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Commercialisation potential of *Tetradenia riparia* (Hochst.) Codd: A review based on traditional uses and scientific validation

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Background: Globally, medicinal plants and their health-related products provide significant income and are recognised as important contributors to livelihoods. There still exist challenges in the commercialisation of certain medicinal plants over others. A medicinal plant widely used by indigenous African communities, *Tetradenia riparia* (Hochst.) Codd presents strong potential for large-scale commercialisation. Despite its widespread use, limited data exist on the potential impact of commercialising *T. riparia*.

Aim: This review explores the commercialisation potential of *T. riparia* by highlighting its traditional uses, scientific validation, possible commercialisation prospects and opportunities for economic growth and product development.

Setting: The review draws on peer-reviewed scientific literature to assess the status of the plant and its potential role in both local and global markets.

Method: A systematic literature review was conducted using targeted search terms related to the commercialisation of medicinal plants and *T. riparia*. Relevant publications were screened by title, abstract and full text, and the most appropriate studies were analysed to provide insights into the plant's commercialisation potential.

Results: Findings reveal that *T. riparia* is a promising medicinal plant with significant commercialisation prospects. In addition to its role as an alternative medicine for various health conditions, the plant demonstrates potential in other markets, including food supplements, oral care products, natural pesticides and food preservation.

Conclusion: This review highlights the medicinal significance of *T. riparia* (Hochst.) Codd (*T. riparia*), emphasising its scientifically validated therapeutic potential and diverse market opportunities.

Contribution: This study contributes to the growing body of knowledge on the potential of *T. riparia* (Hochst.) Codd.

Keywords: commercialisation; plants; ethnopharmacological; cultivation; sustainability.

Introduction

A large portion of the global population still depends on medicinal plants, many of which are commonly traded in informal markets. These plants are valuable natural resources with wide-ranging applications in the pharmaceuticals, food, cosmetics and pesticide industries. As consumer demand for natural products continues to rise, global trade in medicinal plants has expanded significantly. This growing market creates important economic opportunities, particularly for vulnerable communities living in peri-urban, rural and marginalised areas (Rasethe, Semenya & Maroyi 2019; Zamani et al. 2025). Traditional medicines are often preferred because they are readily available, affordable and perceived to have fewer side effects compared to Western medicines (Aguzzi et al. 2024; Zaidi et al. 2022). Although medicinal plants are considered minor crops compared to staple foods, their commercial value ranks among the highest traded plants, providing a vital source of revenue for rural livelihoods (Mofokeng et al. 2022).

Promoting the cultivation of medicinal plants offers opportunities for local economic development through job creation, revival of rural economies and income generation for small businesses such as transport services. Ensuring land accessibility, financial resources and direct market access for rural communities can further elevate their contribution to the industry. Formalisation of lower

levels of the medicinal plant trade is also recommended to strengthen sustainability (Mofokeng et al. 2022). Empirical evidence demonstrates that commercialisation significantly improves livelihoods, increasing net returns by a higher percentage and then per capita expenditure. These findings highlight the importance of policy reforms that encourage active market participation of indigenous knowledge holders, particularly in developing countries where poverty and economic sustainability remain pressing challenges (Ndhlovu et al. 2023). Despite Africa's existing laws to conserve and promote indigenous knowledge, commercialisation of medicinal plants remains low, necessitating greater emphasis on participatory management and cultivation of selected species to stimulate disadvantaged economies (Ndhlovu et al. 2021).

