Pharmacology and ethnobotany of *Vetiveria zizanioides* and integration of its traditional uses with modern therapeutic applications: A scoping review

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Abstract. *Vetiveria zizanioides* (L.) Nash, commonly known as vetiver, is a plant with a rich history in ancient medicine, particularly in Ayurveda, where it continues to be used for its numerous medicinal properties. Traditionally, vetiver roots and leaves have been used to treat conditions such as burns, convulsions, urinary tract infections and gastrointestinal issues, while also serving as an aromatic component in various healing products. Despite thousands of years of extensive experimental trial-and-error and subsequent prolonged applications, modern scientific research has only recently begun to uncover the pharmacological potential of vetiver, revealing potential qualities such as its anticonvulsant, antioxidant, anti-tuberculosis, antifungal, cytotoxic and antimicrobial activities. The present scoping review explores the numerous aspects of the traditional uses of vetiver with its emerging pharmaceutical applications, emphasizing the importance of integrating traditional, herbal medicinal knowledge with contemporary scientific methodologies. The understanding of the mechanisms underlying the effects of vetiver on inflammation and related diseases, and uncovering how it was utilized historically within Ayurvedic/traditional practices, can pave the way for its broader utilization in modern medicine.

Introduction

Vetiveria zizanioides (L.) (*V. zizanioides*) Nash, syn. *Chrysopogon zizanioides* (L.) Roberty, (family Poaceae) commonly known as vetiver or cuscus grass in English and khus or khas in Hindi, is a perennial grass (Fig. 1) that thrives throughout peninsular India particularly in the lateritic slopes of the Sahyadri (Western Ghats) range (Fig. 2). It has been known for centuries in authoritative Sanskrit treatises, such as Ayurved Jadi-Buti Rahasya by Acharya Balkrishna (1) and Dravyaguna Vignyan by Vaidya Vishun Mahadev Gogte (2). These and other texts describe the cool, aromatic root as a remedy for 'burning' fevers, wounds, stomach ailments and painful joints, while noting its calming effect on the mind and heart (1-3). Modern pharmacology is only beginning to confirm some of these observations: Root-oil sesquiterpenes display nanomolar antioxidant and COX-2-modulating activity (4-7); ethanolic extracts enhance GABAergic transmission and abolish electroshock-induced seizures in rodents (8); non-volatile fractions inhibit *Mycobacterium tuberculosis* (TB) *in vitro* (9,10); topical formulations accelerate wound re-epithelialization in diabetic rats (6); and a methanolic extract exhibits antihypertensive and antispasmodic activity (11). Early safety screens suggest a wide therapeutic window; yet the available studies are small and mechanistically disjointed. A systematic approach combining traditional uses with contemporary bioactivity data is therefore essential if vetiver is to progress from a revered folk medicine to rigorously characterized pharmacotherapeutic capable of reducing adverse effect burdens associated with mainstream anticonvulsant, antitubercular, and anti-inflammatory chemicals.

Data and methods

To map this evidence base, the present scoping review was conducted. A scoping review was conducted of all primary studies on *V. zizanioides* from November, 1972 up to November, 2025 (371 records screened), searching PubMed, Web of Science, Scopus, Google Scholar, and MEDLINE-indexed conference proceedings. The inclusion criteria targeted studies that examined the pharmacological effects, therapeutic applications, or mechanisms of action of these plants and their bioactive constituents. The authors retained *in vitro*, *in vivo* and clinical investigations that evaluated crude extracts, essential oil, or isolated constituents and reported either pharmacodynamic or safety outcomes. Search strings combined botanical synonyms with terms such as 'pharmacology', 'benefits', 'use' and 'indication', for example, 'Plant name AND pharmacology' or 'Plant name AND benefits'). Boolean operators (AND, OR) were used when needed to narrow or broaden the search results. The titles and abstracts were first reviewed to identify studies that matched the inclusion criteria.

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Subsequently, the full texts of the selected articles were read to ensure they were suitable for inclusion in the study.

Studies were excluded if they mainly discussed the botanical or agricultural details of the plants, such as classification, growing methods, or where they are found in the environment, and did not address their medical or therapeutic uses. In addition, articles that were not published in the English language or did not have an available abstract or full text were excluded.

In parallel, therapeutic uses were excerpted from the original Hindi/Sanskrit editions of *Ayurved Jadi-Buti Rahasya* (1) and *Dravya Guna Vidnyaan* (2). Of note, two authors (SA and AD) independently extracted the study design, preparation method, dose, mechanistic targets, and adverse findings; discrepancies were resolved by consensus. Modern bioactivities were then cross-tabulated against traditional claims to identify empirically validated indications, untested but historically important uses meriting investigation, and novel pharmacological leads absent from the classical record. The synthesis provides a roadmap for the potential use and benefits of this plant while honoring its Ayurvedic heritage.

Results and Discussion

As modern medicine continues to evolve, one of the most promising areas of growth lies in integrating the rich knowledge of traditional plant-based remedies with contemporary pharmacological research. Vetiver, with its centuries-old use in Ayurveda and other traditional medical systems, provides a powerful example of how ancient practices can translate into modern therapeutic approaches. Traditional medicinal uses of plants, passed down through generations, often reflect an in-depth understanding of local health challenges and the plants' potential to address them. However, for these ancient practices to be fully utilized in modern medical settings, they must undergo rigorous experimental testing.

Testing these traditional uses serves several vital purposes. First, it confirms the therapeutic claims made by traditional healers, offering scientific evidence that can bring credibility to age-old remedies. For instance, the traditional use of vetiver in treating gastrointestinal issues and skin infections has been confirmed by modern research, which has shown its antimicrobial (9,12-14), anti-inflammatory (7) and antioxidant (4-6) properties. Such evidence not only strengthens the case for vetiver as a natural remedy, but also opens the door for its integration into contemporary medical practice (once clinical trial and safety study results are available).

