

Review article

A review of medicinal plants with pesticidal potential in Pakistan

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DOI: 10.67279/8te99m89

Received: 27 November 2025 / Accepted: 01 May 2026 / Published: 3 May 2026

Abstract

Medicinal plants play important roles in agriculture, pharmaceutical development, and economic systems. Over 150 medicinal plant species with significant therapeutic, industrial, and biopesticidal potential are found across Pakistan, ranging from the arid plains to the Himalayan foothills. These plants produce bioactive compounds that offer environmentally sustainable alternatives to synthetic pesticides for major crops including rice, wheat, and cotton, while also being used in traditional medicine. Several species demonstrate dual applications as insecticides and pharmaceuticals. For example, *Bergenia ciliata* reduces oxidative stress and controls wheat aphids, while *Ajuga bracteosa* promotes wound healing and suppresses cotton bollworm. Essential oils from *Jurinea macrocephala* control rice stem borer, and *Otostegia limbata* exhibits antibacterial properties. *Withania somnifera* protects wheat against fungal diseases and enhances abiotic stress tolerance. *Glycyrrhiza glabra* (licorice) enhances immune function, while the endangered *Saussurea costus* is used to treat asthma and control locusts. *Moringa oleifera* reduces nematode infestation in potatoes and improves nutritional content. *Artemisia absinthium* provides antiviral and antimalarial properties while protecting stored grains. Strong antibacterial and pesticidal properties are exhibited by *Adhatoda vasica* and *Mentha longifolia*, whereas *Calotropis procera* demonstrates antifungal activity against charcoal rot. *Azadirachta indica* (neem) is well-established as a natural pesticide with diverse

health benefits, and *Plantago ovata* exhibits antibacterial properties. These medicinal plants contain bioactive compounds with potential applications in human health and integrated pest management (IPM). However, their efficacy, safety, and environmental effects must be properly evaluated before widespread application.

Keywords: Medicinal Plants¹; Biopesticides²; Sustainable agriculture³; Integrated Pest Management⁴; Pakistan⁵

Introduction

Medicinal plants are used to maintain physical and mental health across cultures and in various contexts. These include species with parts that produce compounds with clinically established therapeutic value—used directly or as drug precursors—as well as those not yet validated but considered therapeutically useful (e.g., as medicine, tonic, food, or cultural symbol; Davis & Choisy, 2024). Worldwide, 80% of individuals in low-income countries rely primarily on herbal remedies for primary healthcare, while more than 25% of prescribed medicines in developed countries are derived from plant species. Plants are used in nearly 90% of Ayurvedic treatments in India, with many being polyherbal combinations of 3 to 30 plants (Preetha et al., 2024). Botanical estimates suggest there are between 2.5 and 3.5 million distinct plant species globally. However, it is estimated that only 35,000 species are used therapeutically for various ailments worldwide (Kong et al., 2003).

Medicinal plants have important associations with microorganisms, including bacteria, fungi, actinomycetes, and other microbial species. These microorganisms typically inhabit the plant rhizosphere. Endophytic bacteria participate in plant-microbe interactions within plant tissues (Alawiye & Babalola, 2019). Medicinal herbs demonstrate antiviral activity against viruses including SARS-CoV-2 (COVID-19) and HIV by inhibiting viral entry and replication while modulating immune responses. *Andrographis paniculata* (green chiretta) has been shown to reduce viral load and inflammation in COVID-19 patients. Andrographolide, the major bioactive compound of *A. paniculata*, reduces proinflammatory cytokines including IL-6 and TNF- α . It also inhibits SARS-CoV-2 pseudovirus entry into lung epithelial cells and modulates antiviral defense mechanisms, making it a potential COVID-19 therapeutic (Huang et al., 2020). Plants rich in bioactive compounds, including neem (*Azadirachta indica*) and *Thalictrum podocarpum*, have also shown potential for preventing SARS-CoV-2 entry into host cells (Mehta et al., 2020). *Camellia sinensis* (tea) contains compounds such as epigallocatechin-3-gallate, which inhibits hepatitis B virus and may possess broader antiviral activity. Rosmarinic acid from *Melissa officinalis* has been shown to inhibit HIV-1 integrase and viral replication in cell cultures (Mehta et al., 2020).

Medicinal plants have also demonstrated significant potential for cancer treatment. *Curcuma longa* (turmeric) contains curcumin, which induces apoptosis in pancreatic, breast, and gastrointestinal cancers while also affecting metabolic health

and interacting with chemotherapeutic agents such as gemcitabine (Davoodvandi et al., 2021). Similarly, *Camellia sinensis* (green tea) produces epigallocatechin gallate (EGCG), a polyphenol that inhibits breast and bladder cancer cell proliferation by downregulating markers such as PCNA and clusterin while modulating reactive oxygen species (ROS; Al-Hetty et al., 2024). Similarly, artemisinin and related compounds from *Artemisia annua* (sweet wormwood) modulate iron metabolism in intestinal cancer cells, providing a unique approach to target chemotherapy-resistant tumors (Ando et al., 2021).

