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(REVIEW ARTICLE)

Medically significant monotypic species *Martynia annua* L.: A review on ethnobotany, phytochemistry and pharmacology

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Abstract

Martynia annua commonly known as Thael kodukkai belonging to the Martyniaceae family is an herbaceous plant with many medicinal properties. It is a weedy peculiar species native to tropical and subtropical regions of Mexico. The entire herb is found to exhibit potential pharmacological activities. The various parts of this plant have been reported to show many therapeutic indications like anticancer, antibacterial, anticonvulsant, anti-inflammatory, wound healing, analgesic, antipyretic activity, antioxidant, anti-diabetic, anti-nociceptive, immunomodulatory, hepatoprotective, anti-hemolytic, anti-thrombotic, anti-arthritic, anti-haemorrhoidal, anti-alopecia, anti-muscular, anti-helminthic, gastroprotective and anti-fertility activities. This review aims to provide the compilation of existing knowledge on the phytochemistry and pharmacological properties of *M. annua* from the reported studies. The phytochemical screening results of various extracts of stem, root, leaves and fruits of *M. annua* were discussed in this review. A greater number of phytoconstituents were reported to be present in leaves. This review suggests that this plant contains various phytoconstituents like anthraquinones, terpenoids, flavonoids, tannins and phenolic compounds that are responsible for various pharmacological activities. In the future, this plant provides an immense scope for pharmacological investigations.

Keywords: *Martynia annua*; Martyniaceae; Thael kodukkai; Phytoconstituents; Pharmacological activities

1. Introduction

India is the motherland of revived systems of native or indigenous medicine such as Ayurveda, Siddha and Unani. Ayurveda, an ancient medicine system is considered to be a holistic system of medicine in India. Ayurveda is defined as a complete science of life which is renowned as one of the major systems of alternative and supportive medicine. Due to the availability of several thousands of medicinal plants in different bioclimatic zones, India is known as the "Emporium of medicinal plants". Even with the modernization of medicines, plants remain to be an essential source of these components. Modern drugs are made up of synthetic compounds which may lead to severe side effects but herbal drugs ensure safety and efficacy. Due to this reason, many people prefer to use products obtained from plants and other natural sources. Numerous scientific investigations and studies have been conducted around the world as a result of the understanding of medicinal plants and their applications in the Indian system of medicine. Only a few phytochemical studies have been done on the selected plant at present. The plant was named Martynia, in honor of a professor of botany at Cambridge University, John martyn. The different parts of *M. annua* Linn (seed, roots, stems, leaves, flowers) have been used for many therapeutic indications like analgesic, anti-inflammatory, wound healing, antifertility, anti-oxidant, etc., It has been reported to show potential pharmacological activities including anti-convulsant, antibacterial and anti-inflammatory. *M. annua* is found commonly on the roadside, in degraded dry and wet forest areas, wastelands

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and overgrazed pastures. It is a weedy peculiar species native to tropical and subtropical regions of Mexico, Burma, Central America and throughout India [1-5].

Bentham and Hooker placed the genera Oraniolaria, Proboscidea and Martynia in the family Pedaliaceae, but based on parietal placentation, calyx, fruits and trichomes, Engler and Prantil assigned them to a separate family called Martyniaceae**.** *M. annua* L., is commonly known as Devil's claw, Tiger's claw or snake head [6, 7]. The main focus of this review is based on the pharmacological (from 2002) and phytochemical data (from 2012) collected from the standard literature that is cataloged in Science Direct, PubMed, Google Scholar, Research gate and Google database. The keywords of this survey include, *M. annua*, phytochemicals, secondary metabolites, biological activities, anticancer, antimicrobial, antioxidant and antidiabetic activities, which were used individually or in combination. Here, we summarized the various phytochemical constituents and pharmacological activities of this exotic Indian medicinal plant.