Secondly, the study of traditional remedies also allows for an understanding of the mechanisms of actions. Ancient medicinal knowledge is often based on observation and experience; without the benefit of the modern scientific methods, we cannot know how to study plant compounds for their effects and benefits. For example, the potential of vetiver as an anticancer agent has been demonstrated through its binding affinity to an enzyme, Aldo-keto reductase family 1 member C1 (AKR1C1), in lung cancer (15), was not a claim found in historical texts. This represents a bridge between traditional knowledge and modern scientific discovery, where traditional uses of plants can be tested for novel clinical applications.

Third, this research is crucial for identifying new compounds that may be derived from this and other plants. A number of the most important drugs currently used have origins in plant compounds that were first used in traditional medicine (16-18). For example, compounds from the plant *Taxus brevifolia* were used by indigenous populations of the Pacific Northwest long before the discovery of paclitaxel, a now widely used anti-cancer drug (19). Similarly, the rich chemical profile of vetiver, including compounds such as β-vetispirene (Fig. 3), shows promise not only for the treatment of lung cancer (15), but also for its antioxidant (20) and cytotoxic activities (21). By studying and isolating these compounds, novel treatments can be identified for diseases that are currently difficult to treat.

Figure 1. Image illustrating *Vetiveria zizanioides* (L.) Nash, also known as vetiver and khus grass; a perennial bunchgrass from Poaceae family (image taken by the author, MNG).

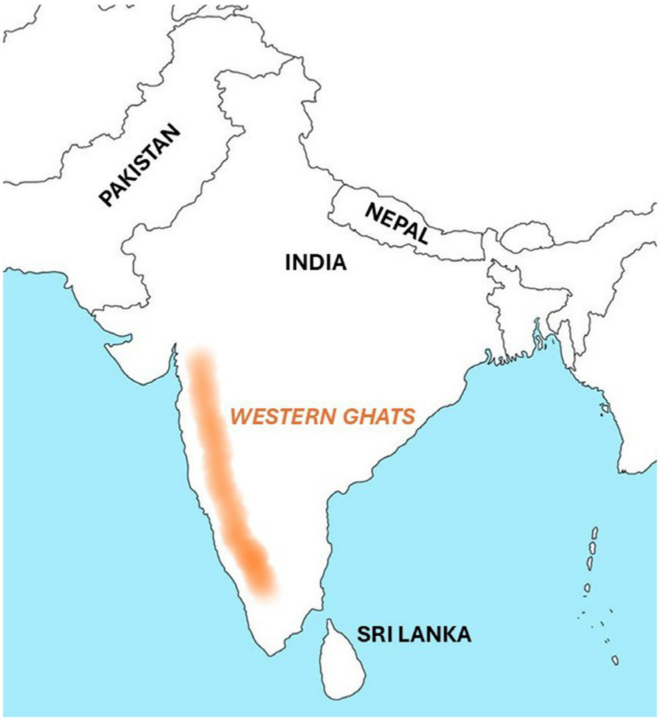
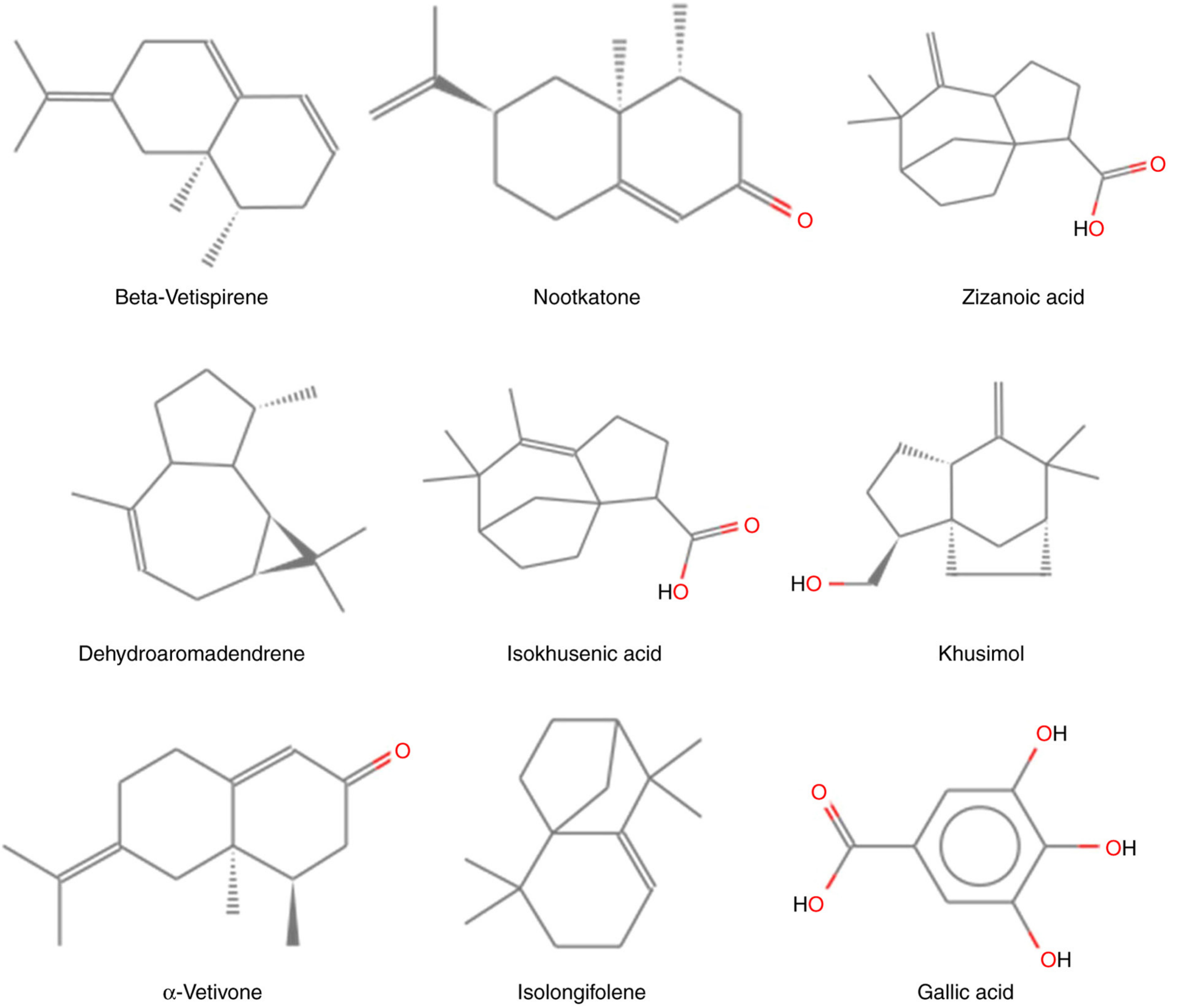