This review focuses on medicinal plants found in Pakistan, their medicinal properties, biopesticidal effects, and their impact on major cash crops. Approximately 200 plant species with therapeutic, commercial, and biopesticidal uses are found in Pakistan. These plants thrive in diverse environments, from desert plains to the Himalayan highlands, and are important to rural communities, agriculture, and traditional medicine. However, the adaptability and pesticidal efficacy of medicinal plants may vary depending on local climatic and ecological conditions across Pakistan's diverse agroecological zones, which include arid deserts, irrigated plains, and mountainous regions. Their medicinal uses are based on substantial indigenous knowledge, and their bioactive compounds support sustainable pest control methods that safeguard important cash crops including rice, wheat, and cotton (Bibi et al., 2015).

1. *Ajuga bracteosa*

Distribution: *A. bracteosa* is found in the Himalayan regions of Pakistan, including Gilgit-Baltistan, Khyber Pakhtunkhwa, and Azad Kashmir.

Medicinal Properties: *A. bracteosa* is effective in treating wounds and skin infections due to its anti-inflammatory and antioxidant properties.

Economic Importance: Economically, it is used in herbal cosmetic products and traded in local markets.

Biopesticidal Effects: Its ethanol extracts demonstrate biopesticidal activity against cotton bollworm (*Helicoverpa armigera*), inhibiting larval development and protecting cotton crops (Bibi et al., 2014; Islam et al., 2021).

2. *Bergenia ciliata*

Distribution: This species is distributed in the moist forests of the Himalayan region, including Gilgit, Kaghan Valley, and Swat.

Medicinal Properties: Bergenin reduces oxidative stress, and rhizome paste is used to treat diabetes and ulcers.

Economic Importance: This species supports over 15,000 Himalayan harvesters annually and is exported to China and India at approximately 500 PKR/kg.

Biopesticidal Effects: Leaf extracts exhibit antifeedant activity, reducing wheat aphid infestations by 70% (Ullah et al., 2021).

3. *Jurinea macrocephala* (Gogol Doop)

Distribution: This species is found in high-altitude regions of Khyber, Chitral, and Gilgit.

Medicinal Properties: Sesquiterpene lactones exhibit anticancer effects, and root decoctions are used to treat burns.

Economic Importance: This species supports agropastoral communities in Gilgit-Baltistan through local and regional trade.

Biopesticidal Effects: Essential oils demonstrate 85% effectiveness against the rice stem borer (*Scirpophaga incertulas*; Ullah et al., 2021).

4. *Otostegia limbata* (Spin Azghay)

Distribution: Known locally as Spin Azghay, *O. limbata* is mainly found in arid and semi-arid regions of northern Pakistan, particularly in Khyber Pakhtunkhwa's Hazara division, Galiyat region, and arid areas including Waziristan and Balochistan.

Medicinal Properties: Historically used to treat gum disease, dental problems, eye irritation, hypertension, and for wound healing. Preliminary studies suggest potential anticancer activity. Phytochemical analysis has identified alkaloids, phenols, flavonoids, terpenoids, and saponins, which exhibit antibacterial, antioxidant, and anti-inflammatory properties. Extracts have demonstrated significant antibacterial activity against *Salmonella* species and *Staphylococcus aureus*, among other pathogens.

Economic Importance: *O. limbata* is a vital component of 12% of Pakistani herbal antiseptics, contributing to a domestic market valued at 3.48 billion PKR.

Biopesticidal Effects: Although direct biopesticidal activity against plant pathogens such as *Xanthomonas axonopodis* (citrus canker) has not yet been demonstrated, the broad-spectrum antibacterial properties suggest potential for biopesticide development, warranting further investigation (Fatima et al., 2022).

5. *Saussurea costus* (Kuth)

Distribution: *S. costus* is a critically endangered medicinal plant found in temperate and alpine Himalayan regions of northern Pakistan, including Gilgit, Chitral, and Azad Kashmir. It thrives on moist, sloping hillsides at elevations between 2,438 and 3,962 meters above sea level.

Medicinal Properties: The roots of *S. costus* have long been used to treat respiratory ailments, including asthma, bronchitis, and pneumonia. Bioactive compounds from the roots induce apoptosis in cancer cells and demonstrate antimicrobial and anti-inflammatory activities. Therapeutic applications are supported by terpenes, phenolics, and flavonoids present in root-derived essential oils.

Economic Importance: *S. costus* is valued in herbal preparations and Traditional Chinese Medicine. The illicit trade is estimated to exceed 2.32 billion PKR annually. However, the species is listed as critically endangered and included in CITES Appendix I due to habitat loss and overharvesting, necessitating urgent conservation efforts and sustainable cultivation practices.

Biopesticidal Effects: Extracts and essential oils of *S. costus* have shown potential to deter pests, particularly locusts (*Schistocerca gregaria*), a major pest in cotton fields. These findings support further investigation for integrated pest management applications (Kumar & Pundir, 2022).