Medicinal plants are endowed with diverse phytochemicals that contribute to their bioactivity and therapeutic potential (Hamilton-Amachree et al. 2024; Njau et al. 2014). Certain renowned species have achieved international acclaim; these medicinal plants include lavender, mint, lemon balm and rosemary, which have been recognised for their nutritional and medicinal value and widely commercialised in global markets (Ivanišová et al. 2021). However, many commonly used plants have not yet reached the global market, presenting untapped opportunities (Street & Prinsloo 2013). To ensure sustainable commercialisation, it is essential to identify the compounds responsible for efficacy, confirm their safety and develop standardised plant extracts through controlled plant propagation while optimising extraction processes to yield higher concentrations of bioactive compounds (Masondo et al. 2025). Plant propagation, which is the art and science of multiplying plants by combining creative techniques such as seed sowing, cuttings, grafting and layering with scientific knowledge of plant physiology, genetics and environmental responses to ensure successful growth and perpetuation of species needs to be well understood (Nagajyothi, Pratheeksha & Pooja 2023). To harness this potential, Africa needs to invest in propagation and cultivation research, ensuring that farmers are well trained on protocols that are regularly updated to account for climate change impacts on crop production (Masondo et al. 2025).

Despite their potential, commercialisation efforts are hampered by middlemen, lack of organised support systems, weak regulatory strategies and unclear criteria for ensuring quality and efficiency (Chidembo et al. 2023). Only a few medicinal plants have been exploited to their full potential in terms of commercialisation (Street & Prinsloo 2013). Globally, thousands of plant species are traded annually, yet past interventions have not ensured sustainable trade, leaving species vulnerable to overharvesting and threatening rural household incomes, the processing industry and government revenues (Smith–Hall et al. 2025). Sustainable cultivation of medicinal plants is therefore critical not only to provide raw materials for medicines and cosmetic products but also to stabilise high-volume markets (Kurnaz & Aksan Kurnaz 2021).

Several species used as herbal medicines are already threatened with extinction because of overharvesting driven by their popularity in local markets (Rasethe et al. 2019). This underscores the necessity of broadening commercialisation to include plant species that remain under-represented in the market.

Among these, *Tetradenia riparia* (Hochst.) Codd (Lamiaceae) stands out as a widely utilised species in African traditional medicine for managing both communicable and non-communicable diseases. All parts of the plant have demonstrated promising activity in treating various medical conditions (Luanda & Ripanda 2023). Understanding the therapeutic actions and scientific validations of *T. riparia* is crucial for advancing the development of new, marketable herbal medicinal products. Beyond its health benefits, commercialisation of this plant holds potential to improve the economic situation of struggling communities, offering livelihood opportunities to millions of people who lack access to formal employment.

Methods

To compile relevant literature for this review, systematic literature searches were conducted using databases: Google Scholar, ScienceDirect and PubMed. A search strategy was employed using targeted keywords and phrases such as commercialisation of medicinal plants, ethnomedicine, cultivation strategies, sustainable management of commercial harvesting of medicinal plants and *T. riparia*. To reduce the inclusion of non-target articles, publications were initially screened by titles and abstracts, with less relevant studies excluded from further consideration. Bibliographies of retrieved articles were also examined to identify additional sources of relevance. All references were systematically organised and managed using the Mendeley reference manager. Both recently published articles (up to 2026) and older studies were included to ensure comprehensive coverage of the topic. The decision to focus on *T. riparia* was informed by its established medicinal importance and its potential sustainability as a candidate for future commercialisation.

Habitat and distribution of *Tetradenia riparia*

The *T. riparia* (Hochst.) Codd plant is a herbaceous shrub belonging to the Lamiaceae family. It is commonly known as the ginger bush or false myrrh. The species naturally occurs along riverbanks, forest margins, dry wooded valleys and wooded hillsides in warmer areas where frost is minimal (Cardoso et al. 2015; Gairola et al. 2009; Gazim et al. 2014). The species is native to the African continent. Its natural distribution ranges from South Africa to Swaziland, Namibia, Angola and northwards through tropical east African countries such as Tanzania, Rwanda, Kenya, Uganda and Ethiopia (Gairola et al. 2009; Njau et al. 2014; Shimira 2022; Van Puyvelde et al. 2018; Zardeto et al. 2022).