Figure 2. Map of the Indian Subcontinent illustrating the location of the Western Ghats Mountain Range, also known as Sahyadri, where vetiver or khus grass abundantly grows. The Western Ghats are spread over a number of provinces in India, such as, Gujarat, Maharashtra, Goa, Karnataka, Kerala, and Tamil Nadu (empty map obtained from a free internet resource, www.deviantart.com; then redesigned with text and color by the author, MNG).



Beta-Vetispirene
Nootkatone
Zizanoic acid
Dehydroaromadendrene
Isokhusenic acid
Khusimol
α-Vetivone
Isolongifolene
Gallic acid

Figure 3. Chemical structures of some of the bioactive compounds in *Vetiveria zizanioides* (chemical structures taken from: https://webbook.nist.gov/chemistry/).

The world is in a unique era of modern science where ancient practices and cutting-edge research offer ample opportunities. As research continues to explore the pharmacological properties of plants such as vetiver, the possibility of providing a more holistic approach to healthcare is becoming more feasible. These traditional practices, once considered secondary to modern pharmacology, are now being recognized as valuable sources of innovative therapeutic agents. The process of testing these traditional uses ensures that potentially life-saving remedies are simply not overlooked as they originate from non-Western traditions. Instead, they can become a fundamental part of the future of healthcare.

Moreover, this approach contributes to the broader concept of personalized medicine. As we gain a better understanding of how different plants, like vetiver, affect human health at a molecular level, we can begin to design treatments that are tailored to an individual genetic makeup, lifestyle, and cultural background. Integrating traditional knowledge into modern medicine not only broadens the therapeutic options but also enhances our ability to offer personalized care to our patients.

The study and testing of traditional plant-based remedies such as vetiver represent a promising path forward for modern medicine. As scientific methodologies are applied to explore and validate these age-old treatments, the potential for new compounds, enhanced therapeutic approaches and a detailed understanding of the mechanisms behind these traditional remedies can be unlocked. The future of medicine, particularly in the context of holistic care, lies in the integration of the best of both worlds: The knowledge of ancient practices and the precision of modern science. Below, the authors explore in more detail the scientific studies available in the literature, reporting pharmacological activities of vetiver. A summary of the published studies on vetiver, along with the different medical and traditional uses, plant parts used and the methods of plant preparation for administration is presented in Table I.

Table I. List of all indications, traditional uses, plant parts used, methods of preparation and published studies for *Vetiveria zizanioides* (vetiver, khus grass).

Category	Use	Traditional/ Ayurvedic use	Plant part	Preparation: traditional or scientific	Research study (Refs.)
Anticancer	Lung cancer	Not used for this purpose	Extracts (various)	Ethanol/methanol extract, *in vitro*	Selectively targets AKR1C1 enzyme, highly expressed in lung cancer, by beta-vetispirene. All tested compounds showed high activity on AKR1C1 and inactivity on AKR1C2 (15).
	Human breast cancer (MCF-7)	Not used for this purpose	Extracts (various)	Ethanol/methanol extract, *in vitro*	Significant inhibition of MCF-7 cell lines with IC_{50} between 5 to 50 μg/ml. β-vetispirene selectively targets AKR1C1 enzyme in lung cancer, suggesting potential as a co-chemotherapy agent (24).
Antibacterial	UTI	Urinary discomfort	Root, leaf	Eat 2-4 g of fine powder mixed with 5 g of sugar/molasses to alleviate urinary discomfort	Methanol extract active against *E. coli*, *P. mirabilis* and *B. subtilis*. Ethanolic extract effective against *S. aureus* and MRSA, reducing biofilm formation in a concentration-dependent manner without affecting cellular viability (4,12,13).
	Skin disease	Skin irritation	Powdered plant	Apply a paste made from equal parts khus powder, coriander seed powder, and nagarmotha to irritated skin	Ethanolic extracts demonstrated significant antibacterial and antifungal properties, supporting the use of vetiver in treating skin infections (6).
	TB	Not used for this purpose	Extracts (ethanol, hexane)	Ingested or applied as an extract	Potent effect countering *Mycobacterium tuberculosis* strains H37Rv and H37Ra (10).
Antifungal	Fingal infections	Skin infections	Extract (ethanol)	Topical application or ingestion	Activity against *Aspergillus niger*, *A. clavatus*, and *Candida albicans*. Experiments showed presence of flavonoids, glycosides, phenols, tannins, saponins and alkaloids (14).
Acaricidal	Parasite Control	Pest deterrence through aromatic properties	Essential oil	Applied as an essential oil solution	Effective in reducing oviposition and larval survival of *Amblyomma cajennense* and *Rhipicephalus microplus*, outperforming some commercial acaricidal products (25).
Ovicidal	Mosquito Control (Malaria Vector)	Pest control through aromatic properties	Essential oil and volatiles	Applied as essential oil or volatile compounds in water	Reduced hatchability of *Anopheles stephensi* eggs and deterred oviposition, demonstrating potential as a natural oviposition deterrent agent for mosquito population control (28).
Antioxidant	Oxidative stress	General health maintenance	Extract (ethanol)	*In vitro* assays	Demonstrates reducing power, superoxide anion radical scavenging, and deoxyribose degradation. Effective in scavenging free radicals and reducing oxidative stress (7).
Anti-inflammatory	RA	Pain condition	Aromatic root oil	Apply aromatic root oil topically to reduce pain in elderly patients	Anti-inflammatory effects observed, reducing pain and inflammation in patients with RA (5,31,32).