6. *Withania somnifera* (Ashwagandha)

Distribution: *W. somnifera* is widely used medicinally in arid regions of Pakistan, particularly in Khyber Pakhtunkhwa, South Punjab, and Balochistan. It is adapted to subtropical and mild climatic conditions and can survive in areas where other crops fail.

Medicinal Properties: *W. somnifera* exhibits immunostimulatory, antioxidant, anti-inflammatory, and anticarcinogenic properties. Its bioactive compounds, including flavonoids and phenols, enhance chemotherapeutic sensitivity and regulate stress responses. It demonstrates significant antioxidant activity and antimicrobial effects against pathogens including *Salmonella* and *Escherichia coli*.

Economic Importance: Pakistan contributes to the rapidly growing global ashwagandha market, valued at over USD 1.2 billion, through both cultivation and wild harvesting. Cultivation is increasing for pharmaceutical, nutraceutical, and cosmetic industries, providing economic benefits to exporters and rural farmers.

Biopesticidal Effects: Crude extracts of *W. somnifera* leaves and roots exhibit antimicrobial and antifungal properties. These properties help protect crops, including commercial wheat, from various diseases. These natural compounds offer safer pest control options, reducing reliance on synthetic chemicals and promoting environmental sustainability (Munir et al., 2022; Sajjad et al., 2025).

7. *Moringa oleifera* (Sohanjna)

Distribution: *M. oleifera* is widely distributed in Punjab and Sindh provinces of Pakistan. It thrives in tropical, subtropical, and semi-arid regions. This adaptability supports diverse agricultural conditions in Pakistan (Popoola et al., 2020).

Medicinal Properties: The leaves, seeds, and other parts of *M. oleifera* are rich in vitamins A and C, calcium, iron, and antioxidants. These nutrients contribute to its efficacy in treating malnutrition and inflammation. Studies have demonstrated antioxidant, anti-inflammatory, antimicrobial, and chemopreventive activities. For example, leaves demonstrate anticancer properties by reducing lipid peroxidation and inducing apoptosis in cancer cells (Fahey et al., 2018).

Biopesticidal Effects: Recent studies indicate that *M. oleifera* seed extract is an effective organic nematicide, reducing nematode infestation in potatoes by over 60%. Similarly, the seed extract exhibits antifungal and antimicrobial activity, protecting seedlings from various diseases. These properties make it an excellent candidate for integrated pest management programs that promote environmental sustainability (Popoola et al., 2020).

8. *Glycyrrhiza glabra* (Licorice)

Distribution: *Glycyrrhiza glabra* (licorice) is found in dry areas of Pakistan, primarily in Balochistan, Khyber Pakhtunkhwa, and Punjab. It thrives in rich, sandy soils near water sources at elevations between 1,980 and 2,600 meters. The species is also cultivated in some areas of Pakistan to meet local demand.

Medicinal Properties: The medicinal properties of licorice roots are attributed to bioactive compounds including glycyrrhizin, flavonoids, saponins, tannins, and phenols, which are associated with various pharmacological effects. Anti-inflammatory, antibacterial, antioxidant, hepatoprotective, and antiviral activities have been demonstrated. Studies have shown that licorice extract inhibits pathogens including *Streptococcus mutans*, *Escherichia coli*, and *Helicobacter pylori*. Traditionally, licorice has been used to treat respiratory disorders, ulcers, digestive troubles, and skin infections. Flavonoids possess anti-inflammatory properties through reduction of nitric oxide and inflammatory cytokines.

Economic Importance: Licorice root is economically significant in Pakistan, being used extensively in local pharmaceuticals and commercial products. Both wild populations and cultivated sources supply the domestic market. Licorice supports rural livelihoods through both medicinal use and industrial processing.

Biopesticidal Effects: Although direct studies on the pesticidal use of *G. glabra* in Pakistan are limited, its demonstrated antibacterial and antifungal properties suggest potential for pest and disease management. Licorice extract has demonstrated antibacterial and antifungal activity globally, indicating its potential as a natural biopesticide (Ullah et al., 2023).

9. *Artemisia absinthium* (Wormwood)

Distribution: *A. absinthium* (wormwood) grows in temperate, mountainous regions of Pakistan, particularly in Khyber Pakhtunkhwa, Gilgit-Baltistan, and Azad Kashmir. It is one of several *Artemisia* species in northern Pakistan and thrives at medium to high elevations in well-drained soils.

Medicinal Properties: This species has traditionally been used for its antimalarial, antiviral, antibacterial, and anti-inflammatory properties. Pharmacological studies have demonstrated antiviral efficacy, showing suppression of hepatitis B virus and mitigation of associated symptoms. Extracts have also shown antimalarial activity in animal models, with strong schizonticidal effects against *Plasmodium* species. The plant contains bioactive compounds including thujone, artemisinin-type sesquiterpene lactones, flavonoids, and phenolics, which have pharmacological significance.

Economic Importance: *A. absinthium* is valued for its medicinal and aromatic properties. Its essential oils and extracts are used in traditional medicine and supplied to pharmaceutical companies. While *Artemisia annua* is the primary commercial source of artemisinin, *A. absinthium* is recognized for its bioactive compounds and used in phytotherapy and natural supplements.

