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Review Article

A mini review on the morphology, phytochemical constituents and selected biological activities of *Mikania micrantha* Kunth (asteraceae)

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Abstract
Mikania micrantha Kunth (Asteraceae) is a well-known fast-growing invasive climber that is widely distributed across tropical and subtropical regions. Although recognised as one of the world's most destructive alien weeds, *M. micrantha* has become the focus of increasing research interest for its phytochemical constituents and pharmacological potential. This mini review highlights current knowledge on its morphology, phytochemical constituents and selected biological activities. Many bioactive compounds, including flavonoids, phenolics, sesquiterpene lactones and alkaloids were reported to contribute to diverse biological properties, such as antioxidant, antimicrobial, anti-tumour and allelopathic effects. These findings demonstrated the dual identity of *M. micrantha* as both a major ecological threat and a promising source of novel therapeutic agents. A deeper understanding of its phytochemistry and bioactivity may help transform this invasive species into a sustainable resource for drug discovery and value-added applications.

Keywords: *Mikania micrantha*, invasive weed, phytoconstituents, pharmacological activities, therapeutic potential

Introduction

Mikania micrantha Kunth is a fast-growing medicinal plant that is native to Mexico, the West Indies, Central and South America, as well as certain parts of Southeast Asia. It has since been widely naturalised in various tropical and subtropical regions, such as the United States, India, Pakistan, Sri Lanka, South China, Bangladesh and the Pacific Islands [1, 2].

This plant belongs to the Asteraceae family, one of the largest families of flowering plants [3]. The genus *Mikania* within this family comprises over 430 species, primarily found in tropical regions. *M. micrantha* is often referred to as 'selaput tunggul', 'ulam tikus' or 'daun ulam gila' in Malaysia and 'sembungrambat' in Indonesia [4]. It goes by several other names, such as American rope, Chinese creeper, climbing-hempweed, bitter vine, mile-a-minute weed and Tarulata [5].

Despite the many names, it is widely recognised for its rapid growth rate, which is up to 8-9 cm per day, allowing it to smother crops, plantations and natural vegetation, severely impacting biodiversity and agricultural productivity with its invasive nature [3,2]. The rapid proliferation of *M. micrantha* has led to severe ecological degradation, posing a major threat to in-situ habitat conservation for endangered species. Once established, the vine aggressively colonises disturbed areas, whereby it forms a dense growth that blocks sunlight, suppresses photosynthesis, and ultimately causes the death of underlying vegetation [6].

M. micrantha can climb or creep over surfaces by using its long, slender stems, making it difficult to control in certain ecosystems [7]. Its aggressive growth habit enables it to form dense mats over trees and shrubs, blocking sunlight and competing for nutrients and water, and thus ultimately posing a serious ecological threat. Consequently, it has been ranked amongst the world's 100 worst invasive species [8] and identified as the second most problematic weed in the South Pacific region [9]. In many countries, it is further listed amongst the top invasive alien species, causing significant ecological, agricultural and economic impacts.

In spite of its invasiveness, some studies also highlighted its potential medicinal properties and

secondary metabolites, which could be explored for pharmacological or biotechnological applications [10]. *M. micrantha* possesses antioxidant, anti-inflammatory, anti-microbial, anti-dermatophytic, anti-protozoal, anthelmintic, cytotoxic, anxiolytic, anti-diabetic, lipid-lowering, spasmolytic, memory-enhancing, wound-healing, anti-ageing and thrombolytic activities. *M. micrantha* might be one of the potential sources of phytotherapeutic compounds against diverse ailments in humans.

Despite being recognized as one of the world's worst invasive weeds, *M. micrantha* also harbours pharmacological and ecological potential that could be harnessed under controlled management. Understanding its biology, ecology, and chemical composition is essential for designing sustainable control strategies while exploring its possible applications. In this mini review, the literature was systematically collected mostly from peer-reviewed articles published between 2004 and 2025. The relevant studies were identified using major scientific databases, including Scopus, PubMed and Google Scholar, employing keywords related to *M. micrantha*, phytochemical constituents and selected biological activities. Overall, this mini review summarizes phytochemical and pharmacological potential of *M. micrantha*, providing as a valuable reference for future research.

Taxonomy

M. micrantha is included within the Kingdom Plantae, encompassing all multicellular photosynthetic organisms. Belongs to the Division Magnoliophyta, which is also known as angiosperms or flowering plants, representing the most diverse group of land plants characterised by presence of seeds enclosed within fruits. In this division, it is assigned to the Class Magnoliopsida or dicotyledons, which is distinguished by presence of two cotyledons in the seed, reticulate venation and floral parts typically arranged in multiples of four or five. The species falls under the Order Asterales, a large and evolutionarily advanced order of flowering plants recognised for their composite flower heads. More specifically, it is a member of the Family Asteraceae, one of the largest families of angiosperms, which includes daisies, sunflowers and many weedy and ornamental species. The Genus *Mikania* comprises more than 430 species of fast-growing twining and climbing plants, many of which are native to the Neotropics [11]. The taxonomy classification of *M. micrantha* is summarised in **Table 1**.

Morphology and botanical description

General plant and habitat

M. micrantha exhibits cylindrical, striated stems and opposite leaves, which is typical of the genus *Mikania*. Its reproductive structures are arranged in characteristic composite inflorescences, reflecting the diagnostic traits of the family. **Figure 1** shows the general morphology of *Mikania* sp. It can grow up to 20 feet in habitats with good sunlight and vertical structures [3]. It is commonly found in agricultural fallows, roadside, forests, waste areas, swampy woods and sometimes even growing at high altitudes [13].

Table 1. Botanical classification of *M. micrantha* [12]

Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Asterales
Family	Asteraceae
Genus	*Mikania*
Species	*Micrantha*

Leaf

Leaves are simple, opposite and distichous (arranged in two vertical rows). They have triangular or heart-shaped leaves with pointed tips and serrated edges. These leaves are 4-13 cm long and 2-9 cm wide, grow in opposite pairs along the stem and are supported by petioles that range from 2-8 cm in length [14, 15]. Young leaves at the top of stem are halberd-shaped. The apex is acuminate, base cordate and margins entire. Venation is camptodromous (secondary veins converging near the margin) [16].