Table I. Continued.

Category	Use	Traditional/ Ayurvedic use	Plant part	Preparation: traditional or scientific	Research study (Refs.)
Antidepressant	Depression	For mental support	Extracts (various)	Ingested mixed with *Foeniculum vulgare*	Plant, in dose of 100 mg/kg, combined with *Foeniculum vulgare* (200 mg/kg) produces antidepressant effect in rats, comparable to fluoxetine (10 mg/kg) (33)
Memory and learning	Dementia	Brain tonic	Extracts (various)	Ingested as a mixture or applied as an extract	Reversed scopolamine-induced amnesia in mice, inhibited AChE activity, and improved memory and learning, indicating potential in managing dementia and Alzheimer's disease (34)
Stimulant and task performance	Cognitive enhancement	Aromatic baths and volatile compounds used to enhance alertness and task performance	Essential oil and volatiles	Aromatic bath or inhalation	Essential oil and volatile compounds enhance alertness and task performance in rats and humans, maintaining high sympathetic nervous system activity. Potential use as a stimulant to improve cognitive functions (38).
Anticonvulsant	Seizure disorders	Seizures	Extract (ethanol)	Ingested as a high-dose extract	Significant reduction in seizures (flexion, extension, clonus, stupor) in the MES model in mice, indicating potential use in managing convulsive disorders (8,39).
Antihyperglycemic	Diabetes	General health maintenance	Powdered plant	Consume 2-4 g khus powder directly with water or with lemon/ginger/honey	Ethanol extract lowers blood glucose in rats with diabetes when given over 28 days, demonstrating antihyperglycemic activity (40).
Nephroprotective	Kidney disease	General health maintenance	Extracts (Methanol)	Ingested as an extract	Protection against renal toxicity in rats with nephrotoxicity inflicted with doxorubicin. Protective compounds identified as: nootkatone, dehydroaromadendrene, isokhusenic acid, α-vetivone, and isolongifolene (41).

AChE, acetylcholinesterase; AKR1C1, aldo-keto reductase family 1 member C1; MCF-7, Michigan Cancer Foundation-7 breast cancer cell line; MES, maximal electroshock stimulation; RA, rheumatoid arthritis; UTI, urinary tract infection; TB, tuberculosis.

Anticancer activity. Vetiver exhibits a strong affinity for AKR1C1 (15), an antioxidant enzyme critical for a number of cellular mechanisms and implicated in several diseases, particularly cancer (22). It is known that reactive oxygen species (ROS) contribute to lung carcinogenesis; however, at the same time, they can also kill cancer cells (23). AKR1C1 can eliminate intracellular ROS (ROS is overexpressed in lung cancer) rendering AKR1C1 a potential therapeutic target (15). However, its structural similarity to AKR1C2 presents selectivity challenges. A previous study investigated vetiver as a selective AKR1C1 ligand for lung cancer co-therapy (15). Gas chromatography-mass spectrometry (GC-MS) identified 354 vetiver-derived compounds (15), which were analyzed using KNIME and molecular docking; β-vetispirene (Fig. 3) demonstrated the strongest AKR1C1 binding affinity (-15.12 kcal/mol), surpassing the native ligand and acetylsalicylic acid. These findings highlight the potential of vetiver as a selective co-chemotherapeutic agent. However, as that study was mainly based on bioinformatics, machine learning, and molecular docking approaches without any *in vitro* or *in vivo* experimental validation, findings remain predictive and require biological and clinical confirmation to establish real anticancer efficacy (15). In addition to this, Chitra *et al* (24) reported that an aqueous extract of vetiver root had marked anticancer potential. Vetiver exhibited *in vitro* cytotoxicity against MCF-7 human breast cancer cell line, using 3-(4,5-dimethyl thiazolyl-2-yl)-2, 5-diphenyl tetrazolium bromide (MTT) and assessment of cell morphology by using acridine orange and ethidium bromide staining, at an IC_{50} concentration of 5 to 50 μg/ml. The maximum inhibition of concentration was at 31 to 37 μg/ml at 24 and 48 h, respectively. That study was limited to an *in vitro* MTT assay using a single breast cancer cell line (MCF-7) without testing on normal cells or additional cancer models. Additionally, there was no effort to isolate and identify any phytoconstituents which limits conclusions about the specific anticancer constituents and their mode of action (24).