2. Plant Profile

2.1. Taxonomy of *M. Annua*

- Kingdom: Plantae
- Phylum: Magnoliophyta
- Class: Angiosperms
- Order: Lamiales
- Family: Martyniaceae
- Genus: Martynia
- Species: *Martynia annua*

2.2. Synonyms

- *Carpoceras longiflora A. Rich*
- *Disteira angulosa (Lam) Ref.*
- *Martynia diandra Glox*
- *Martynia angulosa Lam.*
- *Martynia proboxidea Glox*
- *Proboscidea cordifolia moench*

2.3. Vernacular names

Thelkodukkukai, Puli-nakam, Cat's claw, Tiger's claw, Devil's claw, Hathajori, Bichu, Ulat-kanta, Vichchida Vinchu, Garudamukku, Telukondicchhettu

2.4. Macroscopic Characters

- Colour: Brown–yellow
- Odour: Odourless
- Taste: Tasteless
- Appearance: Oily nature

It is an erect, branched, clammy-pubescent annual herbaceous plant, about 90-120 cm high**.** Stems are green, hollow-branched and covered with glandular hairs**.** Leaves are large [15-23 cm], opposite, cordate, sinuately lobed and minutely dentate often covered with a glutinous dew-like substance**.** Flowers in racemes are large, foxglove-shaped, pink and dark purple blotched with yellow color inside, ill-smelling and zygomorphic**.** Fruits are hard and woody with two sharp recurved hooks, while the seeds are oblong and compressed [8-10]**.** The different parts of the plant *M. annua* are given in Fig 1.

Figure 1 Different parts of the plant *M. annua*

2.5. Microscopic Characters

Powder-Black and rough, groups of thick-walled cells, many fibers, oil globules and unicellular hairs are seen**.** The total ash and acid-insoluble ash of the root, fruit and leaves of *M. annua* were found to be (10.50%, 3.48%), (4.15%, 0.7%) and (4.1%, 0.3%), respectively. The water-soluble ash values of roots and leaves were reported as 18.05% and 2.21% respectively. The alcohol and water-soluble extractive values of roots and fruits were observed as (52.65 % and 32.25%), (29.3% and 6.5%), respectively. The ether soluble extractive value of root is given as 6.45%. The Moisture content of leaf powder was found to be 87.1% [11-13]**.**

2.6. Ethnobotanical Use

The paste of the leaves is used to treat tuberculous glands, venomous stings and epilepsy. Its juice is used for gargling. Additionally, leaves are consumed in the treatment of scabies, tuberculosis, sore throat and neck cancer. Fruit paste is utilized as alexiteric and in the treatment of inflammatory conditions and scorpion stings. Fruit oil is used in the treatment of scabies, eczema and Tinea corporis. Root extract is used in the treatment of sedation, rheumatism, infertility and cancer. For asthmatic irritation, seed powder is used. Its seed oil is reported to have good iodine value, which is applied to treat itching and skin infections. It is also used for arresting grey hair [2, 8, 9].

3. Phytochemistry

Phytoconstituents are defined as the bioactive chemical compounds which are responsible for the pharmacological activity of herbs. They also offer protection to plants from predators. They are also responsible for the morphological characteristics of a plant. Various therapeutic indications of *Martynia* are due to the presence of primary metabolites like carbohydrates, amino acids, proteins and chlorophylls and also due to secondary metabolites like alkaloids, saponins, steroids, flavonoids, tannins, etc., [1, 3].

The higher percentage (69%) of phytochemical constituents was present in the methanolic extract of *M. annua***.** The total flavonoid content of leaves, roots and stems of *M. annua* is reported as 0.122± 0.002, 0.0677± 0.001 and

0.0724±0.002 respectively [14-16]. The phytoconstituents present in different parts of *M. annua* are summarized in Table 1 and Fig 2.

