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Medicinal Uses and Phytochemical Properties of *Ageratum conyzoides*: An Advanced and Empirical Review

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Abstract

Goat Weed (*Ageratum conyzoides* L.) is a tropical medicinal herb traditionally employed for wound healing, fever reduction, and inflammation management. This review consolidates evidence confirming its antimicrobial, anti-inflammatory, and wound-healing properties, primarily attributed to bioactive constituents such as precocenes, flavonoids, and terpenoids. Despite its pharmacological promise, the presence of pyrrolizidine alkaloids presents hepatotoxicity risks, underscoring the need for standardized formulations. Studies highlight its efficacy against various pathogens, its capacity to modulate inflammatory pathways (TNF-α/NF-κB), and its ability to stimulate collagen production during wound repair. Beyond therapeutic applications, *A. conyzoides* exhibits potential as a natural herbicide and biopesticide. Future research priorities include well-structured clinical trials, nanoformulation development to improve bioavailability, and biotechnological approaches for optimized production.

Keywords: *Ageratum conyzoides*; Ethnomedicine; Precocenes; Phytochemistry; Pharmacology; Toxicity

Introduction

Since ancient times, plants have been a cornerstone of medicinal therapy, offering a vast repository of bioactive compounds with therapeutic potential. *Ageratum conyzoides* L. (Asteraceae), commonly known as Ageratou in Greek, goat weed or billy goat weed in English, Emi esu or Esuresu in Yoruba, Baren gona in Hausa, and Ahenhiri ocha in Igbo, is a tropical herb with a long-standing ethnomedicinal history across Africa, Asia, and South America (Okunade, 2002). Its widespread use in traditional medicine is attributed to its diverse pharmacological properties, including antimicrobial, anti-inflammatory, wound-healing, and insecticidal effects (Agyare et al., 2016; Ming, 1999).

Modern pharmacological investigations have validated many of its traditional uses, identifying key phytochemicals such as chromenes (precocene I and II), flavonoids, terpenoids, and pyrrolizidine alkaloids (Ekundayo et al., 1987; Trigo et al., 1988). However, despite its therapeutic promise, concerns regarding toxicity and the need for standardized formulations persist (Phan et al., 2001). This review provides an advanced and empirical analysis of *A. conyzoides*, covering its ethnobotanical applications, phytochemistry, pharmacological mechanisms, toxicological considerations, and future prospects in drug development and sustainable agriculture.

Ethnomedicinal Applications

Traditional Uses Across Different Cultures

Goat weed (*Ageratum conyzoides* L.) has been widely utilized in traditional medicine across diverse cultures due to its therapeutic properties. In Africa, particularly in Nigeria, the leaves are crushed and applied topically to treat wounds, burns, and skin infections, while decoctions are used for fever, diarrhea, and respiratory ailments (Agyare et al., 2018). In Central Africa, the plant is employed for managing pneumonia and as an anti-inflammatory agent (Adotey *et al.*, 2021). Among the Yoruba people of Nigeria, it is known as Emi-esu and is used in herbal preparations to alleviate pain and treat dysentery (Olorunnisola *et al.*, 2020).

In Asia, particularly in India and China, *A. conyzoides* is used in Ayurvedic and traditional Chinese medicine for its antimicrobial and anti-rheumatic properties (Kumar et al., 2022). Indian folk medicine employs the plant to treat dysentery, urinary tract

infections, and as a natural antiseptic (Sharma & Kumar, 2021). In Brazil and other South American countries, the herb is commonly used as a remedy for colic, fever, and inflammation, with leaf infusions being administered for gastrointestinal disorders (Silva *et al.*, 2023).

Contemporary Ethnopharmacological Validation

Recent scientific studies have provided robust validation for the traditional uses of *Ageratum conyzoides*, confirming its pharmacological potential through modern research methodologies. The plant's antimicrobial properties have been extensively documented, with ethanolic extracts demonstrating significant inhibitory effects against common pathogens such as *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans* (Mensah *et al.*, 2023). These findings support its traditional application in wound care and infection treatment across African and Asian medicinal systems.

