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Medicinal Plants of the Mardan Region: Phytochemicals and Pharmacological Insights

Adnan Khan[1], Faryal Naseem Shah[1], Javeria Haqnawaz[1], Ihlam Khan[1], Aneesa Bakhtiar[1], Zaheerud Din[1]

[1]Department of Biotechnology, Abdul Wali Khan University Mardan, KP, Pakistan.

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Correspondence to: Adnan Khan, Department of Biotechnology, Abdul Wali Khan University Mardan, KP, Pakistan.
Email: adnankhandir555@gmail.com

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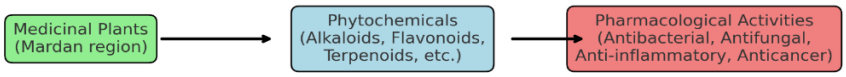
ABSTRACT

Medicinal plants have long been recognized as valuable sources of bioactive compounds with therapeutic potential. This review highlights nine medicinal plants from the Mardan region of Pakistan, emphasizing their phytochemical composition and reported pharmacological activities. Literature was collected from scientific databases and ethnobotanical surveys, with a focus on studies reporting bioactive compounds and experimental validation of traditional uses. The selected species were found to contain diverse classes of phytochemicals, including alkaloids, flavonoids, terpenoids, tannins, and saponins. These metabolites contribute to a wide spectrum of biological activities, particularly antimicrobial, anti-inflammatory, anticancer, and antidiabetic effects. Antimicrobial activity was the most consistently reported, while anticancer and metabolic disorder–related studies remain limited. The analysis underscores the therapeutic promise of local flora but also highlights research gaps, such as insufficient clinical validation and lack of mechanistic studies. Future investigations should prioritize compound isolation, mode-of-action studies, and sustainable utilization. Overall, the findings demonstrate that the medicinal plants of Mardan represent an underexplored reservoir for novel drug discovery and pharmacological innovation.

Graphical Abstract



INTRODUCTION

Medicinal plants have served as a cornerstone of traditional and modern healthcare systems for centuries[1]. Globally, an estimated 80% of the population relies in part on herbal remedies for primary health care, particularly in low- and middle-income countries where access to modern pharmaceuticals may be limited (World Health Organization, 2013). The pharmacological value of these plants is largely attributed to secondary metabolites, including alkaloids, flavonoids, terpenoids, tannins, and phenolic compounds, which exhibit a wide range of biological activities such as antimicrobial, antioxidant, anticancer, and anti-inflammatory effects [2].

In Pakistan, the ethno-pharmacological heritage is particularly rich due to the country's diverse ecological zones and cultural practices[3]. The Khyber Pakhtunkhwa (KPK) province, and specifically the Mardan region, is home to a variety of medicinal plant species traditionally used to treat infectious diseases, metabolic disorders, and inflammatory conditions[4]. Despite their widespread use, systematic scientific evaluation of these plants remains limited, and much of the traditional knowledge is at risk of being lost without proper documentation and validation.

The review brings together existing knowledge on nine medicinal plants from the Mardan region, highlighting their phytochemical components and the pharmacological activities that support their traditional uses. Grouping plants by their reported biological activities allows this review to highlight their therapeutic potential while also identifying key research gaps.

METHODS

To prepare this review, published studies on medicinal plants from the Mardan region of Pakistan were systematically examined. Data sources included PubMed, Google Scholar, ScienceDirect, Scopus, and local ethnobotanical survey reports. The search was carried out between January and June 2025 using combinations of the following keywords: *"medicinal plants," "Mardan," "Khyber Pakhtunkhwa," "Pakistan," "phytochemicals," "pharmacological activities," "ethnobotany," "antimicrobial," "anti-inflammatory," "anticancer,"* and *"antidiabetic."*

Inclusion criteria were: (i) studies reporting phytochemical composition or pharmacological activity of plants collected from the Mardan region or closely related species from Pakistan; (ii) articles published in peer-reviewed journals, theses, or reliable ethnobotanical survey documents; and (iii) studies presenting experimental evidence or well-documented traditional uses. Exclusion criteria were: (i) duplicate records across databases, (ii) studies lacking sufficient phytochemical or pharmacological data, and (iii) unpublished or non-academic sources.