Antibacterial activity. Vetiver demonstrates notable antibacterial and antibiofilm properties (12,13). In a previous study (12), ethanolic (EVZ) and hydroalcoholic (HVZ) root extracts of the plant demonstrated antibacterial activity against *Staphylococcus aureus* and methicillin-resistant *S. aureus* (MRSA), with significantly larger zones of inhibition ($P<0.05$). Both extracts exhibited similar efficacy against *Pseudomonas aeruginosa* and *Candida albicans*. High-performance thin-layer chromatography (HPTLC) revealed 14 bioactive compounds in EVZ, compared to 10 in HVZ, with gallic acid (Fig. 3) identified as a key component, although the enhanced activity of EVZ suggests the synergistic effects of additional compounds (12). This study used only the disc diffusion method, while it was conducted entirely *in vitro* using crude extracts, with no *in vivo* validation to confirm clinical relevance (12). Complementing this, Seshadri *et al* (4) highlighted the potent antibacterial activity of the methanolic extract of vetiver against *Escherichia coli*, *Proteus mirabilis* and *Bacillus subtilis*. When combined in a polyherbal formulation, vetiver significantly enhanced the antimicrobial efficacy, particularly against *P. mirabilis* and *Enterobacter sp*., with a minimum inhibitory concentration (MIC) range of 29-34 μg/ml, demonstrating its broad-spectrum potential (4). Moreover, Kannappan *et al* (13) investigated vetiver root extract (VREX) for its antibiofilm activity against MRSA, finding it effective against biofilm formation in a concentration-dependent manner at sub-MIC levels without affecting bacterial viability. VREX disrupted biofilm-related phenotypes, such as exopolysaccharide production and slime layer formation, while downregulating critical adhesin genes (*fnbA*, *fnbB* and *clfA*) (13). GC-MS analysis identified sesquiterpenes as major bioactive components contributing to these effects. That study was also limited to *in vitro* experiments; no *in vivo* infection model was used to confirm therapeutic applicability (13). Collectively, these studies underscore the potential of vetiver as a promising source of antibacterial and antibiofilm agents, with effectiveness against MRSA and other pathogens. These antibacterial experimental results, albeit *in vitro*, justify the traditional use of vetiver in fever, skin infections/irritation and cholera (3).

Antimycobacterial activity. Previous studies (9,10) have demonstrated an antimycobacterial effect of vetiver. The essential oil exhibited activity against *Mycobacterium smegmatis* using two-fold serial micro broth dilution assay (9). A number of pure compounds were also isolated from guided fractionation and using preparative thin layer chromatography. The compounds exhibited antimycobacterial activity with MIC between 31.25-62.5 μg/ml. A limitation of that study was that it was performed only against *Mycobacterium smegmatis*, which limits direct clinical relevance. Saikia *et al* (10) examined the effects of vetiver root extract and fractions against the tuberculosis-causing bacteria strains of H37Rv and H37Ra, while using a radiometric BACTEC 460 TB system. The ethanol extract of vetiver roots (intact and spent) exhibited potent action against tuberculosis at 500 μg/ml. Additionally, the hexane fraction demonstrated anti-tuberculosis effects, causing a retardation of bacterial growth at 50 μg/ml (10). That study did not isolate or characterize specific active compounds responsible for the observed activity (10). These findings indicate that the ethanol extract and hexane fraction of *vetiver* roots possess significant antimycobacterial activity *in vitro.*

Antifungal activity. Vetiver is traditionally used in Indian folklore as an antimicrobial herb (3). In a previous study, it was evaluated for its antifungal activity against *Aspergillus niger, Aspergillus clavatus* and *Candida albican*s (14). Extracts made with ethanol and water were tested using the disc diffusion method, with results compared to standard antifungal agents, nystatin and griseofulvin. Both extracts demonstrated antifungal activity *in vitro*, with the ethanolic extract exhibiting superior efficacy. The effect was apparent in concentration-dependent manner (50-1,000 μg/ml). The MIC assays further confirmed the potent antifungal effects of the ethanolic extract, particularly against *A. niger* and *A. clavatus* (14). An investigation into the chemical constituents of the plant material revealed the existence of flavonoids, glycosides, phenols, tannins, saponins and alkaloids, which may contribute to its antimicrobial properties (14). No *in vivo* validation, toxicity assessment, or isolation of active antifungal ingredients was performed, limiting translational relevance (14).

Acaricidal activity. The *in vitro* acaricidal activity of vetiver was investigated in the study by Campos *et al* (25) and found to have significant acaricidal activity. Ticks are widespread in tropical and subtropical regions and serve as vectors for zoonotic diseases (26). The overuse of synthetic acaricides has led to resistance, necessitating alternative control methods (27). Campos *et al* (25) assessed the acaricidal effects of the essential oil of the plant with varying concentrations of zizanoic and khusimol acid (Fig. 3), (high and low acidity), against *Amblyomma cajennense* and *Rhipicephalus microplus*. Toxicity tests on adult females and larvae demonstrated that vetiver essential oils, regardless of acidity, significantly reduced oviposition, egg hatching and larval survival (25). Their efficacy exceeded that of some commercial acaricides. That study was conducted entirely under laboratory conditions (*in vitro* on adult and larval ticks) without field validation or safety assessment in animals. The results revealed that vetiver essential oil is a promising natural acaricidal agent (25).