Table 1 Phytoconstituents present in *M. annua*

S. No	Parts of the plant	Phytoconstituents	Reference
1	Flowers	Cyanidin 3- galactoside, p-Hydroxy benzoic acid, Snapic acid, Gentisic acid.	[2, 11]
2	Leaves	Chlorogenic acid, Fatty acid [Palmitic acid, Stearic acid, Arachidic acid], p-Hydroxy benzoic acid, Snapic acid.	[2, 3, 11]
3	Seeds	Arachidic acid, Linoleic acid, Malvolic acid, Oleic acid, Palmitic acid, Stearic acid, Apigenin and Apigenin-7-O-beta Glucuronide.	[2, 3, 11]
4	Fruits	Gentisic acid, Fatty acids [Palmitic acid, Stearic acid, Linolic acid, Oleic acid].	[11]

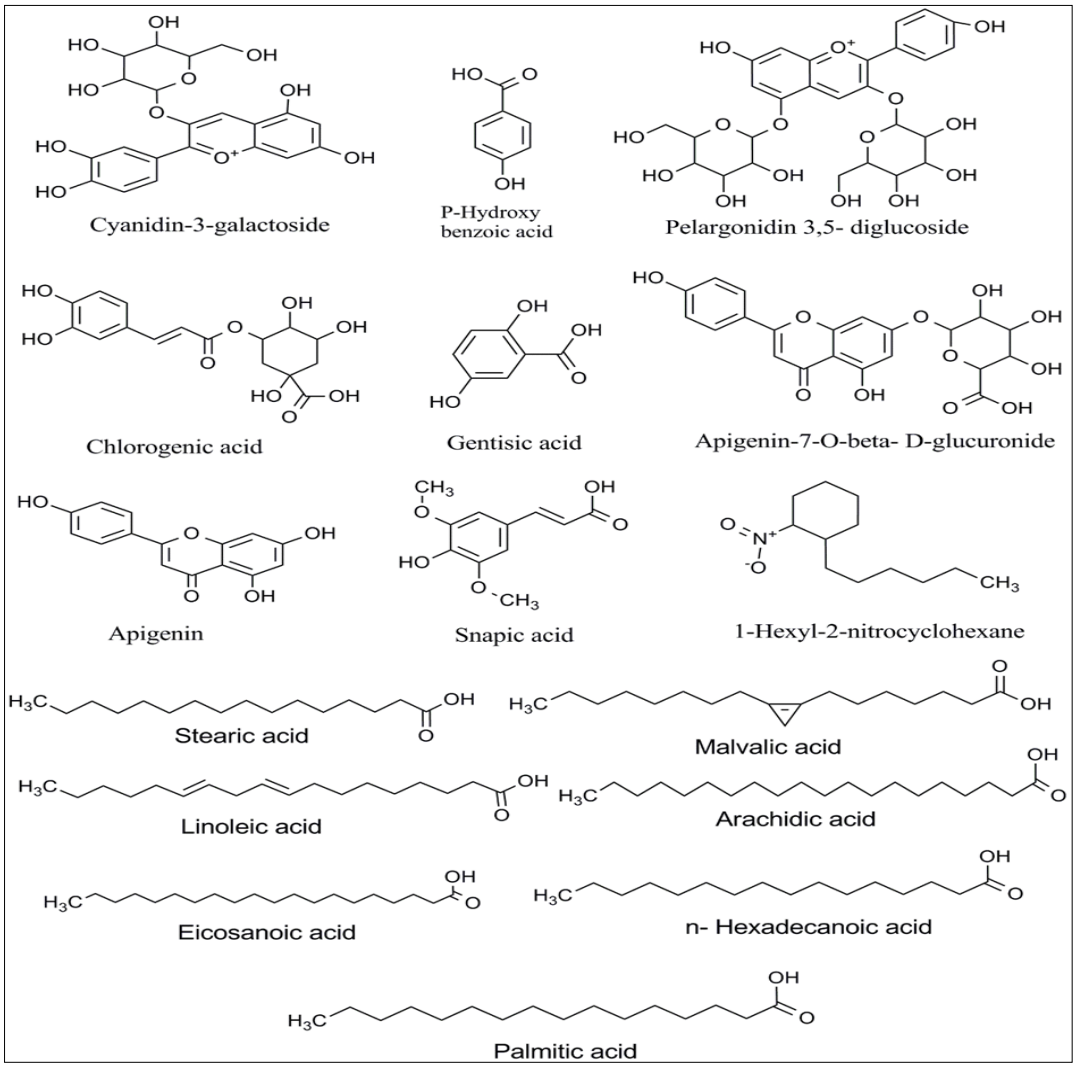

Figure 2 Phytoconstituents of *M. annua*

Further, using GC-MS analysis, Katare and Tyagi identified 11 constituents from the acetone extract of leaves, stems and roots of *M. annua*. Compounds include 2,5-dihydroxybenzoic acid (36.3%), Cyanidin-3-galactoside (34.14%), 1-Hexyl-2-nitrocyclohexane (31.01%), Oleic acid (30.61%), Apigenin (27.07%), Chlorogenic acid (25.07%), Eicosanoic (18.55%), n-Hexadecanoic acid (17.13%), ethanol 2-(2-amino ethoxy) (16.78%), pelargonidin-3,5-diglucoside (12.9%) and apigenin-7-A-D, glucoside (4.4%) [3].

4. Pharmacological Activities

Since herbal medicines were used for several clinical management of a variety of diseases in traditional cultures, the rate of new drug development from herbal medicines has increased due to the presence of secondary metabolites. Different parts of *M. annua* including the stem, leaf, root and flower showed various pharmacological activities.

4.1. Anti-Bacterial Activity

Dhingra AK et al., 2020 studied the antibacterial activity of petroleum ether, chloroform and ethanolic extracts of leaves of *M. annua* by agar plate diffusion method. Bacterial strains like *Staphylococcus aureus*, *Bacillus subtilis*, *Klebsiella pneumonia*e and *Escherichia coli* were used to study the antibacterial activity. Muller Hinton agar medium was chosen. It was reported that ethanolic and ethyl acetate leaf extracts of *M. annua* [100µg/ml] showed the maximum