Stem

The stems are slender, multi-branched and are either smooth or covered with short, soft hairs, providing flexibility for climbing and twining around host plants. They are often green and herbaceous when young, with ability to root at nodes, enhancing vegetative propagation. Whereas the older stems are light brown with distinct ribbed veins.

Capitulum (Flower Head)

The fluffy flower-heads (capitula) are greenish-white or white, disciform and small (3-6mm long). These capitula grow in branched clusters, either emerging from the leaf axils or forming at the tips of branches (axillary or terminal corymbs) [15]. Inflorescences are corymbose and lax, bearing many small capitula that may be sessile or pedicellate. Pedicels range from 0-4 mm in length. Each capitulum has a glabrous receptacle and is subtended by a subinvolucral bract (2.8-5.1 mm long, lanceolate to oblong, pilose, with or without glandular trichomes). The involucre is 5.1-6.1 × 1.5-2.9 mm, with involucral bracts lanceolate, acuminate at apex, truncate at base, ciliate at the margin and pubescent to pilose externally [17, 15].

Corolla

The corolla is tubular, white and small, measuring 3.5-4.8 mm in length. The tube is 2.0-2.8 mm long,

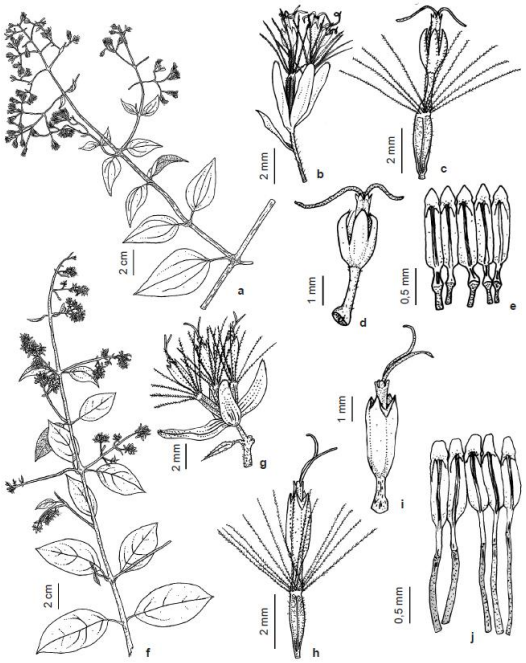

Figure 1. General morphology of *Mikania* sp. a. branch; b. capitulum; c. floret; d. corolla; e. anthers (*Mikania biformis*, f. branch; g. capitulum; h. floret; i. corolla; j. anthers (*Mikania elliptica*) [18]

bearing glandular trichomes with occasionally sparse covering trichomes, and not expanded at the base. The limb measures 1.5-2.2 mm and ends in lanceolate lobes (0.6-1.9 mm), which also bear glandular trichomes [14].

Anther and style

Anthers are syngenesious, forming a tube around the style, a characteristic feature of Asteraceae. They bear an apical appendage that is obtuse to acute, longer than wide, with a truncate base. The anther collar is cylindrical and diagnostic for *M. micrantha*. The style measures 6.1-9.0 mm, with linear, papillose branches that are acute at the apex and dilated at base. This structure enhances pollen reception and fertilisation efficiency [17].

Seed and pappus

The seeds are blackish-brown, tiny (1.2-2 mm long and 0.2-0.6 mm wide), elongated in shape, and five-angled in cross-section. Each seed is topped with a ring-like structure (i.e., pappus) consisting of 30-38 whitish hairs or bristles, measuring 2-4 mm in length [15].

Phytochemical constituents

Phytochemicals are naturally occurring compounds produced by plants, including alkaloids, glycosides, flavonoids, terpenoids, tannins and steroids. These compounds have found wide-ranging uses in commercial, pharmaceutical and industrial applications, particularly as natural sources of flavours, fragrances, enzymes, preservatives, cosmetics, bio-based fuels and plastics, natural colorants and drug bioactive agents [19, 20].

Phytochemical screening

The extracts from *M. micrantha* were found to be particularly rich in a wide range of phytochemicals. According to Sahu et al. (2019), preliminary phytochemical screening of extracts of the whole *M. micrantha* plant revealed presence of alkaloids, flavonoids, tannins, terpenoids, steroids, reducing sugars, saponins, phenolic compounds, amino acids and proteins [5].

Phytochemical investigations into the leaf extracts revealed the presence of tannins, saponins, cardiac glycosides, terpenoids, steroids, flavonoids and alkaloids, with cardiac glycosides and steroids being more abundant in the methanol extract [21]. Subsequent studies on the leaves further confirmed the occurrence of alkaloids, flavonoids, tannins, saponins, steroids/triterpenoids and glycosides [22], and were later supported by Ardianto et al. (2022), who also reported alkaloids, flavonoids, tannins and saponins [4]. More recently, Yasmin et al. (2025) demonstrated a seasonal variation, with alkaloids, tannins, phenols, and flavonoids consistently detected in both winter and summer, while carbohydrates and glycosides were only present in the winter samples [23].The summary of these phytochemical compounds is presented in **Table 2**.