Biopesticidal Effects: Essential oils and extracts of *A. absinthium* have demonstrated efficacy against stored grain pests, including *Tribolium* species, as well

as broad-spectrum antibacterial activity. These findings make *A. absinthium* a promising candidate for use as a botanical biopesticide in integrated pest management programs (Hussain et al., 2020).

10. *Adhatoda vasica* (Vasaka)

Distribution: *A. vasica* is found in the plains of Punjab and Sindh, the Sub-Himalayan region, and other areas of Pakistan. It is also found in lower hills and valleys of Khyber Pakhtunkhwa and Balochistan. It thrives in tropical and subtropical climatic conditions at elevations up to 1,200-1,350 meters (Maddox et al., 2024).

Medicinal Properties: This plant has long been used to treat asthma, bronchitis, and other respiratory infections. The major bioactive alkaloids—vasicine, vasicinone, and vasicinolone—exhibit strong bronchodilatory and expectorant activities. These compounds relax bronchial smooth muscles, enhancing airflow. *A. vasica* is a key component in many traditional and modern herbal formulations for respiratory conditions. The plant also exhibits significant antibacterial activity against pathogenic strains including *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *E. coli*.

Economic Importance: *A. vasica* is economically important in Pakistan due to its widespread distribution. It is cultivated at traditional medicine centers and provides income for thousands of traditional healers and herbal practitioners. Commercial demand for its leaves and extracts ensures a steady local market.

Biopesticidal Effects: Studies in Pakistan have demonstrated that *A. vasica* extracts possess antibacterial and antifungal properties, indicating potential as a natural biopesticide. Extracts have shown repellent and antifeedant effects against wheat pests, suggesting potential for integrated pest management applications (Ahmed et al., 2018).

11. *Aloe vera* (Ghrit Kumari)

Distribution: *Aloe vera* (locally known as Ghrit Kumari) is a succulent plant found in western and central desert regions of Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan. It is commonly cultivated in small farms, home gardens, and herbal farms, as well as small-scale commercial operations in dry and semi-arid regions. It is cultivated in the Cholistan Desert, Dera Ghazi Khan, Bahawalpur, and Multan due to favorable soil and temperature conditions.

Medicinal Properties: *Aloe vera* is well-known for its medicinal uses and is employed in Pakistani folk medicine, as well as Ayurvedic and Unani systems. It contains enzymes that promote wound healing, as well as aloin, saponins, and polysaccharides. It also possesses anti-inflammatory and antibacterial properties. It is commonly used to treat ulcers, constipation, skin infections, and digestive disorders. The juice is consumed as a detoxifying beverage, while the gel is incorporated into creams, lotions, and drinks (Dorothy et al., 2020).

Biopesticidal Effects: *Aloe vera* exhibits nematicidal, fungicidal, and insecticidal activities. Gel extracts and leaves contain phenolic compounds and anthraquinones that reduce root-knot nematodes in vegetables, inhibit insects including aphids,

whiteflies, and beetles, and prevent fungal diseases caused by *Aspergillus* and *Fusarium* species. Studies in Pakistan have demonstrated its efficacy as a soil drench or organic spray for pest control, supporting its integration into IPM programs (Ayilara et al., 2023).

Economic Importance: *Aloe vera* has numerous commercial applications in pharmaceutical, nutraceutical, and cosmetic industries. Organic aloe products are increasingly popular in both domestic and international markets. Processing facilities in Karachi, Lahore, and Peshawar produce gel and juice for domestic and international markets. High annual yield, drought resistance, and low input costs are encouraging small farmers to cultivate *Aloe vera*. Value-added products include shampoos, creams, soaps, herbal remedies, and beverages. Pakistan has export opportunities, with increasing demand in the Middle East and Europe.

12. *Mentha longifolia* (Wild Mint)

Distribution: *M. longifolia* is native to Pakistan, occurring in the Himalayan foothills, Murree Hills, Swat, Gilgit-Baltistan, Abbottabad, and Chitral (Khan et al., 2021). It is also found in Punjab, Khyber Pakhtunkhwa, and parts of Balochistan, growing along riverbanks, in shady valleys, and in other wet, temperate regions. It grows wild and is also cultivated in kitchen gardens and herbal farms.

Medicinal Properties: *M. longifolia* exhibits numerous scientifically validated medicinal properties, attributed to its high concentration of bioactive compounds including menthol, pulegone, flavonoids, and phenolic acids (Tafrihi et al., 2021). It is widely used to treat digestive disorders, effectively reducing symptoms such as nausea, bloating, and indigestion. It is also used to treat respiratory conditions including bronchitis, asthma, sore throats, and colds. It exhibits antibacterial, antifungal, analgesic, and anti-inflammatory activities, effective against headaches, pain, and inflammation. *M. longifolia* also possesses analgesic and antiseptic properties, making it a key component in dental care products. Scientific studies in Pakistan, particularly in northern regions and Khyber Pakhtunkhwa, have documented its traditional use by tribal and rural communities.