The ethnopharmacological uses of *Tetradenia riparia*

Traditional and folk medicine

The *T. riparia* plant has long been valued in folk medicine across Africa, where it is employed to treat a wide range of ailments. Infusions and decoctions prepared from the plant tissues are taken internally to relieve respiratory problems, coughs, colds, flu, bronchitis, stomach pain, flatulence, diarrhoea, mouth ulcers and fevers (Coopoosamy & Naidoo 2012; Okem, Finnie & Van Staden 2012). It is also applied for toothaches, while inhalations are used for headaches (Okem et al. 2012). Decoctions of the leaves are also applied to wounds and skin sores, reflecting its widespread use in traditional healing practices that include dermatology (Coopoosamy & Naidoo 2012).

Antimicrobial and antiparasitic activities

The plant is well known for its antimicrobial and antiparasitic properties. Scientific studies have validated its activity against Gram-positive and Gram-negative bacteria, as well as fungal strains, supporting its traditional use against infections (Coopoosamy & Naidoo 2012; Ndamane et al. 2013). Extracts and essential oils have demonstrated antimicrobial, antifungal, acaricidal and analgesic activities along with insecticidal, trypanocidal and antimalarial effects (Gazim et al. 2014; Scanavacca et al. 2022). In addition, *T. riparia* has shown anthelmintic and antischistosomal activity (De Melo et al. 2015b; Marble, Montero & Vallandares 2019). The essential oil of *T. riparia* (TrEO) is also used for worm infections and has shown activity against *Schistosoma mansoni*, reducing egg development in a dose-dependent manner without significant cytotoxicity to mammalian cells (De Melo et al. 2015b; Van Puyvelde et al. 2018). Bioassays revealed weak larvicidal activity against *Aedes aegypti* larvae (Zardeto et al. 2022). Its essential oils are also used as insect repellents, further highlighting its versatility (Fernandez et al. 2017).

Anti-inflammatory and analgesic uses

Anti-inflammatory and analgesic properties are another cornerstone of *T. riparia's* ethnopharmacological profile. Communities have long used the plant to treat inflammatory and infectious diseases with leaves and essential oils applied for respiratory infections and inflammation (Cardoso et al. 2015; Shimira 2022). Modern assays confirm these traditional claims: stem and leaf extracts strongly inhibit nitric oxide (NO) release and lipoxygenase (LOX) activity, demonstrating potent anti-inflammatory potential (Ghuman et al. 2019). Analgesic activity has also been reported, reinforcing its role in pain management (Gazim et al. 2014).

Antiproliferative, antioxidant and antiviral activities

Beyond its anti-inflammatory effects, *T. riparia* exhibits antiproliferative, antioxidant and antiviral activities. Extracts have shown activity against tumour cell lines, inhibition of NO production and significant antioxidant potential (Sena et al. 2024; Shimira 2022). Essential oils from the plant have been widely investigated for their biological activities, including antimycotoxigenic effects, further supporting its pharmacological promise (Scanavacca et al. 2022). The plant is also traditionally utilised to manage various transmitted and non-transmitted diseases such as human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) and viral respiratory problems (Luanda & Ripanda 2023). These widespread applications underscore its importance as a medicinal resource of economic importance across diverse communities.

Secondary metabolites of *Tetradenia riparia*

Methods of characterisation

The study of phytochemicals and compounds from *T. riparia* has relied on qualitative and quantitative measures such as phytochemical analysis and methods that include fractionation, purification and subsequent structural elucidation to identify bioactive compounds. Characterisation of fractions and isolated metabolites is typically performed using diverse spectroscopic techniques. Recent spectroscopic techniques, particularly two-dimensional nuclear magnetic resonance (2D NMR), mass spectrometry, fourier transform infrared spectroscopy (FT-IR), Ultraviolet-Visible spectroscopy (UV-Vis) and gas chromatography-mass spectrometry (GC-MS) along with the advent of hyphenated methods such as Liquid Chromatography-Mass spectrometry (LC-MS), GC-MS and Liquid Chromatography-Nuclear Magnetic Resonance (LC-NMR), exploit the absorption of electromagnetic radiation by organic molecules to produce spectra specific to certain bonds, thereby enabling precise structural identification (Ebada et al. 2008; Njewa et al. 2025; Verma et al. 2025).