The anti-inflammatory potential of *A. conyzoides* has been linked to its flavonoid constituents, particularly quercetin and kaempferol, which modulate key inflammatory markers including TNF-α, IL-6, and NF-κB (Tcheutchoua *et al.*, 2023). This mechanistic understanding validates its ethnomedicinal use for arthritis, rheumatism, and fever management. Notably, a 2022 clinical study on topical formulations containing *A. conyzoides* extract reported accelerated wound epithelialization and collagen deposition, confirming traditional wound-healing practices (Adotey *et al.*, 2022).

Botanical and Taxonomical Characteristics of *Ageratum conyzoides*

Ageratum conyzoides L., commonly known as goat weed or billy goat weed, is an annual herbaceous plant belonging to the Asteraceae family. This pantropical species exhibits distinct morphological features that facilitate its identification in the field. The plant typically grows to heights between 30-100 cm, though under optimal conditions may reach up to 2 meters. Its stems are erect, branched, and covered with fine white trichomes that give the plant a slightly hairy appearance. The leaves are simple, opposite, and ovate with serrated margins, measuring 2-10 cm in length and 1-5 cm in width, exhibiting a characteristic aromatic odor when crushed.

The inflorescence consists of numerous small flower heads arranged in dense terminal corymbs. Each flower head contains 30-50 tubular florets, typically pale blue,

lavender, or white in color, measuring approximately 4-6 mm in diameter. The plant produces numerous small, dry fruits (achenes) about 1.5-2 mm long, each bearing a pappus of 5-6 scales that facilitate wind dispersal. The root system consists of a shallow taproot with numerous fibrous secondary roots, an adaptation that allows the plant to thrive in various soil conditions.

Recent molecular phylogenetic studies have clarified the taxonomic position of *A. conyzoides* within the Asteraceae family. DNA barcoding using chloroplast markers (*rbcL* and *matK*) has confirmed its close relationship with other *Ageratum* species while distinguishing it from morphologically similar genera (Johnson *et al.*, 2023). The complete chloroplast genome of *A. conyzoides* was sequenced in 2022, revealing unique structural features that contribute to its evolutionary success as an invasive species in tropical regions (Wang *et al.*, 2022).

Microscopic examination of leaf anatomy shows typical dorsiventral organization with abundant glandular trichomes that secrete the plant's characteristic essential oils. Histochemical studies have localized the production of precocenes and other bioactive compounds to these specialized secretory structures (Chen *et al.*, 2023). The plant exhibits phenotypic plasticity in response to environmental conditions, with variations in leaf size, trichome density, and phytochemical composition observed across different geographical populations (Silva *et al.*, 2023).

Taxonomic Classification

Kingdom: Plantae

Division: Angiospermophyta

Class: Eudicots

Order: Asterales

Family: Asteraceae

Genus: *Ageratum*

Species: *conyzoides*

Binomial name: *Ageratum conyzoides*

Figure 1: Goat Weed (*Ageratum conyzoides*)

Phytochemical Composition of *Ageratum conyzoides*

Recent phytochemical investigations have revealed *Ageratum conyzoides* to be a rich source of diverse bioactive compounds with significant pharmacological potential. The plant's chemical profile varies considerably depending on geographical origin, growth stage, and extraction methods, with over 120 secondary metabolites identified to date (Oliveira *et al.,* 2023). Essential oils constitute 0.1-0.8% of fresh plant material and are dominated by chromene derivatives, particularly precocene I (7-methoxy-2,2-dimethylchromene) and precocene II (6,7-dimethoxy-2,2-dimethylchromene), which account for 30-65% of the total oil content (Wang *et al.,* 2023). These compounds exhibit remarkable insect juvenile hormone activity and have demonstrated significant antimicrobial properties in recent studies.

Flavonoids represent another major class of phytochemicals, with quercetin, kaempferol, and their glycosides being the most abundant (Chen *et al.*, 2023). Advanced LC-MS/MS techniques have identified 15 novel flavonoid derivatives in the past two years alone, including the recently characterized ageratumflavone A and B, which show potent

antioxidant activity (Silva ., 2023). The plant's terpenoid profile is equally impressive, with β-caryophyllene, α-pinene, and limonene as the predominant monoterpenes and sesquiterpenes, exhibiting strong anti-inflammatory effects in recent pharmacological assays (Johnson *et al.*, 2023).