inhibition of growth (28 mm and 22 mm) against *S. aureus* followed by *B. subtilis*, *K. pneumoni*ae and *E. coli*. Significant activity was observed in chloroform extract at 50 and 100 µg/ml concentration but the petroleum ether extract of *M. annua* showed the minimum zone of inhibition at 25 and 50µg/ ml against all the microorganisms tested. Kalaichelvi and Dhivya experimented the leaf extract of *M. annua* revealed that the ethanolic extract showed a significant zone of inhibition against *S. aureus, K. pneumoniae, B. subtilis and Proteus mirabilus* [17, 18].

The antibacterial activity of fruit and flower extracts of *M. annua* using the cup plate agar diffusion method against pathogenic bacteria was studied. The results revealed that the methanolic flower extract and fruit extract exhibited the highest antibacterial action against *B. subtilis* than the Streptomycin standard drug. Poor action was exhibited against *E. coli* and *Salmonella typhi* and no action was shown against *S. aureus* by the flower extract of *M. annua* [19, 20].

4.2. Anthelmintic Activity

Nirmal et al., 2007 experimented on various root extracts of *M. annua* to study the anthelmintic activity. Due to the anatomical and physiological resemblance with intestinal roundworms found in human beings, earthworm was used to evaluate the anthelmintic activity of *M. annua*. Three groups each containing equally sized 6 earthworms were taken. One group was treated with vehicle (5% DMF with normal saline), the second group was treated with standard drug (Albendazole) and the third group was treated with extracts. Time taken to cause paralysis and death of individual worms was noted. All the extracts showed a dose-dependent anthelmintic activity, of which petroleum ether extract required the least time to cause paralysis and death of earthworms when compared to the standard drug**.** The potential anthelminthic activity was observed in the methanolic extract at 50 mg/ml concentration when compared to Albendazole as standard [21, 22].

