Antimicrobial and Anticancer Properties of Ageratum conyzoides Linnaeus: A Comprehensive Review

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***Abstract*—Ageratum conyzoides Linnaeus (Asteraceae) is a medicinal herb widely distributed in tropical and subtropical regions and recognized for its remarkable pharmacological diversity. The plant has been used in traditional medicine for managing infections, inflammation, and tumors. Its bioactive constituents, including flavonoids, alkaloids, terpenoids, and chromenes, contribute to potent antimicrobial, antioxidant, and anticancer effects. This review consolidates available evidence on the phytochemical composition, pharmacological activities, and molecular mechanisms underlying the antimicrobial and anticancer potential of A. conyzoides. Despite extensive preclinical validation, standardization of extracts, toxicity assessment, and clinical translation remain essential to realize its therapeutic value**

***Index Terms*—Ageratum conyzoides, antimicrobial, anticancer, phytochemicals, secondary metabolites, natural medicine**

I. INTRODUCTION

Medicinal plants remain a cornerstone of global healthcare, providing a rich source of biologically active compounds that inspire modern drug development [1]. Ageratum conyzoides L., commonly known as Billygoat-weed, is a member of the family Asteraceae and has been extensively used in traditional medicine systems in Africa, Asia, and South America for treating wounds, fever, infectious diseases, and cancers [2–4].

Phytochemical analyses have revealed the presence of flavonoids (quercetin, kaempferol, luteolin), terpenoids, alkaloids, and chromenes such as precocene I and II, which are primarily responsible for its wide range of pharmacological activities [5–7]. These metabolites demonstrate antimicrobial, anti-inflammatory, antioxidant, and cytotoxic effects that support the ethnopharmacological applications of the plant [8,9].

Studies have shown that extracts from different parts of A. conyzoides leaves, flowers, and stems exhibit broad-spectrum antimicrobial activity against Gram-positive and Gram-negative bacteria as well as fungi [10–12]. Furthermore, the plant displays cytotoxic and antiproliferative properties against several human cancer cell lines, including breast (MCF-7), cervical (HeLa), and liver (HepG2) cells [13–16].

Given its pharmacological promise, A. conyzoides has gained attention as a potential phytotherapeutic candidate. However, challenges such as phytochemical variability, lack of dosage standardization, and limited clinical data hinder its integration into mainstream medicine [17–19]. This comprehensive review aims to summarize the current understanding of the antimicrobial and anticancer activities of A. conyzoides, focusing on its bioactive compounds, underlying mechanisms, and future research prospects.

II. ANTIMICROBIAL PROPERTIES

The antimicrobial potential of Ageratum conyzoides L. has been extensively investigated due to its wide ethnomedicinal application in treating skin infections, wounds, and respiratory tract diseases [20]. Studies have demonstrated that extracts prepared using ethanol, methanol, chloroform, and essential oils exhibit inhibitory activity against a variety of bacterial and fungal strains, including Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Candida albicans, and Aspergillus niger [21,22].

2.1 Antibacterial Activity

The antibacterial efficacy of A. conyzoides has been attributed to the presence of flavonoids, terpenoids, alkaloids, and chromenes, which interfere with bacterial cell wall synthesis and enzymatic systems [23]. Methanolic and ethanolic extracts have shown significant inhibitory zones in disk diffusion assays against both Gram-positive and Gram-negative bacteria [24].

The essential oil of A. conyzoides rich in precocene I, precocene II, caryophyllene, and ocimene has demonstrated strong antibacterial activity with minimum inhibitory concentrations (MICs) ranging from 50–200 µg/mL against S. aureus and E. coli [25]. Similarly, aqueous extracts exhibited bactericidal activity against Bacillus subtilis and Klebsiella pneumoniae, suggesting the contribution of polar phytoconstituents [26].

Comparative analyses revealed that leaf extracts generally possess higher antibacterial activity than stems or roots, possibly due to a greater concentration of flavonoids and essential oils [27]. Bioautographic studies confirmed that chromenes and terpenoid derivatives are responsible for growth inhibition through membrane disruption and enzyme inactivation [28].

2.2 Antifungal Activity

The antifungal efficacy of A. conyzoides has also been demonstrated against a broad spectrum of pathogenic fungi, including Candida albicans, Aspergillus niger, and Trichophyton mentagrophytes [29]. Ethanolic and chloroform extracts reduced fungal growth by 70–90% in vitro, suggesting interference with ergosterol biosynthesis and membrane permeability [30]. Essential oils were particularly effective in spore germination inhibition assays, indicating their potential use in dermatological and cosmetic formulations [31].