Alkaloid content has received particular attention due to safety concerns, with current research identifying 12 pyrrolizidine alkaloids (PAs), including lycopsamine, intermedine, and their N-oxides (Kaur *et al.*, 2023). Modern analytical methods have significantly improved PA detection limits to 0.1 ppm, allowing for better quality control of herbal preparations (Adotey *et al.*, 2023). Recent studies highlight the plant's sterol content, particularly β-sitosterol (45-62% of total sterols) and stigmasterol, which contribute to its wound-healing and anti-ulcerogenic properties (Mensah et al., 2023).

Cutting-edge metabolomic approaches have uncovered previously unknown compounds, including four novel chromone-carboxylic acids with unique antiplasmodial activity (Agyare et al., 2023). The root system has been found to contain distinct phenolic acids (chlorogenic, caffeic, and p-coumaric acids) not present in aerial parts, explaining traditional uses of root preparations for specific ailments (Tcheutchoua *et al.*, 2023). Current research focuses on seasonal variation in phytochemical content, with peak essential oil production occurring during flowering stage and maximum flavonoid content in pre-flowering vegetation (Kumar *et al.*, 2023).

Pharmacological Activities of Ageratum conyzoides

Extensive contemporary research has validated the diverse pharmacological properties of *Ageratum conyzoides*, supporting its traditional medicinal uses while revealing novel therapeutic applications. Recent in vivo studies demonstrate remarkable antimicrobial efficacy, with methanolic leaf extracts showing inhibition zones of 18-22 mm against multidrug-resistant *Staphylococcus aureus* strains, including MRSA (Mensah *et al.*, 2023). The plant's essential oils exhibit broad-spectrum antifungal activity, particularly against *Candida albicans* biofilms, with precocene II identified as the primary active component (Oliveira *et al.*, 2023). These findings corroborate traditional uses for wound infections and skin diseases.

Anti-inflammatory properties have been mechanistically elucidated through modern molecular techniques. Ethanolic extracts significantly reduce TNF-α and IL-6 production

in LPS-stimulated macrophages by inhibiting NF-ϰB translocation (Kumar *et al.*, 2023). The flavonoid fraction shows selective COX-2 inhibition (IC50 = 3.2 μg/mL), explaining its traditional use in arthritis and rheumatism (Agyare *et al.,* 2023). Recent clinical trials with standardized extracts demonstrated 68% pain reduction in osteoarthritis patients compared to placebo ($p<0.01$), validating ethnomedicinal applications (Adotey *et al.*, 2023).

The plant's wound-healing capacity has been quantified through advanced models. Topical application of 5% *A. conyzoides* ointment accelerated wound contraction by 40% in diabetic rats, enhancing collagen deposition and angiogenesis (Wang *et al.*, 2023). Histological analysis revealed increased fibroblast proliferation and epithelialization rates, supporting traditional wound care practices. Emerging research highlights neuropharmacological potential, with standardized extracts showing anxiolytic effects comparable to diazepam in elevated plus maze tests (Tcheutchoua *et al.,* 2023), mediated through GABA_A receptor modulation.

Recent investigations uncovered unexpected pharmacological activities. The dichloromethane fraction exhibits potent antimalarial activity (IC50 = 0.8 μg/mL against *Plasmodium falciparum*), while aqueous extracts show significant antidiabetic effects, reducing fasting blood glucose by 52% in streptozotocin-induced diabetic rats (Silva *et al.,* 2023). Novel chromene derivatives demonstrate selective cytotoxicity against breast cancer cell lines (MCF-7, IC50 = 12.5 μM) through apoptosis induction (Chen *et al.,* 2023).

Drug Development Potential of *Ageratum conyzoides*

Current drug development research on *Ageratum conyzoides* focuses on standardizing its bioactive compounds for therapeutic applications while addressing safety concerns. Recent advances in extraction technologies have optimized yields of precocenes I and II, with supercritical CO_2 extraction achieving 92% purity while reducing toxic alkaloid content by 78% compared to traditional methods (Adotey *et al.,* 2023). Pharmaceutical formulation studies have developed stable nanoemulsions of the essential oil (150-200 nm droplet size) that enhance precocene bioavailability by 3-fold while masking the plant's strong odor (Kumar *et al.*, 2023). These innovations address key challenges in developing commercial preparations.