4.3. Anti-Oxidant Activity

Arshad et al., 2017 evaluated the DPPH scavenging activity of fruits of *M. annua*. Among all the extracts, the ethanolic extract was reported to exhibit the highest antioxidant activity. Reducing power assay and lipid peroxidation inhibition assay were also performed and the reports revealed the highest antioxidant potential of the ethanolic extract [3, 15]. Gupta and Deogade et al., 2019 experimented on hydroalcoholic, aqueous, ethanolic extract of roots of *M. annua* using *in vitro* DPPH assay against ascorbic acid as a standard drug. Different concentrations of *M. annua* root extract (25-100µg/ml) were tested for antioxidant activity. An increase in the concentration of extract showed an increase in antioxidant activity. The IC_{50} value of ascorbic acid was 62.91±2.85µg/ml. The IC_{50} (µg/ml) values of hydroalcoholic, aqueous and ethanolic root extract of *M. annua* were reported as 69.56±3.44, 70.91±2.91 and 68.49±3.15, respectively. Out of all the extracts, the aqueous extract showed the highest antioxidant activity at 518nm. Ramya et al., 2015 studied the DPPH radical-scavenging activity using the three parts of *M. annua* (i.e.,) flower, leaf and stem at 0 mins and 16 mins. The percentage of scavenging activity of the extracts of flowers, leaves and stem at 0 mins was found to be 0.151, 0.254, 0.341 and at 16 mins was found to be 73.54, 56.45 and 40.64 respectively. Of all the three parts tested, the methanolic extract of the flower showed the highest scavenging activity followed by the methanolic extract of the leaf and stem. Kenwat et al., 2014 experiment revealed that the DPPH scavenging activity of fruit oil of *M. annua* was due to the presence of phenolic and flavonoid compounds [23-25].

4.4. Anti-Cancer Activity

The *in vitro* anticancer activity of hydroethanolic, ethanolic and aqueous root extract of *M. annua* was evaluated on different human cancer cell lines including Lung cancer cell lines (A549), Leukemia cancer cell lines (K562), Oral cancer cell lines (SCC-40), Breast cancer cell lines (MCF7) and cervix cancer cell lines (SiHa) and its growth inhibition of 50% (GI_{50}) was determined by using sulforhodamine B (SRB) assay technique by comparing with standard drug doxorubicin. The results of the study revealed that aqueous extract is effective against the leukemia cell line having a GI_{50} value of 11.3 µg/ml. The GI_{50} of ethanolic extract of *M. annua* was found to be 20.4µg/ml. Both the aqueous and ethanolic root extract of *M. annua* was found to exhibit higher anticancer activity.

At the GI_{50} value of more than 80µg/ml, all three extracts showed anticancer activity against various cancer cell lines. Anticancer activity on all five cancer cells was found to be due to the presence of phytoconstituents like anthraquinones and terpenoids. Anticancer activity on hormone-dependent cancer cells (breast and cervical) was mainly due to the presence of steroids. The *M. annua* root extracts were proved to be highly effective against fast proliferative cells and the possible mode of action was found to be cell cycle arrest [3, 4].

4.5. Anti-Arthritic Activity

Kaushik et al., 2021 evaluated the anti-arthritic activity of *M. annua* fruit extract in ethanol using Albino Wistar rats [weighing between 150-200g]. Arthritis was induced by intra-articular injection of CFA-Complete Freund's Adjuvant (0.1 ml) on the sub-plantar surface of the right hind paw and the animals were treated with the plant extract at 200 mg/kg and 400 mg/kg doses for 14 days. Assessment of arthritis was done by measuring the paw volume and body weight. The reports showed higher protection of 64.28%. Maximum paw edema reduction (65.33%) was observed at a higher concentration of extract when compared to the standard drug-Indomethacin (10 mg/kg). It is evident from the study that the fruit extracts of *M. annua* have the significant anti-arthritic potential [3, 26].

4.6. Anti-Inflammatory Activity

The flavonoid-rich extracts of *M. annua* were investigated using the paw edema model of Wistar Albino rats. The carrageenan-induced edema (0.1 ml of 1%) was found to be reduced with flavonoid-rich extract ($P< 0.05$) in a dose-dependent manner. Histamine (0.1 ml of 1%) induced edema models also confirmed the anti-inflammatory activity. The results indicated that edema was inhibited at the dose of 300 mg/kg. The extract's ability to inhibit the synthesis, release or action of histamine involved in inflammation was determined to explain its efficacy**.** Kaushik S et al., 2021 confirmed the anti-inflammatory activity of the ethanolic extract of fruits of *M. annua* using a CPL (Calotropis Procera Latex) induced paw edema model in rats [3, 17, 26, 27].