Table 2. The summary of phytochemicals in different parts of *Mikania micrantha*

Plant Part	Origin	Extraction Solvent	Extraction Methods	Phytochemical compounds	References
Whole plant	India	Hexane	Soxhlet	Alkaloid.	[5]
		Ethyl acetate		Alkaloid, tannin, triterpenoid, polyphenols.	
		Chloroform		Alkaloids, triterpenoids, steroids, polyphenols, saponins.	
		Methanol		Alkaloid, flavonoid, tannin, triterpenoid, steroid, reducing sugar, amino acid, protein, polyphenols, saponin.	
		Water		Alkaloid, flavonoid, tannin, amino acid, protein, saponin.	
Leaves	Nepal	Methanol	Maceration	Tannins, saponins, cardiac glycosides, terpenoids, steroids, flavonoids, and alkaloids.	[21]
		Water		Tannins, saponins, flavonoids, and alkaloids.	
Leaves	North Sumatra Province	Ethanol 96%	Maceration	Alkaloids, flavonoids, tannins, saponins, steroids/triterpenoids, and glycosides.	[22]
Leaves	Indonesia	Ethanol	Maceration	alkaloids, flavonoids, tannins, and saponins.	[4]
Leaves	India	50% ethanol	Maceration	alkaloids, tannins, phenols, and flavonoids, carbohydrate, glycosides.	[23]

Phytoconstituents

A study by Li et al. reported three flavonoids, namely quercetin-3-O-diglucoside, 8-OMe-kaempferol-3-O-sophoroside and quercetin-3′,4′,7-trimethyl ether-3-sulfate in *M. micrantha* by using liquid chromatography hybrid ion trap time-of-flight mass spectrometry (LC/MS-IT-TOF) [24].

The subsequent GC-MS analysis of methanol and petroleum ether extracts of *M. micrantha* leaves and stems by Hassan et al. revealed the presence of various phytochemicals, including phenolic compounds and hydrocarbons. In this study, chromatographic peaks were integrated and compared with the spectral database of known compounds available in the GC-MS library, and identified compounds are tabulated in **Table 3** [25].

In a more recent investigation, Ibrahim et al. revealed that LC-QToF-MS analysis of the ethyl

acetate extract of *M. micrantha* stem identified 20 secondary metabolites, amongst which theobromine, ishwarol, pyrimidine, 4-p-coumaroylquinic acid, and pheophorbides were the major bioactive compounds [26].

Table 3. List of identified phytoconstituents by using different methods

Plant part	Extraction Solvent	Method	Compounds	References
Stems	Ethyl acetate	LC/MS-IT-TOF	Quercetin-3-O-diglucoside, 8-OMe-Kaempferol-3-O-sophoroside, Quercetin-3,4,7-trimethyl ether-3-sulfate.	[24]
Leaves	Methanol	GC–MS	Hexadecenoic acid, Phenol,2-methoxy, Phenol,3-(1-methylethyl), Hydroquinone, Phenol, 2-methoxy-4-(1-propenyl), Phenol,2-(1,1-dimethyl-2-propenyl)-3,6-dimethyl, Phenol, 2,4-bis(1,1-dimethylethyl), Phytol, α-Bisabolol, Astaxanthin, Fumaric acid, Cyclobutyl heptyl ester, Globulol, Pentadecanoic acid, methyl ester, Hexadecanoic acid, methylester, Benzenepropanoic acid, 3,5-bis (1,1-dimethylethyl)-4-hydroxy-, methyl ester, Ascorbic acid, 2,6-dihexadecanoate, Ascorbic acid 2,6-dihexadecanoate, Stigmasterol, Lup-20(29)-en-3-ol, acetate.	[25]
Stems	Water	GC-MS	Propanoic acid, 2-oxo-, methylester, Phenol, 3-methoxy-2-methyl, 2-Furoic acid, phenylethylester, Phenol, 3-methyl-1,2-cyclopentenedione, 3(2H)-Furanone, Palatone, Butanoic acid, 2-Methyl-3-oxo-, ethyl ester, Coumaran, Homocatechol, Hydroquinone, 4-Hydroxy-2-methylacetophenone, Vanillin, Benzoic acid, 4-methoxy, Phenol, 2,4-bis (1,1-dimethylethyl), Phenol, 4-methoxy-2,3,6-trimethyl, Hydroquinone, tert-butyl, Fumaric acid, ethyl-3-heptyl ester, Octadecyl chloride, α-Bisabolol, Astaxanthin,	[25]

			Phenol, 4-(3-hydroxy-1-propenyl)-2-methoxy, Phytol, Benzediol, 2,5-bis(1,1-dimethylethyl), Apidic acid, isohexyl methylester, 1-(+)-Ascorbic acid 2,6-dihexadecanoate, Hexadecanoic acid, methyl ester, 1-(+)-Ascorbic acid 2,6-dihexadecanoate, Stearic acid, methyl ester, Stigmasterol.	
Leaves	Petroleum ether	GC-MS	Nonane, 1-Decane, Dodecane, Ethylhexanol, Toluene, m-propyl, Dodecane, 4,6-dimethyl- 5-lsobutylnonane, 1-Decane, 2, 4-dimethyl-, 2-Propylheptanol, Dodecane, 4,6-dimethyl-, Farnesane, Nonane, 5-butyl, Heneicosane, Heptadecane, Eicosane, Dihydrophytol, Isotridecanol, α-Longipinene, Caryphyllene, α-Curcumene, Phenol, 2, 4-bis (l, I-dimethyl).	[25]
Stems	Petroleum ether	GC-MS	Nonane, Decane, Dodecane, Dodecane, 4,6-dimethyl, Heneicosane, Eicosane, Phenol, 2,4-bis(1,1-dimethylethyl)-, Tridecane, 2,5-dimethyl, Hexadecane, 2-methyl-, Heptadecane, 2-methyl, α-Bisabolol,	[25]
Stems	Ethyl acetate	LC-QToF-MS	Theobromine, 1-Methylhypoxanthine, Lathyrine, Pyrimidine, 3,4-Dicaffeoyl-1,5-quinolactone, Laricitrin 3-rhamnoside, 4-*p*-Coumaroylquinic acid, Dihydromikanolide, Formononetin 7-0-glucoide-6"-0-malonate, (Z)-1,5-Tridecadiene, 9Z,12Z,15E-Octadecatrienoic acid, 8Z-Decene-4,6-cliynoic acid, α-9(10)-EpODE, 5Z,8Z,11Z, 14Z-Octadecatetraenoic acid.	[26]

Normammein,
Ishwarol,
1-Linoleoyl glycerol,
Pheophorbide b,
Pheophorbide a.