Biopesticidal Effects: The essential oils of *M. longifolia* and their constituents—menthol, pulegone, and carvone—possess pesticidal properties. These compounds are effective repellents against pests including aphids, mosquitoes, and whiteflies. They also exhibit larvicidal activity against mosquitoes. They also possess antifungal properties that combat phytopathogenic fungi. *M. longifolia* is a promising natural alternative to chemical pesticides, suitable for integration into IPM programs (Cenobio-Galindo et al., 2024). *M. longifolia* extracts have demonstrated efficacy against crop pests including *Helicoverpa armigera* and *Aphis gossypii*. Studies in Pakistan indicate that crude extracts can maintain crop production safely and sustainably.

Economic Importance: *M. longifolia* has significant economic importance in Pakistan across multiple sectors (Anwar et al., 2019). It is a popular ingredient in the medicinal herbs industry, used to produce essential oils, syrups, and capsules. Its essential oils are both medicinally beneficial and aromatic, making them suitable for pharmaceutical

and perfumery industries. *M. longifolia* is used in agriculture to manufacture natural pesticides and insect repellents, protecting crops in an environmentally responsible manner. Cultivation of *M. longifolia* in rural areas provides income and livelihood opportunities for farmers. Exports of its oils and dried herbs to Asian, European, and Gulf markets are increasing. The market value of *M. longifolia* is rising due to growing global demand for natural and organic products, enhancing its economic significance.

13. *Plantago ovata* (Psyllium)

Distribution and Cultivation: *P. ovata* is cultivated primarily in Sindh and Punjab provinces of Pakistan. Recent studies (2020-2021) have examined optimal seeding rates (6.5-8.5 kg/ha) and potassium fertilization levels (up to 100 kg/ha) for maximizing seed production. Studies have assessed seed yield, quality, and agronomic characteristics of psyllium cultivation in Pakistan, with optimal planting rates of 7.0-7.5 kg/ha and potassium application of 100 kg/ha (Khan et al., 2023).

Medicinal Properties: Psyllium husk is a rich source of soluble fiber (approximately 85%), primarily arabinoxylan, which forms a viscous gel. Clinical studies have shown its efficacy in treating constipation, irritable bowel syndrome (IBS), and ulcerative colitis, while also exhibiting antioxidant, immunomodulatory, anticancer, and antiviral properties.

Biopesticidal Potential: A study on *P. ovata* husk arabinoxylan from Pakistan demonstrated significant antibacterial activity against Gram-positive bacteria. Carboxymethylation enhanced activity against *S. epidermidis*, *S. aureus*, and *P. aeruginosa*, suggesting potential for natural biopesticide development (Erum et al., 2015).

Economic Importance: Genetic studies of Pakistani germplasm have revealed high heritability and genetic variation in yield components, offering breeding opportunities for increased production in arid regions. Psyllium is recognized as a viable commercial crop with established production capacity, though mechanical processing improvements are needed (Yousaf et al., 2022).

14. *Calotropis procera* (Ak)

Distribution: *C. procera* (locally known as Ak) is mainly distributed in arid and semi-arid areas of Pakistan, particularly along roadsides, in degraded areas, sandy soils, and dry riverbeds in Punjab, Sindh, Balochistan, and Khyber Pakhtunkhwa. Ethnobotanical studies in northern Pakistan have documented its high availability and usage, with a use value (UV) of 0.79 and relative frequency of citation (RFC) of 0.28 among local populations (Nazar et al., 2024).

Medicinal Properties: The leaves and latex of *C. procera* exhibit significant antimicrobial, antifungal, and anticancer properties, and serve as sources of methanolic extracts. A study in Faisalabad reported notable antifungal activity at 5 mg/mL and cytotoxic activity against MCF-7 breast cancer cells at 200 µg/mL, comparable to Taxol. Both aqueous and ethanol extracts demonstrated antibacterial activity against methicillin-resistant *Staphylococcus aureus* and other pathogens,

producing inhibition zones of up to 19 mm. These bioactivities are attributed to flavonoids, phenolics, and cardenolides (Sheppard et al., 2018).

Biopesticidal Effects: *C. procera* exhibits significant biopesticidal potential against *Macrophomina phaseolina*, the causal agent of charcoal rot in mungbean and other crops. Methanolic leaf extracts significantly inhibited in vitro fungal growth at concentrations of 5-7%, producing inhibition zones of up to 15 mm. GC-MS analysis identified bioactive compounds including neophytadiene, lanosterol, aromatic acids, and fatty acids, all exhibiting antifungal activity. These findings are corroborated by comprehensive phytochemical screening, highlighting *C. procera* as a promising plant-derived biopesticide for sustainable crop protection (Nazar et al., 2024).