2.3 Mechanisms of Antimicrobial Action

The antimicrobial mechanisms of A. conyzoides are multifactorial, involving cell membrane disruption, enzyme inhibition, and reactive oxygen species (ROS) generation [32]. Terpenoids increase membrane permeability, leading to leakage of essential ions, while flavonoids form complexes with bacterial cell walls and proteins, altering their structure and function [33]. Chromenes such as precocene I and II interfere with microbial DNA replication and energy metabolism, contributing to their potent activity [34].

Studies employing scanning electron microscopy revealed morphological alterations in bacterial cells exposed to A. conyzoides extracts, including cell wall deformation and cytoplasmic leakage [35]. This structural damage correlates with loss of metabolic activity and inhibition of nucleic acid synthesis, confirming the bactericidal and fungicidal nature of the plant's phytoconstituents [36].

Collectively, these findings indicate that A. conyzoides possesses broad-spectrum antimicrobial activity mediated by synergistic effects of its diverse secondary metabolites, making it a promising source of natural antimicrobial agents.

III. ANTICANCER PROPERTIES OF AGERATUM CONYZOIDES

Cancer remains one of the leading causes of morbidity and mortality worldwide, with millions of new cases diagnosed annually [37]. Despite major advancements in chemotherapeutic agents, the development of drug resistance, high toxicity, and recurrence rates necessitate alternative therapeutic strategies [38]. Medicinal plants and their bioactive compounds have been extensively studied for their potential to inhibit carcinogenesis through various mechanisms, including apoptosis induction, inhibition of proliferation, oxidative stress modulation, and interference with angiogenesis [39]. Ageratum conyzoides has gained considerable attention as a potential source of anticancer molecules due to its diverse phytochemical composition and long-standing traditional use in treating tumors and inflammatory conditions [40].

3.1 Phytochemicals with Cytotoxic Potential

Phytochemical investigations of A. conyzoides have revealed the presence of several compounds with potential anticancer activity, including flavonoids (quercetin, kaempferol derivatives), chromenes (precocene I and II), terpenoids, and alkaloids [41]. Quercetin and kaempferol derivatives are known to inhibit cancer cell growth by modulating key signaling pathways, such as PI3K/Akt, MAPK, and NF-κB, thereby inducing apoptosis and cell cycle arrest [42]. The plant's essential oils, rich in precocene II and β-caryophyllene, have also demonstrated cytotoxicity against various cancer cell lines, including breast (MCF-7), cervical (HeLa), and hepatocellular carcinoma (HepG2) cells [43].

In one notable study, methanolic and ethanolic extracts of A. conyzoides exhibited dose-dependent cytotoxic effects on MCF-7 breast cancer cells with IC_{50} values ranging between 40–60 µg/mL, primarily due to apoptosis induction via caspase-3 activation and DNA fragmentation [44]. Similarly, chloroform and aqueous extracts of the plant inhibited the proliferation of human cervical (HeLa) and colon (HT-29) cancer cells by upregulating p53 expression and downregulating Bcl-2, suggesting involvement of the intrinsic apoptotic pathway [45].

3.2 Mechanisms of Anticancer Action

The anticancer activity of A. conyzoides is multifaceted, involving both cytotoxic and antiproliferative mechanisms. Studies have demonstrated that the plant extracts promote reactive oxygen species (ROS) generation, leading to oxidative stress-induced apoptosis in cancer cells [37]. Moreover, certain constituents act as topoisomerase inhibitors, interfering with DNA replication and repair, ultimately leading to cell death [38]. The modulation of tumor suppressor genes, such as p53, and inhibition of anti-apoptotic proteins, including Bcl-2 and survivin, have been implicated in its anticancer activity [39].

Additionally, A. conyzoides exerts anti-angiogenic effects by inhibiting vascular endothelial growth factor (VEGF) signalling, which is crucial for tumor neovascularization [40]. Chromenes such as precocene II have also been reported to interfere with the expression of cyclooxygenase-2 (COX-2) and nuclear factor kappa B (NF-κB), thereby reducing inflammatory responses that often accompany tumor progression [41]. These combined effects make the plant a valuable natural source for developing multi-targeted anticancer agents.

3.3 In Vivo and In Vitro Evidence

In vivo studies further support the anticancer potential of A. conyzoides. In murine models, administration of plant extracts significantly reduced tumor volume and improved survival rates in mice inoculated with Ehrlich ascites carcinoma (EAC) cells [42]. The observed effects were accompanied by increased antioxidant enzyme activities (superoxide dismutase, catalase, and glutathione peroxidase), suggesting oxidative stress modulation as a key mechanism [43].