Table 4. A list of isolated compounds from *Mikania micrantha*

Plant Material	Isolated Compounds	References
Whole plant	Mikanin, Eupalitin, Eupafolin, 3,4,5,7-Tetrahydroxy-6-methoxyflavone-3-O-β-D glucopyranoside, Luteolin, 3,5-di-O-Caffeoylquinic acid *n*-butyl ester, 3,4-di-O-Caffeoylquinic acid n-butyl ester.	[27]
Aerial parts	3β-Acetoxy-1,10-epoxy-4-germacrene-12,8;15,6-diolide, 1,10-Epoxy-4-germacrene-12,8;15,6-diolide, Dihydromikanolide, Potassium mikanin 3-sulfate, Mikanin, Alpinetin, Ergosta-7,22-dien-3β-ol.	[28]
Leaves	Deoxymikanolide, Scandenolide, Dihydroscandenolide, Mikanolide, Dihydromikanolide, *m*-Methoxybenzoic acid	[29, 30]
Aerial parts	Benzyl 5-O-β-D-glucopyranosyl-2,5-dihydroxybenzoate, (7S,8R)-Threo-dihydroxydehydrodiconiferyl alcohol 9-acetate, Benzyl 2-O-β-D-glucopyranosyl-2,6-dihydroxybenzoate, 4-Allyl-2,6-dimethoxyphenol glucoside, (+)-Isolariciresinol, Icariol A2, 9,10-Dihydroxythymol, 8,9,10-Trihydroxythymol, Caffeic acid, *p*-Coumaric acid, Ethyl protocatechuate, Protocatechuic aldehyde, 4-Hydroxybenzoic acid, Hydroquinone.	[10]
Leaves	Hydroxymikaperiplocolide A, Hydroxymikaperiplocolide B, Germacrane sesquiterpenoid.	[31]

Isolated compounds from *Mikania micrantha*

Phytochemical investigations on *M. micrantha* revealed a diverse range of secondary metabolites. Wei et al. (2004) reported the isolation of several compounds from ethanol extracts of the whole plant, including mikanin, eupalitin, eupafolin, 3,4,5,7-tetrahydroxy-6-methoxyflavone-3-O-β-D-glucopyranoside, luteolin, 3,5-di-O-caffeoylquinic acid *n*-butyl ester and 3,4-di-O-caffeoylquinic acid *n*-butyl ester [27].

In a subsequent study, But et al. identified additional constituents from the dried aerial parts, such as 3β-acetoxy-1,10-epoxy-4-germacrene-12,8;15,6-diolide,

dihydromikanolide, 1,10-epoxy-4-germacrene-12,8; 15,6-diolide, potassium mikanin 3-sulfate, mikanin, alpinetin and ergosta-7,22-dien-3β-ol [28]. Notably, 1,10-epoxy-4-germacrene-12,8;15,6-diolide displayed moderate inhibitory activity against respiratory syncytial virus and parainfluenza type 3 virus, while the major constituent, potassium mikanin 3-sulfate, exhibited potent antiviral activity against parainfluenza type 3 virus, with IC_{50} values comparable to those of the standard antiviral agent ribavirin [28].

In another study, further phytochemical investigations revealed that the aerial parts of *M. micrantha* also contained a wide variety of structurally diverse phenolic compounds. Dong et al. successfully isolated two novel phenolics compounds, namely benzyl 5-O-β-D-glucopyranosyl-2,5-dihydroxybenzoate and (7S,8R)-threo-dihydroxy dehydrodiconiferyl alcohol 9-acetate, alongside twelve known compounds which included benzyl 2-O-β-D-glucopyranosyl-2,6-dihydroxybenzoate, 4-allyl-2,6-dimethoxyphenol glucoside, (+)-isolariciresinol, icariol A2, 9,10-dihydroxythymol, 8,9,10-trihydroxythymol, caffeic acid, p-coumaric acid, ethyl protocatechuate, protocatechuic aldehyde, 4-hydroxybenzoic acid and hydroquinone [10]. Several bioactive compounds were reported from the leaves of *M. micrantha* through bioactivity-guided fractionation, which included deoxymikanolide, scandenolide, dihydroscandenolide, mikanolide, dihydromikanolide and *m*-methoxybenzoic acid [29, 30]. Later, Ma et al. reported the isolation of two new germacrane sesquiterpenoids, hydroxymika periplocolide A and hydroxymikaperiplocolide B from the leaves of *M. micrantha*, along with a known germacrane sesquiterpenoid [31]. A list of these isolated compounds is in **Table 4**.

More recently, Dong et al. (2023) reported the isolation of four new germacrane sesquiterpene dilactones (**1-4**), along with five known compounds (**5-9**) from the aerial parts of *M. micrantha*. These compounds exhibited significant antibacterial and cytotoxic activities, particularly against drug-resistant strains such as methicillin-resistant *Staphylococcus aureus* (MRSA) [32] (**Figure 2**).