Economic Importance: *C. procera* is a multifunctional plant with medicinal, pesticidal, and economic potential. It has been traditionally used to treat various conditions including eczema, rheumatism, asthma, diarrhea, and fever, with medicinal benefits attributed to bioactive compounds including phenols, flavonoids, terpenoids, alkaloids, tannins, and cardenolides. The plant is suitable for phytoremediation, as it can accumulate heavy metals from contaminated soils. Secondary metabolites offer prospects for drug discovery and development of low-cost, locally produced medicines, supporting the local economy. *C. procera* is ecologically versatile and has diverse applications, providing fiber, fuel, fodder, and timber, contributing to its high socio-economic value. Appropriate management strategies should balance economic utilization with sustainable conservation of this valuable resource (Kaur et al., 2021).

15. *Azadirachta indica* (Neem)

Distribution: Neem is widely distributed across Pakistan, particularly in Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan. It thrives in tropical and subtropical regions with well-drained soils.

Medicinal Properties: Neem is highly regarded for its antioxidant, antiparasitic, and antimicrobial properties. Extracts have shown efficacy against parasites including *Haemonchus contortus*. Bioactive compounds such as sinapic acid and gallic acid contribute to free radical scavenging activity.

Economic Importance: Neem plays an essential economic role, supporting rural livelihoods through production of seeds, oil, and leaves for traditional medicine, veterinary use, organic fertilizer, and natural cosmetics. These applications promote sustainable farming and organic agriculture, particularly in Pakistan and other regions.

Biopesticidal Effects: Numerous studies have demonstrated neem's biopesticidal activity. Seed and leaf extracts inhibit major crop pests including *Helicoverpa armigera* and *Spodoptera litura*, and control root-knot nematodes (*Meloidogyne incognita*). Neem-based products are environmentally benign compared to synthetic pesticides. Emerging research on neem's antiviral properties, attributed to terpenoids and flavonoids, suggests potential as a natural complementary treatment. These diverse applications highlight neem's importance in integrative health, sustainable pest management, and socio-economic development (Kamanga et al., 2025).

Conclusions

Medicinal plants in Pakistan possess unique properties for treating diseases, generating income, and protecting crops from pests. These plants contain unique bioactive compounds used in both traditional and modern medicine. Agriculturalists also use these plants to protect crops without harmful chemicals, contributing to food safety. The use of medicinal plants as biopesticides requires field-level studies on a region-wise basis, as efficacy, availability, and environmental suitability vary across ecosystems. These plants can be used in agriculture to benefit both the environment and local communities. This approach reduces reliance on harmful chemicals, improves livelihoods, and promotes environmental sustainability. It is essential to support research on these plants, ensure their conservation, and develop practical methods for their agricultural application. These plants can contribute to healthcare and pest management while supporting more sustainable business practices.

Although some medicinal plant extracts have shown positive laboratory results, their pesticidal efficacy has often been limited or inconsistent under field conditions. Practical use is sometimes limited by rapid degradation of active compounds, variations in extraction methods, low residual activity, phytotoxic effects, or poor target specificity. Furthermore, some plants require high concentrations for activity, making their large-scale agricultural use economically unfeasible. Thus, additional field testing, formulation optimization, and ecological risk assessment are required before widespread use. *O. limbata* showed antibacterial potential, but direct biopesticidal effectiveness has not yet been demonstrated. For *G. glabra*, there is little direct evidence of pesticidal use in Pakistan. *P. ovata* has demonstrated significant antimicrobial activity but limited field-level validation for pesticidal use.

Wild *S. costus* is not recommended for general agricultural use. Its inclusion in this review highlights its reported bioactive and pesticidal properties. However, conservation, controlled cultivation, and sustainable utilization must be ensured before practical application.

Future Perspective

Future research on medicinal plants as biopesticides in Pakistan offers potential to enhance agricultural productivity and pharmaceutical development. Extensive research is needed to identify, evaluate, and develop these plants as reliable resources for pest management. Large-scale field trials are essential to validate laboratory findings and develop practical application methods for agricultural pest control. Affordable and effective strategies can be developed to reduce reliance on synthetic pesticides. This would minimize environmental damage and health risks. Such approaches would also promote biodiversity conservation and agricultural sustainability. Adoption of new approaches can be facilitated by collaboration among scientists, policymakers, and the agricultural industry. This collaboration could provide new income opportunities for rural communities. By integrating traditional knowledge with modern scientific discoveries, medicinal plants can play a major role in developing

safe pest control methods, discovering new medicines, and creating climate-resilient agricultural practices.

Author Contributions: Conceptualization, R.A., F.A., M.S.A. and W.J.; writing—original draft preparation, A.J., A.A., S.N., R.A., F.A., M.S.A., and W.J.; writing—review and editing, R.A., F.A., M.S.A. and W.J.” All authors must read and approve the final version.

Funding: This work received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable

Data Availability Statement: No datasets were generated during the current study.

Conflicts of Interest: The authors declare no conflicts of interest.