Phytochemical screening

Phytochemical screening of *T. riparia* crude extracts has revealed the presence of alkaloids, coumarins, flavonoids, phenolics, saponins, tannins and sterols (Marble et al. 2019; Njau et al. 2014; Sena et al. 2024). Additional studies confirmed the presence of terpenes, anthocyanins, cardiac glycosides, steroidal rings and gallotannins (Chepng'etich et al. 2018; Mutuku et al. 2014; Okem et al. 2012; Scanavacca et al. 2022).

Extract composition and isolated compounds

The TrEO has been extensively studied, with GC-MS analyses revealing terpenoids as major constituents, particularly oxygenated sesquiterpenes (Cardoso et al. 2015). Decades of research have focused on isolating chemical constituents from leaves, floral buds and stems (Panda et al. 2022). A study by Van Puyvelde et al. (2018) led to an isolation of a bioactive compound where bioassay-guided isolation of anthelmintic compounds from the leaves of *T. riparia* was conducted using *Caenorhabditis elegans* as the testing model.

Extracts of different solvents were tested and the hexane extractexhibited the highest activity, further fractionation was then applied to the hexane extract. Subsequent liquid–liquid partitioning of the hexane fraction (into hexane and dichloromethane phases), followed by column chromatography of the dichloromethane fraction over silica gel, led to the isolation of the active anthelmintic principle: 8(14), 15-sandaracopimaradiene-7α,18-diol.

Several studies have reported specific major constituents of TrEO. These include fenchone (15%), δ-cadinene (11%), 14-hydroxy-β-caryophyllene (8%) and tau-cadinol (7%) compounds found in the essential oil from aerial parts of the plant where TrEO was analysed by GC-flame ionisation detection and GC-MS (Blythe et al. 2020). Other compounds isolated include 9β,13β-epoxy-7-abietene and 6,7-dehydroroyleanone as well as the sesquiterpene hydrocarbon 14-hydroxy-9-epi-(E)-caryophyllene (Araujo et al. 2018; Gazim et al. 2014). Gas chromatography and GC-MS analysis of the essential oil from plant leaves also identified aromadendrene oxide (14.0%), (E,E)-farnesol (13.6%), dronabinol (12.5%) and fenchone (6.2%) as major constituents (De Melo et al. 2015a).

Profiling of the essential oil by GC-MS revealed 49 compounds, with oxygenated sesquiterpenes (45.95%) and sesquiterpene hydrocarbons (35.20%) as the dominant classes. The major components included isospathulenol (17.40%), β-caryophyllene (15.61%), 14-hydroxy-9-epi-caryophyllene (10.07%), 14-hydroxy-α-muurolene (8.32%) and 9β,13β-epoxy-7-abietene (5.53%) (Ferarrese et al. 2023). Collectively, these findings highlight the chemical diversity of *T. riparia*, with secondary metabolites spanning across terpenoids, flavonoids, phenolics, tannins, saponins and glycosides, many of which contribute to its pharmacological and ethnomedicinal significance. This diversity can directly play a role for its commercialisation use in the different markets.

Cultivation and preparation of *Tetradenia riparia*

Cultivation approaches

Cultivation research consistently receives little attention, limiting sustainable availability of quality medicinal plant raw materials (Masondo et al. 2025). Recent advances in cultivation techniques have demonstrated that aeroponic systems provide significant opportunities for improving the quantity, quality, consistency and biomass production of medicinal plant roots. In the case of *T. riparia*, aeroponic cultivation produced clean, high-quality roots in large quantities, with bioactivity confirmed through antibacterial, antiplasmodial and cytotoxicity assays. This method facilitates rapid propagation for therapeutic potential, conservation purposes and commercial use, meeting the demands of both traditional medicine and the pharmaceutical industry (Kumari et al. 2016). The production of high-quality roots in large quantities by such methods as aeroponic systems could solve the sustainability issue regarding the long-term use of *T. riparia* roots both in the informal and formal commercial sector.