Ovicidal activity. The ovicidal activity of vetiver was previously found to be significant *in vitro* (28). *Anopheles stephensi* is a primary vector of malaria (29), and alternative plant-based control measures are required due to increasing resistance to conventional pesticides (30). A previous study evaluated the ovicidal and oviposition deterrent potential of vetiver root against *A. stephensi* (28). Dried plant material was powdered, while ethanol was used as solvent to prepare the extract, which was further fractioned with acetone, and freshly laid *A. stephensi* eggs were challenged with different concentrations of the plant material for 2 days. Hatchability rates were calculated, and gravid female mosquitoes were observed for oviposition deterrence. Exposure to vetiver extract significantly reduced hatchability, with complete inhibition (zero hatchability) at 375 ppm (28). The oviposition deterrent test revealed a potent repellent effect, with an effective repellency (ER) of 78.9% at 375 ppm and 53.7% even at the minimum dose of 125 ppm. The negative oviposition effect index confirmed its deterrent properties. The ethanolic extract of vetiver roots demonstrated potent ovicidal and oviposition deterrent effects against *A. stephensi*. That study used crude ethanolic extract without isolating or characterizing specific active compounds, and no toxicity assessment or long-term environmental safety evaluation was performed (28).

Antioxidant properties. Subhadradevi *et al* (5) reported the antioxidant functions of vetiver. This plant is widely used in traditional medicine for aromatherapy, stress relief and insomnia (1-3). Subhadradevi *et al* (5) evaluated its ethanolic root extract for *in vitro* antioxidant activities, including reducing power ability, superoxide anion scavenging, deoxyribose degradation, total antioxidant potential, and the content of phenols and flavonoids. The action of the extract was compared with standard antioxidants, such as butylated hydroxytoluene, ascorbic acid, quercetin, α-tocopherol, pyrocatechol and curcumin. It effectively scavenged free radicals, including O_2^-, H_2O_2, OH and NO, in a concentration-dependent manner (5). These findings confirm the potent antioxidant activity of vetiver, supporting its traditional use in managing oxidative stress-related diseases. That study validated its ethnomedical claims and highlighted its antioxidant potential, rendering it a promising natural antioxidant source. However, that that the study was limited to *vitro* antioxidant assays without any *in vivo* or clinical validation to confirm biological relevance (5).

Anti-inflammatory properties. Several groups have shown the beneficial effects of vetiver in reducing and inhibiting inflammation. In a clinical study performed on human subjects, Alfiyansah *et al* (31) reported that vetiver root oil therapy effectively reduced pain levels from mild to moderate to severe in elderly patients with rheumatoid arthritis (RA) after 5 days of topical application, with statistically significant improvements ($P<0.05$). This effect was attributed to its anti-inflammatory property. That study included a small sample size (only 10 participants), which limits its generalizability. The follow-up period of 5 days was also short, while the pain was measured using a subjective scale without objective inflammatory markers (31). Grover *et al* (7) further highlighted the role of vetiver in reducing oxidative stress and inflammation by activating antioxidant enzymes, restoring oxidant-antioxidant balance, and suppressing pro-inflammatory mechanisms. Arafat *et al* (32) demonstrated that vetiver root extracts modulate biological signaling pathways to suppress inflammatory cytokines in complete Freund's adjuvant (CFA)-induced RA model in Wistar rats, *in vivo*, providing mechanistic evidence for its traditional use in treating inflammatory conditions. That study was performed in rats; thus, the findings cannot be directly translated to humans, while long-term safety and toxicity were also not fully determined (32). Similarly, Zahoor *et al* (6) emphasized the anti-inflammatory and antioxidant benefits of vetiver, linking these effects to sesquiterpenes and other bioactive compounds that collectively reduce pain and oxidative damage. As discussed above, sesquiterpenes are also the responsible constituent of vetiver for its antibacterial potential. Collectively, these findings underscore the potential of vetiver as a natural anti-inflammatory agent for managing conditions such as rheumatoid arthritis and other inflammatory disorders, while encouraging further research to fully elucidate its mechanisms and therapeutic applications. They also provide pharmacological basis for the traditional use of this plant in fever, pain, headaches and inflammation (3).

Antidepressant properties. In an *in vivo* study using Wistar albino rats, vetiver extract, along with an extract of *Foeniculum vulgare*, exhibited significant antidepressant properties (33). Vetiver is traditionally known for its use in aromatherapy and as a brain tonic and stimulant (3); it also exhibits anti-inflammatory properties as discussed above. Inflammation is linked to depression, and a previous study (33) opted to use an extract that has dual anti-inflammator,y as well as antidepressant effects. That study compared the antidepressant effects of fluoxetine (10 mg/kg) and a mixture of vetiver (100 mg/kg) and *F. vulgare* (200 mg/kg) in rats using the forced swimming and tail suspension tests. Extracts were administered 30 min before testing, and immobility time was recorded for 6 min. The combination of the two extracts significantly reduced immobility, exerting antidepressant effects comparable to fluoxetine. However, in that study, the sample size per group (n=6) was relatively small, limiting statistical power. Additionally, only short-term, acute behavioral tests were part of the study with no emphasis on any chronic depression models. As the study was performed in animals, clinical relevance to humans is uncertain (33).

Memory and learning enhancing. In an *in vivo* study performed by Velmurugan *et al* (34), the learning and memory enhancing effects of vetiver were evaluated in mice using the elevated plus maze (EPM) test. Various extracts, including chloroform (CEVZ), ethyl acetate (EAEVZ), ethanol (EEVZ) and aqueous (AEVZ), were administered orally at 500 mg/kg (duration of 4 weeks). The results revealed that EEVZ and AEVZ significantly improved learning and memory. This was due to the fact that there was a reduction in transfer latency (TL) in the EPM test noted. CEVZ had no effect, while EAEVZ had a lesser impact than EEVZ and AEVZ. Additionally, these extracts significantly reversed scopolamine-induced amnesia (0.4 mg/kg orally), suggesting a neuroprotective effect (34). To explore the underlying mechanism, central nervous system acetylcholinesterase (AChE) levels were determined. All extracts, barring CEVZ, notably reduced AChE activity (34), implying enhanced cholinergic function and potential for use in memory related disorders such as Alzheimer's disease (17,35,36). Piracetam (200 mg/kg, intraperitoneal), a standard nootropic, was employed as a standard reference (34). That study (34), as it was performed on mice using behavioral models (EPM) and acute scopolamine-induced amnesia, does not fully replicate human AD pathology. Vetiver is known to have gallic acid (Fig. 3) as one of its bioactive components (12). In previous research, the authors have demonstrated the AChE inhibitory activity of gallic acid (37). Thus, the presence of gallic acid in vetiver may be responsible for its memory enhancing effect. These findings highlight the potential of vetiver as a cognitive enhancer *in vivo* in mice.