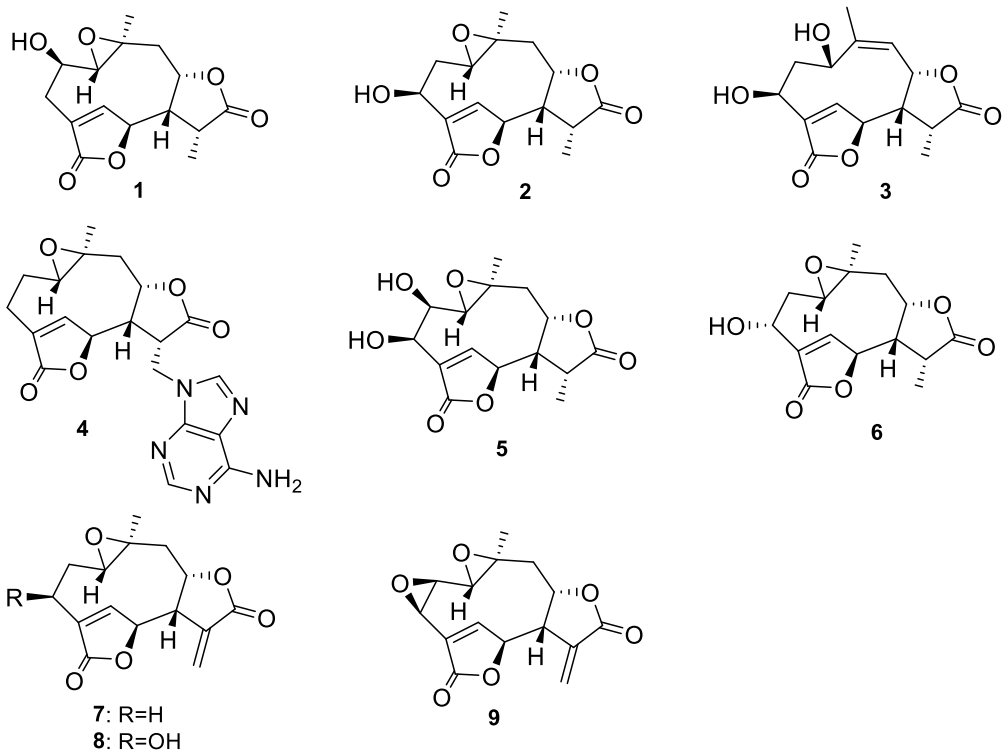

Figure 2. Current Isolated compounds from *M. micrantha:* **1:** 2-hydroxyl-11,13-dihydrodeoxymikanolide, **2**: 3-hydroxyl-11,13-dihydrodeoxymikanolide, **3**: 1,3-dihydroxy-4,9-germacradiene-12,8:15,6-diolide, **4**: 11,13-dihydrodeoxymikanolide-13-yl)-adenine, **5**: 2β,3β-dihydroxy-11β,13-dihydroxydeoxymikanolide, **6**: 3α-hydroxy-11β,13-dihydroxydeoxymikanolide, **7**: deoxymikanolide, **8**: 3β-hydroxy-deoxymikanolide, and **9**: mikanolide. [32]

Biological activities

Antioxidant activities

Antioxidants play a crucial role in slowing down or preventing degenerative diseases that arise from oxidative damage to cellular components, primarily by stabilising or neutralising free radicals [33, 34]. Primary antioxidants function as chain-breaking agents, eliminating radical species through hydrogen donation. Phenolic compounds derived from medicinal herbs and dietary plants, such as flavonoids, tannins, coumarins and xanthenes, had demonstrated radical-scavenging activity, and thus were considered as promising therapeutic agents against free radical-related disorders [35]. The antioxidant properties of *M. micrantha* were extensively evaluated by using different in vitro assays, including total antioxidant capacity (TAC), ferrous reducing capacity (FRC) and 1,1-diphenyl-2-picryl-hydrazyl (DPPH) free radical scavenging activity (DRSA). Collectively, these assays demonstrated the strong radical-neutralising and reducing potential of *M. micrantha*, attributable mainly to its high content of phenolic compounds. Khatun *et al*. (2020) studied three different species of *Mikania*, namely *M. cordata*, *M. micrantha* and *M. scandens*. They reported that amongst the three species, *M. micrantha* showed lower TAC and FRC as compared to *M. cordata*, but higher than *M. scandens* [36]. Both assays indicated the presence of phenolic compounds, which might act as electron donors; hence, the intense activity of TAC and FRC was due to the presence of the highest concentration of polyphenols [37]. DRSA was also observed to be higher in *M. micrantha*. According to Litwinienko and Ingold (2003) and Foti and Roberto (2000), the DPPH assay was based on the ability of DPPH to accept an electron in the presence of antioxidants [38, 39], and thus correlated well with the results of Khatun et al. (2020) [36], whereby all extractives are free radical scavengers, which might be attributed to their electron donating ability.

The same group of researchers also determined the hydroxyl radical scavenging activity (HRSA) of the extracts. The results indicated higher scavenging activity of more than 60% as compared to standard catechin (CA). Hydroxyl radicals are the major reactive oxygen species (ROS), causing lipid oxidation and enormous biological damage [40]. The process of lipid peroxidation is mediated by interaction of hydroxyl radicals with the cell membrane, subsequently producing lipid-derived free radicals [41]. The results obtained in this study revealed that *M. micrantha* showed ability to quench hydroxyl radicals; hence, a better source to prevent lipid peroxidation. A similar observation was determined in another assay, the hydrogen peroxide assay (HPSA). Higher HPSA indicated that this plant can scavenge hydrogen peroxide. Hydrogen peroxide may cause harmful physiological responses, which may lead to the development of cell damage and various diseases such as diabetes, atherosclerosis, ischemic injury, inflammation and carcinogenesis, leading to oxidative stress [42].

Antioxidative defense mechanisms

Reactive oxygen species (ROS), including superoxide radicals ($O_2^{\bullet -}$), hydrogen peroxide (H_2O_2) and hydroxyl radicals (•OH), are inevitable by-products of plant metabolism, particularly under stress conditions, such as drought, high irradiance, cold, and pathogen attack. Excess ROS accumulation can damage cellular structures through lipid peroxidation, protein oxidation and DNA injury, ultimately impairing plant growth. To counterbalance these effects, plants have evolved a complex antioxidant defense system consisting of enzymatic and non-enzymatic components [43].