Cultivation conditions, including shading levels and seasonal variations, strongly influence essential oil yield and composition. Plants grown under 30% and 50% shading produced the highest yields, while full sunlight and 80% shading resulted in lower yields. Certain compounds, such as verbenone, were exclusive to full sunlight treatments, whereas others were unique to shaded conditions, highlighting the role of environmental factors in metabolite diversity of *T. riparia* (Araujo et al. 2018). When seasons were compared as a factor in the bioactivity of TrEO extracts, it was seen that they only caused a slight difference in the seasonal TrEO extracts' effects on cytotoxicity and bioactivity. *Tetradenia riparia* essential oil harvested in summer showed the least cytotoxicity. While NO production in assays did not change with samples from different seasons, also the extracted TrEO maintained consistent activity against the *Leishmania amazonensis* parasite tested on, without toxicity to mammalian spleen cells (Cardoso et al. 2015). This shows that the plant can be cultivated and harvested during different seasons of the year, while for optimal yield, direct constant sunlight must be avoided where possible.

Extraction and yield

Phytochemical extraction methods significantly influence yield and bioactivity. Aqueous and alcoholic extracts from dry leaves yielded 14.07% and 23.0%, respectively (Marble et al. 2019). Essential oil yields were reported at 0.29% ± 0.22% in leaves and 0.38% ± 0.17% in flower buds (Zardeto-Sabec et al. 2020). Comparative solvent studies revealed that water extracts produced the highest yields and strongest antibacterial activity against chest and cough-related infections, whereas dichloromethane extracts showed no inhibitory effect (Ndamane et al. 2013). Variability in isolated compounds across studies may be attributed to differences in plant parts used, collection and processing methods, extraction techniques and geographical or growth conditions (Panda et al. 2022). High polarity solvents, such as water being able to produce a good extraction yield and bioactivity, will make the extraction of the *T. riparia* a low-cost and safe process.

Preparation and administration in traditional medicine

Preparation methods for *T. riparia* vary across cultures and include the use of fresh or dried plant materials. Common techniques involve extraction, infusions, decoctions, tinctures, ashing and other miscellaneous methods (Abubakar & Haque 2020; Malini, Saranya & Parameswari 2023). Traditional medicines may be administered orally, rectally, topically or nasally. Other practices include smoking dried plant material, passive inhalation, steaming and inhaling volatile oils from boiling plant material to relieve congestion, headaches or pulmonary problems. Sitz baths are also used for conditions such as piles (Frimpong, Asong & Aremu 2021; Rankoana 2022; Sarbaz et al. 2019).

The choice of preparation and administration method is often guided by efficiency, safety and cultural practices. For example, syrups or tinctures may be more suitable for children than tablets because of ease of ingestion. Adherence to recommended methods of administration is critical, and consumers are advised to consult traditional medicine practitioners or retailers for appropriate dosage forms, including tablets, teas, capsules and salves (Ekor 2014; Smith, Leggett & Borg 2022; Van Wyk & Prinsloo 2020). It is important that the scientific community works with the traditional practitioners to help the farmers of *T. riparia* prepare the medicinal plant in the best way possible to retain its bioactivity even at post-harvesting period.

Stability studies

Stability of medicinal plant products refers to their ability to resist disintegration of individual components within the product. Conducting stability studies is essential to ensure the quality, safety and efficacy of herbal medicines (Chaudhary & Kumari 2022). Several environmental and chemical factors can influence stability, including temperature, pH, light exposure, moisture, solvents, air and enzymatic degradation. Different testing methods are employed depending on the specific stability parameters being assessed (Briscoe & Hage 2009; ElGamal et al. 2023).

Recent innovations highlight nanoencapsulation as a promising strategy to enhance the stability of TrEO. Furthermore, encapsulation of TrEO into poly(lactide) (PLA) nanoparticles preserved antimicrobial efficacy, reduced cytotoxicity and improved physicochemical stability (Makimori et al. 2026). Toxicological studies by Rabelo et al. (2024) confirmed that oraladministration of nanoemulsified TrEO did not result in acute toxicityin mice at levels that maintain insecticidal and antimicrobial properties against *Aedes aegypti, Staphylococcus aureus, Escherichia coli and Pseudomonas aeruginosa*. These findings indicate a high safety threshold at tested concentrations, reinforcing the importance of looking into stability technologies in the commercialisation of some *T. riparia* products.