Stimulant and task performance. Vetiver is widely cultivated for its essential oil, known for its aromatic and therapeutic properties. While its oil components have been extensively studied (20,21,25,31), the effects of vetiver volatile and essential oil inhalation on cognitive function and physiological responses remain underexplored. The study by Matsubara *et al* (38) demonstrated the impact of vetiver root emitted volatile compounds and essential oil on brain activity and cognitive performance in human volunteers. Participants exposed to low-dose root volatiles (1.0 g) during a visual display terminal task exhibited more rapid responses and increased sympathetic nerve functioning, measured via electrocardiography. However, these effects were absent at higher volatile concentrations (30 g) (38). The total volatile emission was 0.25 μg (low dose) and 1.35 μg (high dose), suggesting a dose-dependent response in cognitive and autonomic nervous system modulation. The study used a small sample size (n=6-12 per condition), limiting statistical power and generalizability. Also, only short-term exposure was determined only, while no long-term cognitive or physiological effects were tested (38). Another study by Cheaha *et al* (39), examined the activity of the essential oil respiratory intake of the plant on sleep-wake patterns and electroencephalogram (EEG) activity *in vivo* in Wistar rats. Plant oil inhalation profoundly increased the state of wakefulness and relaxed slow wave sleep. EEG analysis revealed lower alpha and beta1 functioning in frontal and parietal cortices, along with higher gamma functioning in frontal cortex, indicative of heightened alertness (39). These changes occurred almost immediately following exposure. As that study was conducted only in male Wistar rats, it limits its translation to humans (39). Taken together, these findings suggest that vetiver volatiles and essential oil may enhance cognitive performance and promote wakefulness by modulating sympathetic nervous system activity and brainwave patterns (38,39). This supports its potential application as a natural cognitive enhancer and stress modulator.

Anticonvulsant properties. Vetiver has been medicinally employed in the South Asian cultures for treating a number of different disorders, including seizures, although its anticonvulsant activity remains unexplored (1,2). In an *in vivo* study (8), the anticonvulsant potential of its extract in ethanol (EEVZ) in mice was evaluated using maximal electroshock stimulation (MES) and pentylenetetrazole (PTZ) for 8 days. EEVZ was administered to the animals in increasing concentrations (100-400 mg/kg). The LD_{50} of EEVZ was reported as 600 mg/kg. At the maximum dose of 400 mg/kg, EEVZ suppressed seizure parameters ($P<0.001$) in the MES model, including flexion (15.98 to 3.73 sec), extension (13.73 to 0.96 sec), clonus (14.07 to 4.93 sec) and stupor (6.29 to 1.22 sec). For the PTZ model, the plant material delayed the onset of clonic (88.25 to 708.32 sec) and tonic (139.52 to 1126.39 sec) seizures. Survival rates improved, with 100% protection observed in EEVZ (200 and 400 mg/kg) and the standard phenobarbital-treated groups. As the study was performed in mice using acute seizure models (MES and PTZ), the findings may not fully translate to human epilepsy (8).

Antihyperglycemic activity. Vetiver has shown significant antihyperglycemic activity (40). In a previous study, plant material was evaluated for its antihyperglycemic activity *in vivo* in Wistar albino rats with diabetes induced with alloxan monohydrate (150 mg/kg, intraperitoneally). The test animals were separated into 6 groups (40). The first batch of animals was left untreated, another was administered the standard drug, glibenclamide (10 mg/kg), while the remaining batches were administered ethanol extract of vetiver roots (100-750 mg/kg orally) for 28 days. Blood glucose levels were monitored throughout the duration of the experiment. Phytochemical screenings and acute toxicity studies were also conducted. The results revealed a pronounced lowering of blood glucose levels in all extract-treated groups by day 28, with effects comparable to glibenclamide (40). These findings support the traditional use of vetiver for its antidiabetic potential. That study concluded that the ethanol extract of vetiver possessed hypoglycemic and antihyperglycemic properties. However, in that study, the sample size selected (n=6 per group) was small and the absence of detailed biochemical parameters (e.g., insulin levels, lipid profile, oxidative stress markers) limit mechanistic insight. Long-term toxicity and safety evaluation were also not comprehensively assessed (40).

This antihyperglycemic effect, together with the antihypertensive (11), memory enhancing (34) and nephroprotective benefits of vetiver (41), not only relates to its traditional use in heart and brain related conditions (3), but also indicates the potential of this medicinal herb in diabetes, diabetes induced complications and metabolic syndrome (42).