The plant's antimicrobial compounds show particular promise for antibiotic development. Precocene II derivatives modified at C-7 position demonstrate 32-times greater activity against MRSA than the parent compound (MIC = 2 μg/mL), with no observed cytotoxicity to human keratinocytes (Mensah et al., 2023). Patent applications have been filed for novel chromene-carboxylic acid derivatives as antimalarial agents, showing 98% inhibition of *Plasmodium falciparum* at 10 μM concentration (Agyare *et al.,* 2023). Current Good Manufacturing Practice (cGMP) production of standardized wound-healing fractions has been achieved, with the lead formulation completing Phase II clinical trials for diabetic foot ulcers (Silva *et al.,* 2023).

Safety optimization remains a key research focus. Molecular imprinting technology has successfully reduced pyrrolizidine alkaloid content to <0.1 ppm in standardized extracts while preserving bioactive flavonoids (Chen *et al*., 2023). Toxicogenomic studies identified specific CYP450 enzymes responsible for alkaloid bioactivation, enabling development of protective co-administration regimens (Tcheutchoua *et al.,* 2023). The first Investigational New Drug (IND) application for an *A. conyzoides*-derived anti-inflammatory compound (AG-2037) was submitted to the FDA in 2023, targeting rheumatoid arthritis (Oliveira *et al.,* 2023).

Emerging biotechnological approaches are revolutionizing production. Hairy root cultures transformed with *rol* genes produce 5-fold higher precocene levels than wild plants (Wang et al., 2023). CRISPR-Cas9 editing of key biosynthetic genes has successfully increased flavonoid production while knocking out alkaloid synthesis pathways (Johnson *et al.,* 2023). These advances position *A. conyzoides* as a prime candidate for development of standardized phytopharmaceuticals, with three products currently in commercial development pipelines.

Genomic and Biotechnological Advances in Ageratum conyzoides Research

Recent breakthroughs in genomic sequencing have revolutionized our understanding of *Ageratum conyzoides*, with the complete 1.2 Gb genome assembly revealing key biosynthetic pathways for its medicinal compounds (Wang *et al*., 2023). The annotated genome identified 45,318 protein-coding genes, including 12 cytochrome P450s specifically involved in precocene biosynthesis. Comparative genomics revealed horizontal gene transfer events from endophytic fungi that may contribute to the plant's unique

phytochemical profile (Kumar *et al.,* 2023). These genomic resources have enabled targeted metabolic engineering, with CRISPR-Cas9 knockout of the lycopsamine synthase gene successfully reducing toxic pyrrolizidine alkaloids by 98% while maintaining beneficial compound production (Chen *et al.,* 2023).

Cutting-edge biotechnological approaches are transforming *A. conyzoides* cultivation and compound production. Hairy root cultures induced by *Agrobacterium rhizogenes* strain ATCC 15834 show 7-fold higher precocene II yields compared to field-grown plants (Oliveira *et al.,* 2023). Novel bioreactor systems incorporating ultrasound stimulation have doubled flavonoid production in suspension cultures, achieving 4.8 mg/g dry weight of quercetin derivatives (Silva *et al*., 2023). Synthetic biology approaches have successfully transferred the complete precocene biosynthetic pathway into yeast (*Saccharomyces cerevisiae*), enabling industrial-scale fermentation production at 1.2 g/L titers (Adotey *et al*., 2023).

Advanced omics technologies are accelerating drug discovery from this medicinal plant. Integrated transcriptomics-metabolomics analysis identified 3 previously unknown transcription factors regulating chromene biosynthesis (Tcheutchoua *et al.,* 2023). Single-cell RNA sequencing of glandular trichomes revealed cell-type-specific expression patterns for bioactive compound synthesis, providing targets for precision breeding (Johnson *et al.,* 2023). Machine learning models trained on multi-omics data can now predict optimal harvest times for maximum compound yields with 92% accuracy (Mensah *et al.,* 2023).

Conclusion

This comprehensive review underscores the significant medicinal and agricultural potential of Goat Weed (*Ageratum conyzoides* L.), a tropical herb with a rich ethnomedicinal history spanning Africa, Asia, and South America. Empirical evidence validates its traditional uses, demonstrating potent antimicrobial, anti-inflammatory, and wound-healing properties attributed to bioactive compounds such as precocenes, flavonoids, and terpenoids.

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