4.7. Analgesic and Antipyretic Activity

The analgesic and antipyretic activities of petroleum ether, ethanol, chloroform and aqueous extracts of fruits of *M. annua* was studied using Swiss Albino mice and Adult Wistar rats. Brewer's yeast was used to induce hyperpyrexia in them. Out of all the extracts, the petroleum ether and chloroform extract were found to show potential analgesic and antipyretic activity when compared to a standard drug, Diclofenac [3, 28].

4.8. Wound Healing Activity

The wound healing property of ethanolic leaf extract of *M. annua* was evaluated using excision and incision models on rats using Povidone iodine ointment as the reference standard. Using the excision model, wound contraction, biochemical parameters and histopathological studies were done and tensile strength was determined using the incision model. The flower extract treated group showed greater wound contraction and tensile strength of skin tissues and also exhibited a higher level of protein and hydroxyproline content. Thus, the wound-healing property of *M. annua* is proved. Luteolin and flavonoid fraction was topically applied at the concentration of 0.2 % and 0.5% w/w on diabetic wounds of rats. *M. annua* is reported to show significant wound-healing activity in streptomycin-induced diabetic rats. Lodhi and co-workers also confirmed the significant wound-healing activity of the methanolic fraction of *M. annua.* Saxena M and Kishore K., 2022, reported the potent wound-healing activity of *M. annua* using an excision wound model [29-32].

4.9. Anti-Muscular Activity

The anti-muscular property of various parts of *M. annua* was evaluated using Wistar Albino rats in a rotarod test. 200 and 400 mg/kg doses of acetonic extracts were used to study this activity. The time spent by the animals on the revolving rod was measured to evaluate the muscle relaxant property of rats. Acetone extract of *M. annua* was shown to exhibit a significant muscle relaxant activity by a 70% reduction in the time spent by the animals on the rotarod. But the highest

reduction percentage was shown in the leaf extract (89.48%) followed by seeds, stem and roots when compared to Diazepam as a standard drug [3, 33].

4.10. Anti-Nociceptive Activity

The antinociceptive and CNS depressant activity in *M. annua* extracts of roots was investigated by using acetic acid to induce writhing. Using the hot plate method, petroleum ether extract was found to show a high elevation in reaction time at the dose of 50 mg/kg I.P., when compared to the standard drug, paracetamol and pentazocine. This extract also exhibited reduced locomotory activity in comparison with the standard drug Diazepam [3].

4.11. Anticonvulsant Activity

Babu et al., 2013 experimented on the methanolic extract of *M. annua* leaves to study the anticonvulsant activity using Albino rats. To induce convulsion, Maximal Electron Shock (MES) and Pentylenetetrazole (PTZ) was used. The *M. annua* extract was given at the dose of 200 mg/kg and 400 mg/kg body weight (MES-induced rat) which showed anticonvulsant activity at 66.3% and 82.73 % respectively when compared to the standard drug, diazepam. It was also reported to show protection from mortality at 83.33% to 100% on PTZ-induced convulsions in rats. The fidelity level of *M. annua* decoction of leaves to treat epilepsy was found to be 53.33% [3, 34].

4.12. Anti-Diabetic Activity

The anti-diabetic activity of flower extracts of *M. annua* was investigated using male Albino Wistar rats. Diabetes was induced using Streptozotocin (STZ 55 mg/kg) and Streptozotocin-Nicotinamide (STZ-NIC 55,110 mg/kg) in Wistar rats. Then the methanolic flower extract was administered at the dose of 200 mg/kg and 400 mg/kg to diabetic rats for 21 days. After 21 days a better reduction in the level of blood glucose, triglyceride and glycosylated hemoglobin and an increase in the level of HDL was observed in a dose-dependent manner. Thus, the methanolic flower extract was found to exhibit good antidiabetic activity. Alrabie and co-workers experiment revealed that 50g/ml of methanolic plant extract of *M. annua* showed a maximal inhibition of α-glucosidase (59.13%) and salivary *α–amylase* (73.3%) which was greater than metformin at 10g/ml. The Antidiabetic property of *M. annua* was found to be due to the presence of flavonoids, terpenoids and tannins [35, 36].