A total of nine medicinal plant species were selected for this review based on their frequency of use in traditional medicine, reported bioactive compounds, and availability of pharmacological studies. Information was extracted on phytochemical classes, experimental models, and validated pharmacological activities. The collected data were organized by biological activity and presented in a consolidated table for clarity.

Phytochemical Overview

Medicinal plants owe much of their therapeutic value to secondary metabolites, which serve as protective compounds in nature but act as bioactive agents in humans[5]. Among the most important classes found in the flora of the Mardan region are **alkaloids, flavonoids, terpenoids, tannins, saponins, and phenolic compounds[6]**.

Alkaloids: Nitrogen-containing compounds that are derived from plants and known to exhibit antimicrobial, analgesic, and anticancer properties[7]. Many act directly on enzymes or receptors, and contribute to traditional remedies and modern drugs[5].

Flavonoids, a group of extensively found polyphenolic compounds, are known primarily for their antioxidant capacity[8]. They also have anti-inflammatory, cardio protective and anticancer effects by scavenging free radicals and decreasing oxidative stress[9].

Terpenoids are among the structurally most diverse of the known plant metabolites[10]. They show antimicrobial, anti-inflammatory and anticancer effects and they are as well precursors of some important biomolecules; hormones and vitamins[11].

Tannins are astringent polyphenols with antimicrobial and wound-healing properties[12]. They are also known to be useful in antidiabetic and anti-diarrheal uses[13].

Saponins make soap-like froth in solution and have immune-boosting, cholesterol-lowering and anticancer properties[14]. They are also being explored more and more as adjuvants in vaccine design[15].

Phenolic compounds, including simple phenols and complex polyphenols, exert powerful antioxidant properties[16]. Consumption of them has been associated with lower risk of cardiovascular diseases, cancer and neurodegenerative diseases[17].

Thus collectively, these groups of phytochemicals are responsible for the biochemical rationale for the diverse range of pharmacological properties in medicinal plants of Mardan. Their participation can explain Traditional Uses variability and the increasing pharmacological evidence of it.

Figure 1

Major phytochemical classes identified in medicinal plants of the Mardan region and their associated therapeutic effects. Alkaloids, flavonoids, terpenoids, tannins, saponins, and phenolics contribute to a wide range of pharmacological activities.

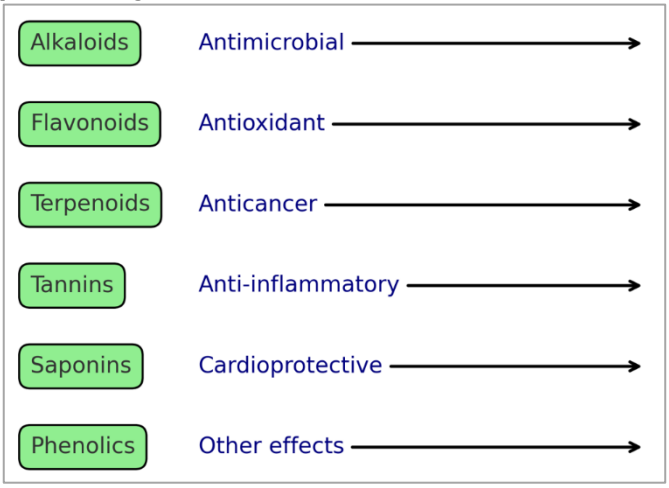
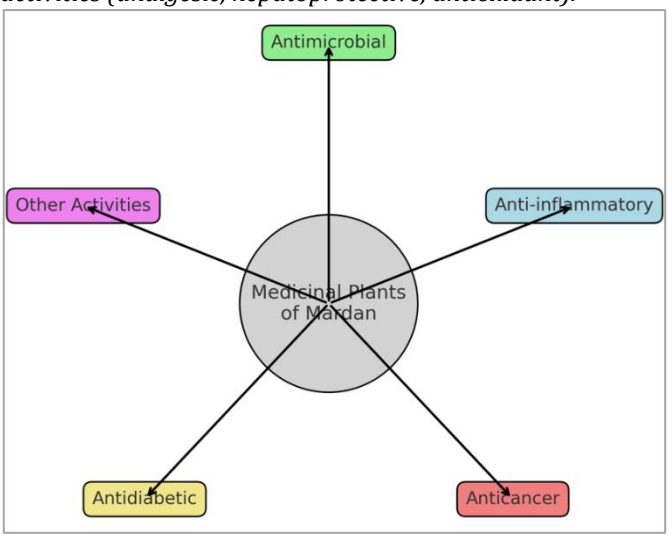