Enzymatic antioxidant systems

As a highly invasive species, *M. micrantha* thrives in diverse environments, ranging from disturbed terrestrial habitats to moist riparian ecosystems. One of the keys to its ecological success might lie in its robust antioxidant defense system, which enables it to cope with elevated ROS under stress conditions such as drought, flooding, pathogen attack and high irradiance. Superoxide dismutase (SOD) provides the first line of defense against oxidative stress, whereby it converts $O_2^{\bullet -}$ into H_2O_2 and oxygen (O_2). Further breakdown of H_2O_2 into water (H_2O) and O_2. Studies on *M. micrantha* under drought and high light conditions revealed significantly elevated SOD activity, which protected photosynthetic machinery from ROS-induced damage [44]. Increased CAT activity has also been reported in *M. micrantha* seedlings during combined light and water stress, although prolonged stress conditions reduce its effectiveness [45]. Another enzyme, peroxidases (POD/GPX) play a critical role in reducing H_2O_2 by utilising phenolic substrates or glutathione, and is particularly important under biotic stress. In *M. micrantha*, infection with *Puccinia spegazzinii* was shown to activate peroxidase-linked defense pathways, highlighting their role in pathogen resistance [46]. In addition, enzymes such as ascorbate peroxidase (APX) and glutathione reductase (GR), though less frequently studied in this species, are suggested by transcriptomic analyses to be upregulated under stress. Together, APX and GR sustain the ascorbate–glutathione cycle, thereby ensuring effective ROS detoxification and maintaining cellular redox homeostasis [47].

Non-enzymatic antioxidant systems

Alongside its enzymatic system, *M. micrantha*

accumulates diverse non-enzymatic antioxidants**,** including phenolics, flavonoids, carotenoids, ascorbic acid and glutathione**.** Flavonoid accumulation was correlated with enhanced stress tolerance and radical scavenging efficiency, while carotenoids protect chloroplasts by quenching singlet oxygen during high light stress [48]. It was found that the methanolic extracts of *M. micrantha* leaves and flowers exhibit strong DPPH, ABTS and FRAP activities, largely attributed to their high phenolic and flavonoid content [49, 50]. The ascorbate–glutathione (AsA–GSH) cycle also plays a pivotal role in ROS detoxification, with ascorbate acting both as a direct scavenger and an essential cofactor for APX. Ascorbic acid (Vitamin C) serves as a primary antioxidant in scavenging free radicals and regenerating oxidised glutathione. Extracts of *M. micrantha* show radical scavenging activity comparable to or higher than ascorbic acid standards [10], indicating significant endogenous pools of this molecule. Glutathione (GSH) functions as a redox buffer and cofactor for GR and GPX. Increased GSH levels in *M. micrantha* seedlings under high irradiance and drought stress support its role in detoxification and stress tolerance [45]. Pigments such as chlorophyll, carotenoids, and anthocyanins accumulated in the leaves and stems of *M. micrantha*. These pigments increase antioxidant capacity, protect chloroplasts from photoinhibition and reduce oxidative stress damage during winter [51]. In addition, although primarily considered as an osmoprotectant, proline accumulation in *M. micrantha* also contributes to ROS scavenging under abiotic stress, enhancing resilience [45].

Therefore, the balance between enzymatic and non-enzymatic antioxidants ensures that plants maintain cellular homeostasis under fluctuating and stressful environments. The coordinated activation of SOD, CAT, and POD, along with the accumulation of flavonoids, phenolic compounds, pigments, vitamins, and glutathione, provides robust oxidative stress tolerance [43] (**Figure 3**). This biochemical adaptability is one of the critical traits underlying its success as an invasive species, allowing it to outcompete native vegetation even under adverse conditions.

Antimicrobial activities

As a fast-growing invasive climber, *M. micrantha* has gained increasing attention for its rich repertoire of bioactive metabolites with potential pharmacological and agricultural applications. Amongst these, its antifungal (**Table 5**) and antibacterial (**Table 6**) activities were widely reported, with extracts from leaves, stems, and roots showing inhibitory effects against a broad spectrum of pathogens through certain compounds involved, such as mikanolide, deoxymikanolide, scandenolide, dihydroscandenolide, and dihydromikanolide [52] (**Figure 4**). Moreover, this plant extract has been shown to inhibit the growth of both Gram-positive and Gram-negative bacteria. Methanol and ethanol extracts demonstrated strong inhibitory effects against *Staphylococcus aureus*, *Bacillus subtilis*, and *Escherichia coli*, suggesting the presence of potent bioactive compounds with antibacterial potential [53, 2]. In contrast, chloroform and hexane extracts also exhibited antibacterial activity but were generally less effective as compared to polar extracts. The antimicrobial properties of *M. micrantha* are largely attributed to its secondary metabolites, particularly flavonoids, phenolic acids, sesquiterpenes and other phytochemicals, which may act individually or synergistically to disrupt bacterial cell walls, inhibit protein synthesis, and interfere with metabolic pathways [54, 55].

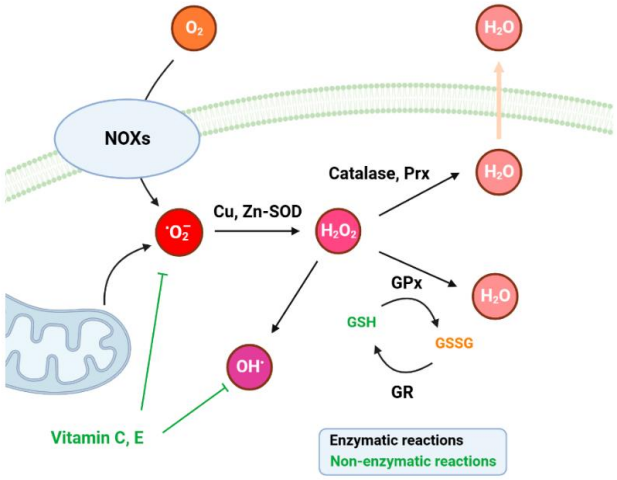

Figure 3. Schematic presentation of antioxidation systems with enzymatic and non-enzymatic antioxidants. Black arrows indicate enzymatic reactions, and green lines indicate non-enzymatic reactions. NOXs: the NADPH oxidases; SOD: superoxide dismutase; Prx: peroxiredoxin; GPx: glutathione peroxidase; GR: glutathione reductase; GSH: glutathione; GSSG: glutathione disulfide [43].