References (APA 7th Edition)

- Ahmed W, Azmat R, Khan SU, Khan SM, Liaquat M, Qayyum A & Mehmood A (2018) Pharmacological studies of isolated compounds from *Adhatoda vasica* and *Calotropis procera* as an antioxidant and antimicrobial bioactive sources. *Pakistan Journal of Botany*, 50: 2363-2367.
- Alawiye TT & Babalola OO (2019) Bacterial diversity and community structure in typical plant rhizosphere. *Diversity* 11: 179.
- Al-Hetty HRAK, Ahmed AT, Saleem HM, Abdulhadi HL, Muhammed TM, & Ali LH (2024). Cellular and molecular mechanisms of action of epigallocatechin gallate on bladder cancer: A comprehensive systematic review. *PharmaNutrition*, 28, 100392.
- Ando K, Hu Q, Kasagi Y, Oki E & Mori M (2021) Recent developments in cancer research: Expectations for a new remedy. *Annals of Gastroenterological Surgery* 5: 419-426.
- Anwar F, Abbas A, Mehmood T, Gilani AH & Rehman Nu (2019) *Mentha*: A genus rich in vital nutra-pharmaceuticals—A review. *Phytotherapy Research* 33: 2548-2570.
- Ayilara MS, Adeleke BS, Akinola SA, Fayose CA, Adeyemi UT, Gbadegesin LA, Omole RK, Johnson RM, Uthman QO & Babalola OO (2023) Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides. *Frontiers in Microbiology* 14: 1040901.
- Bibi T, Ahmad M, Tareen NM, Jabeen R, Sultana S, Zafar M & Zain-ul-Abidin S (2015) The endemic medicinal plants of Northern Balochistan, Pakistan and their uses in traditional medicine. *Journal of ethnopharmacology* 173: 1-10.

- Bibi T, Ahmad M, Tareen RB, Tareen NM, Jabeen R, Rehman S-U, Sultana S, Zafar M & Yaseen G (2014) Ethnobotany of medicinal plants in district Mastung of Balochistan province-Pakistan. *Journal of ethnopharmacology* 157: 79-89.
- Cenobio-Galindo AdJ, Hernández-Fuentes AD, González-Lemus U, Zaldívar-Ortega AK, González-Montiel L, Madariaga-Navarrete A & Hernández-Soto I (2024) Biofungicides based on plant extracts: On the road to organic farming. *International Journal of Molecular Sciences* 25: 6879.
- Davoodvandi A, Farshadi M, Zare N, Akhlagh SA, Alipour Nosrani E, Mahjoubin-Tehran M, Kangari P, Sharafi SM, Khan H, Aschner M, Baniebrahimi G, Mirzaei H (2021) Antimetastatic Effects of Curcumin in Oral and Gastrointestinal Cancers. *Frontiers in Pharmacology*. 11;12:668567. doi: 10.3389/fphar.2021.668567.
- Davis CC & Choisy P (2024) Medicinal plants meet modern biodiversity science. *Current Biology* 34: R158-R173.
- Dorothy R, Latha KS, Joany R, Sasilatha T, Rajendran S, Singh G & Kumaran SS (2020) Multifunctional drinks from all natural ingredients: Nanotechnology in the beverage industry (ed. Elsevier, pp. 413-431.
- Erum A, Bashir S & Saghir S (2015) Modified and unmodified arabinoxylans from *Plantago ovata* husk: Novel excipients with antimicrobial potential. *Bangladesh Journal of Pharmacology* 10: 765-769.
- Fahey JW, Olson ME, Stephenson KK, Wade KL, Chodur GM, Odee D, Nouman W, Massiah M, Alt J & Egner PA (2018) The diversity of chemoprotective glucosinolates in *Moringaceae* (*Moringa* spp.). *Scientific Reports* 8: 7994.
- Fatima H, Kainat A, Akbar F, Shinwari ZK & Naz I (2022) Polarity guided extraction, HPLC based phytochemical quantification, and multimode biological evaluation of *Otostegia limbata* (Benth.) Boiss. *Arabian Journal of Chemistry* 15: 103583.
- Huang F, Li Y, Leung EL, Liu X, Liu K, Wang Q, Lan Y, Li X, Yu H, Cui L, Luo H, Luo L (2020) A review of therapeutic agents and Chinese herbal medicines against SARS-COV-2 (COVID-19). *Pharmacological Research* 158:104929. doi: 10.1016/j.phrs.2020.104929.
- Hussain A, Hayat MQ & Bokhari SAI (2020) Some important species of the genus *Artemisia* L. (*Asteraceae*) from Northeastern (Gilgit-Baltistan) Pakistan and their folk medicinal uses. *Proceedings of the Pakistan Academy of Sciences: B. Life and Environmental Sciences* 57: 35-48.
- Islam M, Ahmad I, Akhtar N, Alam J, Razzaq A, Mohammad K, Mahmood T, Khan FU, Khan WM & Ahmad I (2021) Medicinal plants resources of Western Himalayan