Review findings

The global trade and commercialisation of *Tetradenia riparia*

The *T. riparia* plant in its native African continent is considered one of the most popular aromatic medicinal plants, thus representing economic benefits as well (Makimori et al. 2026; Panda et al. 2022). Currently, the plant is mostly sold on the informal medicinal market as a raw plant product; there is a need to infiltrate different markets if the plant is to play a bigger part in the economy.

Pesticide applications

In a study carried out by Blythe et al. (2020), short-range attraction bioassays were used where sterile male *Ceratitis capitata* flies were tested in small cages under controlled laboratory conditions. A Petri dish containing filter paper treated with TrEO was introduced, and fly responses were recorded after 30 min as the percentage attracted to the dish. Each assay was replicated five times with randomised cage positions. The TrEO showed great promise in integrated pest management, functioning as natural repellents, attractants and toxicants with reduced environmental impact. In Brazil, resistance of *Rhipicephalus sanguineus* ticks to some insecticides such as pyrethroids has motivated research into phyto-insecticides derived from *T. riparia* leaves and flower buds, as a natural pesticide (Zardeto-Sabec et al. 2020).

A study by Zardeto-Sabec et al. (2020), where the larvicidal activity of TrEO was evaluated using the larval packet test, TrEO dilutions were applied to filter paper 'sandwiches' containing larvae, with mortality assessed after 24 h against positive and negative controls. In parallel, anticholinesterase activity was determined through a bioautographic method, in which Essential oil (EO) samples were applied to chromatoplates, treated with enzyme and substrate solutions, incubated and visualised with Fast Blue B reagent to detect activity. Both assays were conducted in triplicate, and results were statistically analysed. The researchers concluded that the *T. riparia* species shows strong promise as a candidate for inclusion among chemical larvicides used to control this ectoparasite.

The study was also supported by Ferarrese et al. (2023), where the larvicidal activity of TrEO was evaluated against *Rhipicephalus microplus* and third-instar *Aedes aegypti* using the larval packet and larval immersion tests, respectively. Anticholinesterase activity was assessed through a bioautographic method. The bioassays revealed that the essential oil was highly active, with an LC_{50} of 1.56 µg/mL against both *R. microplus* and *A. aegypti* larvae, and it also exhibited acetylcholinesterase inhibitory activity. The findings indicated that TrEO holds strong potential for the development of novel, environmentally safe agents to control these pests.

Oral care products

In Brazilian folk medicine, the plant has traditionally been used to treat toothaches and dental abscesses, reinforcing its relevance in dental health applications (De Melo et al. 2015a). In a study by De Melo et al. (2015a), the antibacterial effects of from TrEO leaves grown in Southeastern Brazil were evaluated against a representative panel of oral pathogens. The antibacterial activity was assessed using minimal inhibitory concentration (MIC), with TrEO displaying values between 31.2 and 500 µg/mL. The lowest MICs were observed against *Streptococcus mitis* (31.2 µg/mL), *Streptococcus mutans* (62.5 µg/mL), *Streptococcus sobrinus* (31.2 µg/mL) and *Lactobacillus casei* (62.5 µg/mL). Time-kill experiments further demonstrated that TrEO exhibited bactericidal activity against *S. mutans* within the first 12 h, producing a curve profile comparable to chlorhexidine. The findings highlighted the promising potential of TrEO in combating cariogenic bacteria, particularly *S. mutans*.

This bioactivity of *T. riparia* against cariogenic bacteria is indicative of its potential use in oral care products such as toothpaste, mouthwash, dental gels, chewing gums and lozenges.