4.13. Hepatoprotective Activity

The hepatoprotective activity of *M. annua* leaves was evaluated against the CCl_4-induced hepatotoxic model of Wistar Albino rats at the doses of 200 mg/kg and 400 mg/kg body weight. Silymarin (100 mg/kg) is used as the standard drug. Some biological parameters like Serum Glutamate Oxaloacetate Transaminase [SGOT], Serum Glutamate Pyruvate Transaminase [SGPT] were estimated by using Reitman and Frankel's method; alkaline phosphate (ALP) and serum bilirubin was estimated by using Kind King's method. Methanolic extract of *M. annua* at the dose of 400 mg/kg showed a significant decline (similar to Silymarin) in SGPT, SGOT and serum bilirubin levels. It was also reported that *M. annua* extract can reduce the abnormalities and restore the altered histopathological changes in a dose-dependent manner. In addition, the hepatoprotective activity of *M. annua* was mainly due to the presence of flavonoids [37].

4.14. Gastroprotective Activity

The gastroprotective activity of leaves of *M. annua* in Albino rats was studied using ethanolic extract at the doses of 200 mg/kg and 300 mg/kg. The ulcer was induced by 1 ml of 80% ethanol in the oral route. Omeprazole (20 mg/kg) was chosen as the standard. The Effect of the extract was determined by calculating the ulcer index based on lesions, pH and percentage inhibition. A significant change in gastric volume, ulcer index and pH were observed at 300 mg/kg dose. It is reported that the antioxidant property of *M. annua* served as a support for gastroprotective activity due to the presence of flavonoids [38].

4.15. Immunomodulatory Activity

The immunomodulatory activity of the barks of *M. annua* was evaluated using healthy mice. All the animals were given 0.2 ml of 10% Sheep Red Blood Cells (SRBC) on day 5 to measure the humoral response activity. It was shown that hemagglutination reaction (antibody titer) increased with an increased dose of Methanolic extract of *M. annua* (MEMA)-treated animals. The CP (cyclophosphamide) and plant extract-treated animals showed good recovery of immunosuppressant activity than the only CP-treated group. Thus, the humoral response activity of *M. annua* was proved.

To determine the cellular immune response or delayed-type hypersensitivity (DTH), a footpad reaction test was performed. The plant extract-treated groups showed an increased DTH reactivity. This reaction proved the stimulatory

effects of Methanolic extract of *M. annua* bark (MEBC) and Methanolic extract of *M. annua* leaves (MEAL) on T-cells. The MEBC-treated group also showed an increase in WBC count whereas the decrease in WBC count was observed in only CP-treated animals. CP+ MEBC (150 mg/kg) and MEBC (300 mg/kg); CP+ MEAL (800 mg/kg) and MEAL (1200 mg/kg) treated groups were found to show good bone marrow recovery than the only CP-treated group. A decrease in organ weight for the spleen was observed only in CP-treated animals. Thus, the immunomodulatory effect of *M. annua* was proven [3, 39].

4.16. Anti-Haemolytic Activity

The anti-hemolytic activity of hydroethanolic leaf extract of *M. annua* was evaluated by using the blood samples collected from healthy adult human volunteers. Sterile Alsevier's solution was used as a blood preservative. 500µl of RBC suspension was added to all tubes containing 800 µl of 1% w/v Triton X-100 with phosphate buffer and incubated at 37 ℃ for 1 hr and centrifuged for 5 min at maximum speed. The Percentage of hemolysis was calculated by measuring the absorbance of collected supernatant at 541 nm against phosphate buffer as blank. The capability of the plant extract to stabilize the RBC membrane was determined which served as an indication of the plant's ability to prevent hemolysis. Hydroethanolic extract of *M. annua* showed 65% maximum inhibition at 1000µg/ml concentration [40].