In vitro assays, including MTT and trypan blue exclusion tests, have shown selective cytotoxicity toward cancer cells, with minimal impact on normal human fibroblast cells [44]. This selectivity indicates that A. conyzoides extracts may exert cytotoxic effects primarily through apoptosis rather than necrosis, minimizing collateral damage to healthy tissues. Furthermore, combining A. conyzoides extract with standard chemotherapeutic agents such as doxorubicin or cisplatin enhanced anticancer efficacy, suggesting potential synergistic effects [45].

IV. INTEGRATED MECHANISMS AND DISCUSSION

The pharmacological activities of Ageratum conyzoides are the result of a complex interplay between its phytochemical composition and multi-target molecular mechanisms. The same secondary metabolites particularly flavonoids, chromenes, and terpenoids are responsible for both antimicrobial and anticancer effects, suggesting a unified biochemical basis for its bioactivity [46].

4.1 Phytochemical Synergy and Bioactivity

Several bioactive constituents of A. conyzoides act synergistically to enhance therapeutic efficacy. Flavonoids such as quercetin, kaempferol, and their glycosides exert antioxidant, pro-apoptotic, and enzyme-inhibitory properties that contribute to both infection control and tumor suppression [47]. These compounds modulate signalling cascades such as NF-κB, MAPK, and PI3K/Akt, thereby attenuating inflammation, suppressing cellular proliferation, and inducing apoptosis. Similarly, chromenes (precocene I and II) exhibit selective cytotoxicity by promoting reactive oxygen species (ROS) generation, which disrupts microbial and tumor cell metabolism [48]. This shared oxidative mechanism illustrates how the plant's phytochemistry provides a dual defence system against pathogenic and malignant cells.

4.2 Molecular and Therapeutic Integration

The cross-linked mechanisms of A. conyzoides indicate that antimicrobial and anticancer activities are not isolated phenomena but stem from common molecular pathways. Both activities involve oxidative stress modulation, mitochondrial dysfunction, and regulation of inflammatory mediators such as COX-2 and TNF-α [49]. The suppression of inflammation—a key component of chronic infections and carcinogenesis—further reinforces the plant's therapeutic versatility. Notably, bioactive extracts have shown selective toxicity towards cancer cells while sparing normal tissues, highlighting potential for low-toxicity therapeutic formulations [50].

This integrative pharmacological behavior positions A. conyzoides as a promising candidate for developing multi-target phytomedicines, especially in conditions where infection and inflammation co-exist with neoplastic transformation. Future research should therefore focus on mechanism-driven drug design and bioassay-guided fractionation to isolate lead compounds with high specificity and safety.

V. METHODS

A structured literature review was conducted following established scientific guidelines for narrative reviews [51]. Relevant articles published between 2000 and 2025 were identified through databases such as PubMed, Scopus, ScienceDirect, and Google Scholar, using the search terms "Ageratum conyzoides", "antimicrobial", "anticancer", and "phytochemical properties." Studies reporting in vitro, in vivo, or mechanistic evaluations of A. conyzoides were included, while non-experimental or duplicate reports were excluded. Data were synthesized qualitatively, emphasizing reproducibility, phytochemical characterization, and pharmacological relevance [52].

VI. FUTURE PERSPECTIVES

Despite substantial preclinical evidence supporting the antimicrobial and anticancer potential of Ageratum conyzoides, its clinical translation remains limited. Future studies should focus on standardization of extracts, dose optimization, and comprehensive toxicological evaluation to ensure reproducibility and safety [53]. Integration of A. conyzoides phytochemicals with nanotechnology-based delivery systems may enhance bioavailability and target specificity [54]. Furthermore, well-designed clinical trials and molecular docking studies are required to identify specific receptor targets and signalling pathways, facilitating the development of novel phytopharmaceuticals [55]. Sustainable cultivation and conservation strategies must also be prioritized to preserve this valuable medicinal species.

VII. CONCLUSION

Ageratum conyzoides L. is a rich reservoir of biologically active phytochemicals such as flavonoids, terpenoids, and chromenes that contribute to its broad-spectrum antimicrobial and anticancer properties [46]. The plant exerts its pharmacological effects mainly through oxidative stress modulation, apoptosis induction, and anti-inflammatory activity, highlighting its potential as a multi-target phytotherapeutic agent [50]. However, the translation of these preclinical findings into clinical applications requires rigorous standardization, toxicological assessment, and human studies to confirm efficacy and safety [52]. Collaborative efforts combining phytochemistry, molecular pharmacology, and clinical research are essential for the rational development of A. conyzoides-derived formulations.

Conflict of InterestThe author declares no conflict of interest regarding the preparation and publication of this review.

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