Food supplements and preservation

Studies have shown its potential as both a dietary additive and an antibacterial remedy (Hamilton-Amachree et al. 2024). In a study by Hamilton-Amachree et al. (2024), the antimicrobial activity of the extracts was tested against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Bacillus subtilis* using the agar well diffusion method. Bacterial cultures were incorporated into nutrient agar, and wells were filled with the test extract (5 mg/mL in methanol), and antimicrobial efficacy was then assessed by measuring the diameter of inhibition zones. Among the tested extracts, the wet leaf methanol extract exhibited the strongest activity, showing inhibition zones of 20 mm against *P. aeruginosa* and 22 mm against *E. coli*. The study then further looked at the mineral content of *T. riparia*, and it was determined following standard procedures. Briefly, the sample was first ashed, dissolved in a suitable solvent and the resulting solution aspirated into an air–acetylene flame. Quantification was carried out using atomic absorption spectrophotometry, while flame emission spectrophotometry was employed for specific elements. The high macronutrient composition of *T. riparia* contained calcium, potassium and iron, which positions it as a prospective nutritious food supplement.

Furthermore, research has demonstrated the antimicrobial activity of *T. riparia* leaf essential oil against foodborne pathogens, highlighting its potential role in combating food spoilage and reducing reliance on synthetic preservatives (Scanavacca et al. 2023). In a study by Scanavacca et al. (2023), the antimicrobial activity of *T. riparia* leaf essential oil was evaluated using the broth microdilution method. The oil demonstrated broad antibacterial and antifungal effects, showing fungistatic and fungicidal activity against *Aspergillus versicolor* and *Penicillium ochrochloron*, as well as bacteriostatic and bactericidal activity against *Bacillus cereus*, *Listeria monocytogenes* and *S. aureus*.

Herbal medicines and synergistic therapy

Globally, much of the population continues to consult traditional healers alongside instead of depending wholly on Western medical practitioners, underscoring the need for collaboration between the two systems (Jama et al. 2024; Masola & Maotoana 2025). International examples from countries such as China, India and South Korea demonstrate the feasibility of integration, where modern and traditional medicine are legally formalised through integrated clinics (Thamizhoviya 2025). These models highlight the potential for medicinal plants, including *T. riparia*, to be marketed within integrated healthcare frameworks. As healthcare models that merge traditional and modern practices expand globally, the financial benefits to medicinal plant farmers, including *T. riparia* farmers and stakeholders, are expected to increase.

Conclusion

This review has discussed strategies for the sustainable management of medicinal plant harvesting, alternative cultivation approaches and the potential economic impact of *T. riparia* (Hochst.) Codd. The findings indicate that *T. riparia* can be cultivated and harvested throughout different seasons although optimal yields require careful management, such as avoiding prolonged direct sunlight. Furthermore, the use of high-polarity solvents such as water has proven effective in achieving good extraction yields and bioactivity, making the extraction process both low cost and safe. Collaboration between the scientific community and traditional practitioners is essential to ensure that farmers prepare and process the plant in ways that preserve its bioactivity even after harvesting through standardisation methods.

Beyond its traditional uses, scientific validation has demonstrated broad applications ranging from natural pesticides and larvicides to oral care products, food supplements and preservatives. Its antimicrobial, antifungal and nutritional properties position it as a versatile candidate for integration into diverse industries, while its role in herbal medicine highlights opportunities for synergistic therapy within modern healthcare frameworks. Collectively, these findings underscore the plant's strong commercialisation potential, suggesting that *T. riparia* can transition from informal trade into formal global markets, benefiting farmers, stakeholders and consumers. Although *in vivo* and *in vitro* toxicological studies on the plant have shown promising results, there remains a need to assess formulated products for clinical safety and efficacy. Such evaluations will further support the establishment of sustainable plant supply chains. However, commercialisation efforts remain limited. To fully realise its economic contribution, future research should prioritise clinical trials, quality control and cultivation practices. Embedding the harvesting, collection, processing and product development of *T. riparia* within both local and global commercialisation, agendas will be critical to unlocking its potential as a sustainable resource for economic development.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRediT authorship contribution

Sithembiso L. Ndwandwe: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft. Sechene S. Gololo: Formal analysis, Project administration, Writing – review & editing. Both authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication and take responsibility for the integrity of its findings.

Ethical considerations

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Data availability

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