Figure 2

Pharmacological activities of medicinal plants from the Mardan region. Documented effects include antimicrobial, anti-inflammatory, anticancer, antidiabetic, and other activities (analgesic, hepatoprotective, antioxidant).



Antimicrobial Plants

Several medicinal plants from Mardan have been traditionally used to treat infections and have shown antimicrobial activity in experimental studies.

Cannabis sativa (C. sativa) has demonstrated inhibitory effects against a range of bacterial and fungal strains due to its rich content of terpenoids, flavonoids, and cannabinoids[18]. Extracts of this plant have been reported to act against *Staphylococcus aureus* and *Escherichia coli*, supporting its ethno-medicinal use for wound infections[19].

Mentha arvensis (M. arvensis) contains menthol and other volatile oils with broad-spectrum antimicrobial properties[20]. Studies indicate activity against both Gram-positive and Gram-negative bacteria, making it valuable in respiratory and gastrointestinal infections[21].

Sonchus asper (S. asper) has demonstrated antibacterial activity, largely attributed to its alkaloids and phenolic compounds[22]. Extracts of this plant inhibit several common pathogens, supporting its traditional use in the treatment of infections.

Similarly, ***Solanum nigrum (S. nigrum)*** contains alkaloids such as solanine and solasodine, along with flavonoids and glycoproteins, which contribute to its antimicrobial effects[23]. The consistent antimicrobial activity reported across multiple species highlights the potential of Mardan's flora as a source of new antibacterial and antifungal agents. However, much of the available research has relied on crude extracts, with limited efforts to isolate and characterize individual bioactive compounds. Future studies should emphasize compound purification, mechanistic investigations, and evaluation of possible synergistic effects with conventional antibiotics.

Anti-inflammatory Plants

Inflammation underlies a wide range of chronic and acute diseases, including arthritis, cardiovascular disorders, and metabolic syndromes. Several medicinal plants from the Mardan region are traditionally used for the treatment of inflammatory conditions, and pharmacological studies provide evidence for their bioactivity.

Cannabis sativa (C. sativa) contains cannabinoids such as cannabidiol (CBD), which interact with the endocannabinoid system to exert anti-inflammatory and analgesic effects[24]. Experimental studies support its role in reducing edema and inflammatory cytokine production[25].

Mentha arvensis (M. arvensis), rich in menthol and flavonoids, has demonstrated inhibition of pro-inflammatory mediators including prostaglandins and nitric oxide[26]. Its essential oil extracts are commonly used for respiratory and muscular inflammation[27].

Sonchus asper (S. asper) has been reported to possess anti-inflammatory properties linked to its alkaloid and flavonoid content[28]. In animal models, extracts have reduced carrageenan-induced paw edema, suggesting potential in managing acute inflammation[29].

Solanum nigrum (S. nigrum) contains glycoalkaloids and flavonoids that modulate inflammatory pathways[30]. Traditional use in treating swelling and pain is consistent with experimental findings showing reduced levels of inflammatory enzymes.

Collectively, these plants highlight the therapeutic relevance of bioactive compounds such as cannabinoids, terpenoids, and flavonoids in regulating inflammation. Despite promising laboratory findings, clinical studies remain scarce, and future research should explore standardized extracts and molecular targets to validate their efficacy.

Anticancer Plants

Cancer is a growing global health concern, with limited treatment accessibility in low- and middle-income countries. Natural products, particularly phytochemicals, have long been investigated as sources of anticancer agents. Several medicinal plants of the Mardan region have demonstrated cytotoxic and ant proliferative activities in experimental studies.