In addition, nine germacrane sesquiterpenoids were tested for antibacterial activity against seven bacterial strains (**Figure 2**), including human pathogens (*S. aureus*, methicillin-resistant *S. aureus*, MRSA, *B. cereus*, *E. coli*, *S. typhimurium*) and plant pathogens (*C. flaccumfaciens*, *P. solanacearum*) [31, 56]. Compound 4 and compounds 7-9 showed strong broad-spectrum activity with MIC values of 6.25 – 12.5 μg/mL, comparable to kanamycin and vancomycin, while the other compounds were inactive. Importantly, these four compounds exhibited potent activity against MRSA, highlighting their potential as novel antibacterial agents for both medical and agricultural applications [57]. The methanolic extract of *M. micrantha* exhibited in vitro antibacterial activity against *Staphylococcus aureus* [58]. Recently, Cheng et al. (2024) reported that the ethyl acetate fraction and volatile oil of this plant exhibited antipruritic effects, with GC-MS analysis identifying β-caryophyllene and humulene as the main active compounds [6].

Antitumour potential

M. micrantha has exhibited antitumour effects in experimental models, supported by both crude extract studies and isolated phytochemicals. Its aqueous extract demonstrated notable antitumour activity both in vitro and in vivo, with tumour inhibitory rates ranging from 12.1% to 46.9%. It effectively inhibited the proliferation of K562 and HeLa cells and significantly suppressed tumour growth in S180 sarcoma-bearing animal models through multiple mechanisms, including cell cycle arrest, induction of apoptosis and necrosis, as evidenced by Hematoxylin-Eosin-stained tumour sections, while exhibiting minimal toxicity towards immune organs [69]. According to Debaprotim et al., the *n*-butanolic extract of *M. micrantha* (BEMM) exhibited significant antitumour activity against EAC cell lines in Swiss albino mice [70]. Oral administration of the extract resulted in a marked reduction in tumour volume, prolonged lifespan, and restoration of haematological parameters to near-normal levels. [70].

Table 5. Antifungal activities of *M. micrantha*

Source	Target Pathogens	Active Compounds	Bioactivity	References
Leaf & root extracts (methanol, ethyl acetate, acetone, chloroform)	*Fusarium solani*, *Rhizoctonia solani*, *Phytophthora parasitica*, *Pythium aphanidermatum*		General inhibitory activity; chloroform was most effective	[29]
Chloroform extract (isolated compounds)	*F. solani*, *R. solani*, *P. parasitica*, *P. aphanidermatum*	Sesquiterpenes: mikanolide, dihydromikanolide, deoxymikanolide, scandenolide, dihydroscandenolide (deoxymikanolide most active)		[29] [59] [30]
Rhizosphere soil	*Fusarium graminearum*		Growth inhibition	[60]
Application of dihydromikanolide in soil	*Pseudorobillarda*, *Massarina*, *Robillarda* spp.		Suppressed abundance of pathogenic fungi	[61]
Rhizosphere soil (microbial community influence)	*Fusarium oxysporum*, *Ralstonia solanacearum* (reduced abundance)		Enhanced biocontrol bacteria (*Catenulispora*, *Pseudomonas*, *Candidatus entotheonella*) and polyketide synthase gene abundance	[60] [62] [63] [64]

Table 6. Antibacterial activity of *Mikania micrantha* extracts

Extract Type / Compound	Target Microorganism(s)	Observed Activity	References
Methanol leaf extract	*Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*	Significant growth inhibition (zone of inhibition ≥15 mm)	[65]
Ethanol extract (leaf & stem)	*Pseudomonas aeruginosa*, *Klebsiella pneumoniae*	Moderate antibacterial activity	[66]
Chloroform extract	*Escherichia coli*, *Salmonella typhi*	Weak to moderate inhibition	[67]
Hexane extract	*Staphylococcus aureus*	Mild inhibition	[14]
Aqueous extract	*Bacillus subtilis*, *E. coli*	Limited or no significant effect	[68]

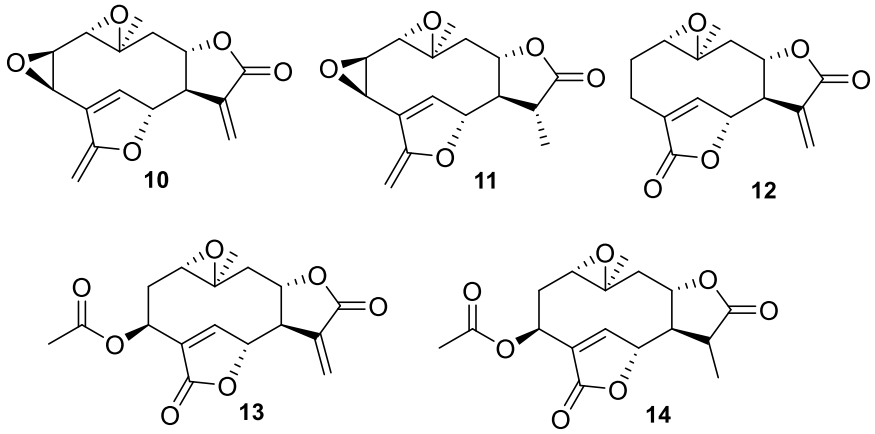

Figure 4. Compounds involved in the antifungal activity of *M. micrantha*: **10:** mikanolide, **11**: dihydromikanolide, **12**: deoxymikanolide, **13**: scandenolide, **14**: dihydroscandenolide. [52].

Beyond whole extracts, specific sesquiterpene lactones and dilactones isolated from the aerial parts of *M. micrantha* demonstrated in vitro cytotoxic activity against cancer cell lines, indicating that these metabolites contribute to the antitumor potential of the species [32]. Additionally, recent work by using *M. micrantha* leaf extract to mediate silver nanoparticle synthesis showed that such silver nanoparticles could effectively induce cytotoxicity and inhibit colony formation in A549 lung cancer cells in a dose-dependent manner, promoting DNA damage and oxidative stress that contribute to cancer cell death [71].