4.17. Anti-Thrombotic Activity

Brindha et.al, 2018, evaluated the anti-thrombotic activity of hydroethanolic leaf extract of *M. annua* using the venous blood drawn from healthy volunteers. Blood samples were taken in a sterile microcentrifuge tube and incubated at 37 ℃ for 45 mins. The Serum was removed after clot formation and the clot weight was determined. Observations were made to determine the clot lysis and then the weight is measured, which exhibited more significant activity than that of the standard (Streptokinase) [40].

4.18. Anti-Hemorrhoidal Activity

Singh and Kori, 2022, investigated the flavonoid-rich extracts of leaves of *M. annua* for anti-hemorrhoidal activity using Wistar rats. Hemorrhoids were induced by using a cotton swab soaked in croton oil preparation by inserting it into the anus. After 24 hr, animals were treated with doses of 200 mg/kg and 300 mg/kg of extract for 5 days. Observations were made by collecting the blood samples from the retro-orbital sinus and by the estimation of inflammatory cytokines using the Elisa Microplate reader. Croton-induced hemorrhoid groups showed a substantial decline in GSH (glutathione) content. The reports revealed that the flavonoid-rich extract of *M. annua* was able to restore the endogenous non-protein sulfhydryl GSH content. It was also concluded that the significant improvement in hemorrhoidal healing was due to the anti-oxidant property and free-radical scavenging property of *M. annua* [27].

4.19. Anti-Alopecia Activity

The hair growth activity of medicated oil of fruit extract [MOFE] and medicated oil of leaf extract [MOLE] using testosterone (1% w/w) induced Swiss Albino mice alopecia model was evaluated. It was reported that MOLE administration in mice, blocked the hair follicle miniaturization effect of testosterone. When compared with the control group, significant improvement in the anagen/telogen ratio (increased number of hair follicles) and follicular density was found in MOLE treated group. So, medicated oil of *M. annua* was proven to inhibit the androgenic activity similar to finasteride (2%). The phytoconstituents such as polyphenols, steroids and saponins in leaves were found to be responsible for this activity. It was also concluded that significant hair growth property is exhibited by the plants possessing good anti-androgenic and anti-oxidant activities. This study serves as evidence in support of the traditional and medicinal use of *M. annua* in hair-related disorders [41].

4.20. Antifertility Activity

Joshi et al., 2011 and Mali et al., 2002 experimented using the ethanolic extract of roots of *M. annua* in male Albino rats to study the antifertility activity. Animals were treated with 50 mg/kg, 100 mg/kg and 200 mg/kg doses for 60 days. A significant decrease in the weight of testes, epididymides, seminal vesicles and ventral prostates was observed in male rats (a greater decline was seen at 100 mg/kg). A dose-related decline in testicular and epididymal sperm count was seen. A decrease in levels of luteinizing hormone and testosterone was observed in the serum but FSH concentration remained unaltered. Final body weight was found to be increased in all the groups. It was concluded that the extract showed a dose-dependent decrease in the reproductive activity of male albino rats with alteration in normal body mechanisms [3, 42, 43]

5. Conclusion

Many studies performed on *M. annua* Linn. described its various medicinal properties. The entire plant is found to show significant pharmacological activity. A greater number of phytoconstituents were found to be present in leaves. This review reported many therapeutic indications of the plant which include anti-cancer, antibacterial, anti-inflammatory, wound healing, analgesic, antipyretic activity, anti-oxidant, anti-diabetic, anti-convulsant, anti-nociceptive activity, immunomodulatory, hepatoprotective activity, anti-hemolytic, anti-thrombotic, anti-arthritic activity, anti-hemorrhoidal activity, anti-alopecia, anthelmintic activity, gastroprotective activity and anti-fertility activities. This plant is found to have broader scope for phytochemical and pharmacological investigations. Further, a diversified type of research is required to study the health benefits and importance of *M. annua* in the human body. Only a limited number of phytoconstituents have been reported for this plant. By employing the various analytical techniques, we can identify more bioactive compounds that can be tested against various ailments by employing various *in silico, in vitro* and *in vivo* models.

Compliance with ethical standards

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Authors Contribution

All the authors had contributed equally.

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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