Cannabis sativa (C. sativa) contains cannabinoids, particularly cannabidiol (CBD) and Δ9-tetrahydrocannabinol (THC), which have been shown to induce apoptosis, inhibit angiogenesis, and suppress tumor progression in various cancer cell lines[31]. These findings support its potential role as a source of anticancer agents, though concerns about dosage and safety require further investigation.

Sonchus asper (S. asper) exhibits cytotoxic activity attributed to flavonoids and phenolic compounds. Extracts have demonstrated growth-inhibitory effects against human cancer cell lines, including breast and liver cancers, highlighting its potential in future drug discovery[32].

Solanum nigrum (S. nigrum) is widely reported in ethno medicine for cancer treatment. Scientific studies confirm that its glycoalkaloids and polysaccharides exert cytotoxic effects through apoptosis induction and modulation of signaling pathways in cancer cells[33].

Mentha arvensis (M. arvensis) contains essential oils and flavonoids that exhibit modest cytotoxicity, with potential chemo preventive effects[34]. Although data are limited, initial findings suggest a role in complementary anticancer therapy.

Overall, the anticancer properties of these plants are encouraging but remain underexplored. Most studies are limited to in vitro assays, with few in vivo or clinical investigations. Systematic evaluation of bioactive compounds, toxicity profiling, and mechanistic studies are essential to validate their therapeutic potential.

Antidiabetic Plants

Diabetes mellitus is one of the most prevalent metabolic disorders worldwide, and its incidence is rapidly increasing in South Asia, including Pakistan[35]. Traditional medicine in the Mardan region employs several plants for managing hyperglycemia, and experimental studies provide support for their antidiabetic potential.

Sonchus asper (S. asper) has demonstrated hypoglycemic activity in animal models. Its bioactive constituents, particularly flavonoids and phenolic compounds, are thought to improve glucose tolerance and enhance insulin sensitivity[36].

Solanum nigrum (S. nigrum) is traditionally known to be used for diabetes and preclinical studies have established its antidiabetic potential. Its glycoalkaloids and polysaccharides have been hypothesized to reduce blood glucose level through regulation of carbohydrate metabolism and preservation of β-cells in the pancreas[37].

Antidiabetic activity of *M. arvensis* is also well documented which can be mainly attributed to its essential oils and flavonoids. Both experimental studies and clinical data have shown decrease in blood glucose with the extracts of this plant.

Taken together, these results suggest that the flora of Mardan region is a rich source of plants that can be used in the management of diabetes and its complications due to their phytochemical diversity. However, there is still not a standard for clinical trials or optimal dose regimens which limits therapeutic application. Further research for the

isolation of active compounds and rigorous evaluation of safety and effectiveness in human beings is warranted.

Other Reported Activities

In addition to antimicrobial, anti-inflammatory, anticancer and antidiabetic activities, several plants used in ethnomedicines of the Mardan area show other pharmacological properties.

Cannabis sativa (C. sativa) is one well known plant that has gained attention as an analgesic, its action being attributed to the modulation of the endocannabinoid system[38]. Nonetheless, traditional remedies that use *P. alliaceous* for appetite stimulation and sedation provide additional evidence of the plant's multiple medical potentials.

Mentha arvensis (M. arvensis) is the source of antipyretic and analgesic activity being due to menthol as well as related terpenoids[39]. Extracts of the plant have been used for fever, headache and digestive upsets in folk remedies[34].

Sonchus asper (S. asper) Tremendous antioxidant properties of the extract have also been attributed to antioxidant potential in a higher range owing to its flavonoids and phenolic compounds. This is in agreement with its Protective Action against oxidative stress-related diseases including cardiovascular disease[40].

Solanum nigrum (S. nigrum) has hepatoprotective effects, which may be attributed to its glycoalkaloids and polysaccharides content. Experimental studies have demonstrated hepatoprotective effects against chemically-induced liver damage, which agrees with the traditional use of the extract in treatment of liver diseases[41].

These other pharmacological activities broaden Mardan's medicinal plants therapeutic spectrum. Yet, majority of results are still preliminary and more work is required to elucidate how they exert their effects and examine their possible clinical use.

Table 1

Medicinal plants traditionally used in the Mardan region, with their botanical and local names, families, major phytochemicals, pharmacological activities, and references. Plant names are abbreviated (e.g., Cannabis sativa → C. sativa) for brevity.