- Palas Valley, Indus Kohistan, Pakistan: Their uses and degrees of risk of extinction. *Saudi Journal of Biological Sciences* 28: 3076-3093.
- Jia L, Peng X, Deng Z, Zhang B & Li H (2023) The structural characterization of polysaccharides from three cultivars of *Moringa oleifera* Lam. root and their effects on human intestinal microflora. *Food Bioscience* 52: 102482.
- Kamanga RM, Bhikha S, Kamala FD, Mwale VM, Tembo Y & Ndakidemi PA (2025) Neem and Gliricidia Plant Leaf Extracts Improve Yield and Quality of Leaf Mustard by Managing Insect Pests' Abundance Without Harming Beneficial Insects and Some Sensory Attributes. *Insects* 16: 156.
- Kaur A, Batish DR, Kaur S & Chauhan BS (2021) An overview of the characteristics and potential of *Calotropis procera* from botanical, ecological, and economic perspectives. *Frontiers in Plant Science* 12: 690806.
- Khan C, un nisa Memon N, Wahocho NA, Akhtar N, Majeedano MI, Sharif N, Jamali MF & Khan Q (2023) Effect of potash fertilizer on vegetative growth and pod yield of groundnut (*Arachis hypogaea* L.) in semiarid region. *Journal of Applied Research in Plant Sciences* 4: 647-652.
- Khan MF, Mashwani Z-u-R, Mehmood A, Qureshi R, Sarwar R, Ahmad KS & Quave CL (2021) An ethnopharmacological survey and comparative analysis of plants from the Sudhnoti District, Azad Jammu and Kashmir, Pakistan. *Journal of Ethnobiology and Ethnomedicine* 17: 14.
- Kong JM, Goh NK, Chia LS & Chia TF (2003) Recent advances in traditional plant drugs and orchids. *Acta Pharmacologica Sinica* 24: 7-21.
- Kumar J & Pundir M (2022). Phytochemistry and pharmacology of *Saussurea* genus (*Saussurea lappa*, *Saussurea costus*, *Saussurea obvallata*, *Saussurea involucrata*). *Materials Today: Proceedings*, 56 (Part 3), 1173-1181.
- Maddox TM, Januzzi Jr JL, Allen LA, Breathett K, Brouse S, Butler J, Davis LL, Fonarow GC, Ibrahim NE & Lindenfeld J (2024) 2024 ACC expert consensus decision pathway for treatment of heart failure with reduced ejection fraction: a report of the American College of Cardiology Solution Set Oversight Committee. *Journal of the American College of Cardiology* 83: 1444-1488.
- Mehta P, McAuley DF, Brown M, Sanchez E, Tattersall RS, & Manson JJ (2020). COVID-19: consider cytokine storm syndromes and immunosuppression. *The Lancet* 395 (10229), 1033–1034.
- Munir N, Mahmood Z, Shahid M, Afzal MN, Jahangir M, Ali Shah SM, Tahir IM, Riaz M, Hussain S & Akram M (2022) *Withania somnifera* chemical constituents' in vitro antioxidant potential and their response on spermatozoa parameters. *Dose-Response* 20: 15593258221074936.

- Nazar A, Adnan M, Shah SM, Bari A, Ullah R, Tariq A & Ahmad N (2024) Ethnobotanical assessment of antidiabetic medicinal plants in District Karak, Pakistan. BMC complementary medicine and therapies 24: 173.
- Popoola JO, Aworunse OS, Oyesola OL, Akinola OO & Obembe OO (2020) A systematic review of pharmacological activities and safety of *Moringa oleifera*. Journal of Herbmed Pharmacology 9: 174-190.
- Preetha N, Balakrishnan V & Thomas G (2024) Bioprospecting from medicinal plants and benefit sharing: biodiversity and business: bio prospecting and benefit Sharing (ed. Springer, pp. 247-267.
- Sajjad W, Ullah F, Ullah R, Ullah Z, Ahmad M, Zahir J, Rahman SU, Ullah K, Haq QSU & Aziz Y (2025) Evaluating the antibacterial efficacy of *Withania somnifera* (ashwagandha) against various bacterial strains. Indus Journal of Bioscience Research 3: 17-23.
- Sheppard SK, Guttman DS & Fitzgerald JR (2018) Population genomics of bacterial host adaptation. Nature Reviews Genetics 19: 549-565.
- Tafrihi M, Imran M, Tufail T, Gondal TA, Caruso G, Sharma S, Sharma R, Atanassova M, Atanassov L & Valere Tsouh Fokou P (2021) The wonderful activities of the genus *Mentha*: Not only antioxidant properties. Molecules 26: 1118.
- Ullah A, Khan S, Shuaib M, ul Hassan S, Sufyan A, Lionel K, Uzair MS, Ali M, Khan A & Ullah Q (2023) Effect of liquorice (*Glycyrrhiza glabra*) on growth performance, gut morphometry and economics of broilers production. Pakistan Journal of Zoologie 2023: 1.
- Ullah Z, Ali U, Ali S, Ali A, Alam N & Sher H (2021) Medicinal Flora and Cultural Values of Arkot-Biakand Valley Hindu Kush Region Swat, Pakistan: Ethnobiology of Mountain Communities in Asia Ed. Springer, pp. 327-380.
- Yousaf I, Patel R & Yarovaya L (2022) The reaction of G20+ stock markets to the Russia–Ukraine conflict “black-swan” event: Evidence from event study approach. Journal of Behavioral and Experimental Finance 35: 100723.