Allelopathic effects

Allelopathy refers to the interaction between donor and receiver plant species through the release of bioactive compounds, known as allelochemicals. Allelochemicals are produced and released by the donor plant species, which can suppress germination, growth, and development of the receiver plant species [72-74]. Extracts of *M. micrantha* tissues (leaves, roots, and stems) were consistently reported to inhibit germination, growth, biomass accumulation, and chlorophyll content in a range of crop and weed species, including *Lycopersicon esculentum*, *Brassica chinensis*, *Eleusine indica*, *Cyperus iria*, *Ageratum conyzoides*, and thus indicating the presence of potent extractable allelochemicals [45, 75-79].

Earlier reports suggested that phenolic compounds were key allelochemicals in *M. micrantha*. Yamauchi and Watada reported that resorcinol could disrupt chlorophyll structure and vanillic acid reduces soybean biomass and photosynthetic rate [80, 81]. Caffeic acid was shown to inhibit germination and growth in both goosegrass and tomato [82, 83], while p-hydroxybenzaldehyde suppressed peach tree growth [84]. Recently, phytochemical analyses had

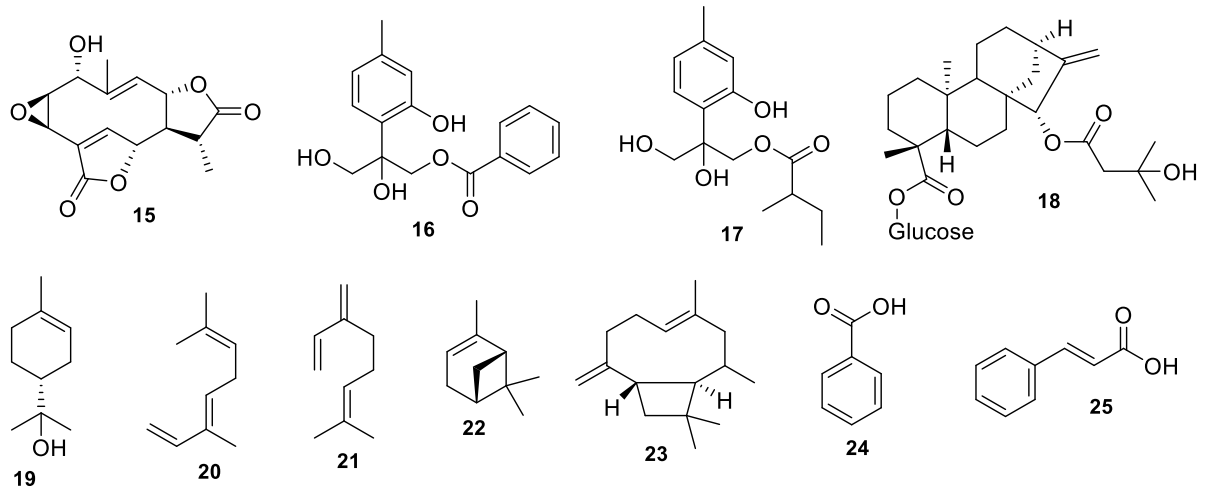

Figure 5. Compounds involved in the allelopathic activity of *M. micrantha*. **15**: 2,3-epoxy-1-hydroxy-4,9-germacradiene-12,8:15,6-diolide, **16**: 8,10-dihydroxy-9-benzoyloxythymol, **17**: 8,10-dihydroxy-9-(2-methylbutyryloxy) thymol, **18**: β-D-glucopyranosyl-15α-(3-hydroxyl-3-methylbutanoyloxy)-ent-16-kauren-19-oate, **19**: α-terpineol, **20**: β-ocimene, **21**: β-myrcene, **22**: α-pinene, **23**: β-caryophyllene, **24**: benzoic acid, **25**: cinnamic acid [52]

identified several bioactive compounds, including three sesquiterpenoids (dihydromikanolide, deoxymikanolide, and epoxy-germacradiene derivatives) [76], thymol derivatives [85], and ent-kaurene diterpene glucosides [86], that exhibited strong inhibitory effects on seed germination and seedling growth. In addition, volatile compounds, including α-terpineol, β-ocimene, β-myrcene, α-pinene, and β-caryophyllene, suppressed neighbouring plants by inducing oxidative stress [87]. Similarly, benzoic and cinnamic acids isolated from leaf extracts decreased chlorophyll content, suppress antioxidant activity and promote oxidative stress damage in target species [88] (**Figure 5**)

Conclusion

Mikania micrantha is a fast-growing invasive plant notable for its rich phytochemical diversity and wide range of biological activities. Many studies had investigated its biological properties, identifying natural compounds that may underlie its therapeutic potential. These findings suggest that this invasive plant could be transformed from a troublesome weed into a valuable source of health benefits. Its secondary metabolites, including flavonoids, phenolic acids, sesquiterpene lactones, and volatile compounds, contribute to antioxidant, antifungal, antibacterial, anti-inflammatory and antitumour effects observed in experimental studies. The strong antioxidant capacity of plant, mediated through both enzymatic and non-enzymatic defense systems, likely supports its stress tolerance. Beyond its ecological impact, the bioactive properties of *M. micrantha* highlight its potential for applications in pharmaceuticals, agriculture and natural product development, particularly as a source of antimicrobial and atitumour agents. Despite growing research, significant gaps remain, including limited characterisation of active compounds, incomplete understanding of their mechanisms of action, lack of standardised extraction protocols, and insufficient dose-response and toxicity data. Future studies should prioritise the in-depth identification and validation of its bioactive compounds, comprehensive pharmacological evaluations, and the development of strategies that integrate its utilisation into sustainable management practices. Such efforts could transform *M. micrantha* from a problematic invasive weed into a valuable resource for medicinal, nutraceutical, and cosmeceutical applications. Integrating its utilization into sustainable management strategies may not only advance drug discovery but also provide innovative approaches for ecological control and valorisation of this invasive species.

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