Nephroprotective effects. In the by Amarasiri *et al* (41), a renal-preserving potential of a water-based extract of vetiver was evaluated in a doxorubicin-induced renotoxic model in Wistar rats. Freeze-dried plant extract (25-100 mg/kg) was administered to nephrotoxic animals, leading to a dose-dependent lowering in serum creatinine, β2-microglobulin, and blood urea nitrogen, while elevated serum total protein and albumin ($P<0.05$). Histological analysis revealed the attenuation of renal injury (41). GC-MS analysis identified bioactive compounds, including nootkatone, dehydroaromadendrene, isokhusenic acid, α-vetivone, and isolongifolene (41) (Fig. 3). Out of these pure compounds, only nootkatone is a well-studied chemical reported for its nephroprotective effects (43-46). These results suggest that vetiver possesses significant nephroprotective properties in rats *in vivo*, potentially due to its antioxidant activity. Currently, there is no definitive evidence for its clinical benefits as no human clinical validation was performed in the study, limiting translational applicability. Traditionally used in kidney-related ailments, it is also a dietary ingredient with recognized health benefits. Given its antioxidant potential, vetiver may serve as a promising lead for further research in the area of kidney diseases.

Possible role in functional nutrition. Vetiver is an age-old edible herb, regarded for its numerous uses and benefits. It is known in folk medicine for being a tonic for the heart and brain, antispasmodic, diuretic, diaphoretic, and for increasing menstrual blood flow (3). Its root infusion is traditionally used in fever, inflammation and irritability of the stomach, which suggests that it could be added to beverages or food products as a functional ingredient. Based on animal studies showing antioxidant (5), hypoglycemic (40), antihypertensive (11), neuroprotective (34) and nephroprotective (41) effects, vetiver may have potential not only in supporting people at risk for metabolic syndrome but also for medical complications and consequences arising in diabetics. However, more research in humans is needed to confirm its safety, proper dosage, and real benefits before it can be recommended as a functional food or dietary supplement.

Toxicity, interactions and standardization of extracts. As with any chemical or medication, plant material can also possess side-effects along with their medicinal benefits. For this reason, it is important that apart from the discussion of the positives of plants and herbs, insight is also shed on any potential adverse effects. Reviewing the profile of vetiver from the available traditionally used medicinal plant books (1-3), no side-effects or points of concern were identified. On the experimental side, Yeram *et al* (47) undertook a comprehensive study on the toxicity potential of a hydroalcoholic extract of vetiver roots. In that study, they performed acute and repeated-dose toxicity studies on the extract. The results revealed that the extract in a single dose of 5 g/kg, did not exhibit any toxicity or mortality in rats. Similarly, in the repeat dose study spread over 28 days, the extract did not alter any of the hematologic or biochemical parameters. None of the plant compounds exhibited any cytotoxic or mutagenic activities. However, at a high dose of 1 g/kg, administered daily for 28 days, the extract led to an increase in liver enzymes, indicating that at a high dose used daily, it could pose some harm for the liver (47). Thus, vetiver is generally considered safe; however, information regarding its interactions with conventional medicines and other herbs and foods is limited.

Using standardized extracts in medicinal plant pharmacology research is critical. Plants can vary in their chemical composition depending on where they belong and where they grow, how they are harvested, and how they are processed. If researchers do not use standardized extracts, the number of active compounds may differ from one study to another. This makes it difficult to compare results across studies or to repeat the same experiment and get similar outcomes. Standardized extracts help ensure consistency, improve the reliability of findings, and make research more reproducible for the scientific community. From the literature, it was identified some studies (41,48) have used standardized extracts when reporting their findings on vetiver. Amarasiri *et al* (41), in reporting the nephroprotective effects of an aqueous root extract of vetiver, processed the extract to determine its different characteristics, such as as h value, extractive value, moisture content, microbial contamination and heavy metal analysis. They also developed a thin layer chromatography fingerprint of the extract, while also identified pure compounds in the extract via use of from GC-MS.

Conclusion and future perspectives. Drawing together the extensive historical record and the growing body of modern research, vetiver emerges as a plant with notable therapeutic promise. Centuries of Ayurvedic practice document its utility in treating a broad range of ailments-from inflammatory conditions and infectious diseases to mental health disorders and metabolic imbalances. Contemporary studies now provide scientific support for many of these applications, demonstrating the antimicrobial, anticonvulsant, anti-inflammatory, antidiabetic and even anticancer properties of vetiver. Key bioactive compounds, such as β-vetispirene, exhibit targeted efficacy, most notably against AKR1C1 in lung cancer, while ethanol and hexane extracts exhibit potent antibacterial and antimycobacterial activities. These converging lines of evidence underscore vetiver's potential to serve both as a standalone therapy and as an adjunct to conventional treatments, helping to mitigate issues like drug resistance, adverse side effects, and limited efficacy in chronic conditions. Yet, despite promising outcomes, most studies remain small-scale or preclinical, indicating the need for more rigorous, large-scale clinical investigations. Future research should focus on standardizing extraction methods, elucidating molecular pathways of action, and optimizing delivery forms consistent with traditional dosing regimens. In doing so, the Ayurvedic heritage of the plant will be honored, while integrating it into the modern pharmacotherapeutic landscape. As the conversation around holistic health continues to evolve, vetiver stands as a testament to how traditional knowledge, when combined with rigorous scientific inquiry, can lead to new paradigms in safe, effective, and culturally informed healthcare.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

SA, ZD and AD contributed to the writing and preparation of the original manuscript. MNG contributed to the writing, reviewing and editing of the manuscript. ZD and AD contributed to design of the study while SA and MNG were involved in conception and design of the study. SA and MNG confirm the authenticity of all the raw data. All authors have read and approved the final manuscript.

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Not applicable.

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Not applicable.

Competing interests

The authors declare that they have no competing interests.

Use of artificial intelligence tools

During the preparation of this work, AI tools were used to improve the readability and language of the manuscript or to generate images, and subsequently, the authors revised and edited the content produced by the AI tools as necessary, taking full responsibility for the ultimate content of the present manuscript.

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