Botanical name	Local name	Family	Major phytochemicals	Pharmacological activities
Cannabis sativa (C. sativa)	Bhang	Cannabaceae	Cannabinoids (THC, CBD), flavonoids, terpenoids	Antimicrobial, anti-inflammatory, anticancer, analgesic, sedative
Mentha arvensis (M. arvensis)	Podina	Lamiaceae	Menthol, flavonoids, terpenoids, tannins	Antimicrobial, anti-inflammatory, antidiabetic, antipyretic, analgesic
Sonchus asper (S. asper)	Dodhak	Asteraceae	Flavonoids, phenolics, alkaloids, tannins	Antimicrobial, anti-inflammatory, anticancer, antidiabetic, antioxidant
Solanum nigrum (S. nigrum)	Kachmach	Solanaceae	Glycoalkaloids (solanine, solasodine), flavonoids, polysaccharides	Antimicrobial, anti-inflammatory, anticancer, antidiabetic, hepatoprotective
Chenopodium album (C. album)	Bathua	Amaranthaceae	Saponins, flavonoids, phenolics	Anthelmintic, antioxidant, antimicrobial
Fumaria indica (F. indica)	Papra	Fumariaceae	Alkaloids (fumaramine, protopine), flavonoids	Antipyretic, hepatoprotective, antimicrobial
Euphorbia hirta (E. hirta)	Dudhi	Euphorbiaceae	Tannins, flavonoids, saponins	Antibacterial, antidiarrheal, antiasthmatic
Calotropis procera (C. procera)	Aak	Apocynaceae	Cardiac glycosides, alkaloids, terpenoids	Anti-inflammatory, antimicrobial, analgesic, anticancer
Achyranthes aspera (A. aspera)	Puthkanda	Amaranthaceae	Alkaloids, saponins, flavonoids	Antidiabetic, antimicrobial, anti-inflammatory

Limitations and Future Prospects

This review highlights the phytochemical diversity and pharmacological potential of medicinal plants from the Mardan region. However, several limitations must be acknowledged. First, most studies conducted to date rely on crude plant extracts, with limited work on the isolation and characterization of specific bioactive compounds. Second, many pharmacological investigations have been restricted to in vitro assays or animal models, making it difficult to predict clinical relevance. Third, variations in extraction methods, plant parts used, and experimental protocols reduce the reproducibility and comparability of results across studies. Finally, traditional knowledge regarding dosage and preparation methods is often under-documented, creating a gap between ethnomedical practices and scientific validation.

Future studies should give priority to isolating and characterizing active compounds through advanced chromatographic and spectroscopic techniques. Equally important are mechanistic investigations at the molecular and cellular levels to clarify how these phytochemicals produce their effects. Clinical trials are also needed to establish safety and efficacy in human populations, as most evidence to date remains preclinical. Alongside laboratory research, attention must be given to sustainable harvesting and cultivation to protect these valuable resources. By integrating contemporary pharmacological methodologies with local ethnobotanical wisdom, investigators are able to simultaneously conserve cultural traditions and discover promising medical leads in this relatively unexplored plant life.

CONCLUSION

Mardan flora has tremendous potential to produce bioactive chemicals leading towards drug discovery. In the nine species reviewed, a variety of phytochemicals, such as alkaloids, flavonoids, terpenoids, glycoalkaloids and phenolics have been isolated conferring biochemical basis for their broad spectrum pharmacological activities. Antimicrobial/anti-inflammatory activities are the most

frequently validated, whereas anticancer, antidiabetic, and hepatoprotective effects are promising yet less travelled terrains.

Through combining the age-old information with the upcoming pharmacological findings, this review tries to indicate the importance of scientific re-validation of indigenous plants. Prospective research should focus on the purification and characterization of bioactive compounds, elucidate their mechanism of action, and perform well-conducted clinical studies to verify therapeutic efficacy. Conservation and sustainable use of these plants will also be necessary to maintain supplies for the future.

In general, the medicinal flora of Mardan is an underutilized resource and holds potential for local health care as well as drug discovery at global level.

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