2 µM, while compound 3 showed an IC_{50} value of 18.3 ± 1.6 µM against HepG2 cells. Erythro-guaiacylglycerol-β-coniferyl (compound 3) also has significant selectivity for HepG2 cells with an IC_{50} value of 18.3 ± 1.6 µM. Finally, erythro-guaiacylglycerol-8-O-4′-(coniferyl alcohol) ether (compound 5) displays moderate cytotoxic activity against MCF-7 cells with an IC_{50} value of 20.5 ± 1.3 µM. Aranjani *et al*. (2013) [1] determined the anticancer potential of *X. strumarium* using both *in vitro* and *in vivo* models. The chloroform and hexane fractions from roots, leaves, and fruits exhibited significant cytotoxic activity against cancer cells. In Dalton's Ascitic Lymphoma (DLA)-bearing mice, these fractions reduced tumor growth and tumor volume. Treatment also increased the survival time of tumor-bearing animals and improved hematological parameters. The study demonstrated that *X. strumarium* possesses promising antitumor activity and may serve as a source of potential anticancer agents.

Antimicrobial

Sharifi-Rad *et al*. (2015) [21] reported that the essential oil of *X. strumarium* exhibited strong antimicrobial activity against *Staphylococcus aureus* and *Bacillus subtilis*, with minimum inhibitory concentrations (MICs) of 0.5 ± 0.1 µg/mL and 1.3 ± 0.0 µg/mL. At 100 µg/mL, the essential oil produced zones of inhibition (ZOI) of 124.4 mm against *S. aureus*, 98.5 mm against *B. subtilis*, 58.1 mm against *Klebsiella pneumoniae*, and 64.4 mm against *Pseudomonas aeruginosa*. The antimicrobial activity of acetone, methanol, and ethanol extracts of *X. strumarium* roots was determined against *Enterococcus faecalis, S. aureus, Escherichia coli*, *P. aeruginosa*, and *Candida albicans*. The acetone extract exhibited a strongest antimicrobial activity, showing the lowest minimum inhibitory concentration (MIC) values against all tested microorganisms. In contrast, methanol and ethanol extracts shows moderate activity, with MIC values of approximately 1250 µg/mL against *E. coli* and *P. aeruginosa* and 2500 µg/mL against *S. aureus*. The enhanced activity of the acetone extract was attributed to its higher content of phenolic compounds and flavonoids (Beyatli, 2025). Qader *et al*. (2022) [2, 13] determined the antibacterial activity of the ethanolic extract of *X. strumarium* against *S. aureus*, *B. subtilis*, *Klebsiella* spp., and *P. aeruginosa*. The strongest antibacterial activity was observed against *P. aeruginosa* and *Klebsiella* spp., while *S. aureus* showed the lowest susceptibility. Wankhade (2025) [30] reported the antimicrobial activity of *X. strumarium* by agar well diffusion method. The acetone extract showed measurable zones of inhibition (ZOI) against tested microbes. The highest ZOI was observed against *Bacillus subtilis* (17 mm), followed by *S. aureus* (15 mm) and *Pseudomonas aeruginosa* (13 mm). For antifungal activity, moderate inhibition was recorded against *Candida albicans* (14 mm) and *Aspergillus niger* (12 mm). Zazharskyi *et al*. (2024) [33] studied the antibacterial effectiveness of ethanolic extract of fruit, leaves, stems and roots from *X. strumarium* against 13 bacterial species. The leaf extract exhibited the highest antibacterial activity against *Bacillus subtilis* with a 17.6 mm zone of inhibition and *Enterococcus faecalis* with a 15.4 mm zone of inhibition. The fruit extract also demonstrated high antibacterial activity against *Bacillus subtilis* (15 mm), *Staphylococcus aureus* (14.2 mm), *Klebsiella pneumoniae* (12.8 mm) and *Escherichia coli* (11.9 mm). The root extract inhibited *Bacillus subtilis* (15 mm) and *Staphylococcus aureus* (11.7 mm.) growth. The results indicated that the leaves and fruit extracts exhibited the highest antibacterial effectiveness as compared to other parts of the plant.

Conclusion

X. strumarium is one of the medicinal therapeutic herb rich in phytoconstituents such as sesquiterpene lactones, flavonoids, steroids, phenylpropenoids, glycosides, alkaloids, tannins, triterpenoids, and saponins which are responsible for pharmacological activities such as antioxidant, antifungal, anticancer *etc*. Experimental studies, both *in vitro* and *in vivo,* have demonstrated its potential against various cancer cell lines and pathogenic microorganisms, supporting its traditional medicinal uses. Future research studies must focus on isolating bioactive compounds from various parts of the plant and must carrying out clinical trials to confirm effectiveness of the plant in treating the diseases.

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