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A Comprehensive Review On Ethnopharmacological and Bioactive Potential of Plants in Family Acanthaceae

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Abstract

The Acanthaceae family, comprising a wide range of medicinally important plants, holds a significant place in traditional and modern healthcare systems due to its diverse therapeutic properties. This review focuses on five prominent species—Justicia adhatoda, Andrographis paniculata, Acanthus ilicifolius, Barleria cristata, and Ruellia tuberosa—recognized for their extensive pharmacological potential. These plants have been traditionally employed across various cultures, and recent scientific investigations have validated their efficacy in combating microbial infections, inflammation, oxidative stress, and metabolic disorders such as diabetes. The review consolidates and critically evaluates the reported antimicrobial, anti-inflammatory, antioxidant, and antidiabetic activities of the selected species, highlighting their active phytochemical constituents and mechanisms of action. The study aims to provide a comprehensive understanding of these plants' therapeutic scope within the Acanthaceae family, thereby supporting their continued exploration for drug development and integrative medicinal practices.

Keywords: Acanthaceae, Justicia adhatoda, Andrographis paniculata, Acanthus ilicifolius, Barleria cristata, Ruellia tuberosa, Antimicrobial activity, Anti-inflammatory activity, Antioxidant activity, Antidiabetic activity

1. Introduction

A vast and varied family of flowering plants, the Acanthaceae are primarily found in tropical and subtropical areas of the world. Encompassing over 4,000 species across more than 230 genera, this family is notable for its ethnobotanical and pharmacological significance, particularly in traditional medical systems such as Ayurveda, Unani, Siddha, and regional folk practices[1,2].

Numerous Acanthaceae species have been traditionally utilized by indigenous communities across Asia. Justicia adhatoda has been used extensively in India to treat inflammatory and respiratory diseases.[1] In Thailand, ethnic groups from the North, Central, and Northeastern regions have used Andrographis paniculata, Barleria cristata, and Ruellia tuberosa for managing fever, skin infections, gastrointestinal issues, and pain-related conditions[2]. Scientific research has increasingly supported these ethnomedical uses, identifying several phytochemical constituents responsible for their **antimicrobial**, **anti-inflammatory**, **antioxidant**, and **antidiabetic** properties[1,2].

This review focuses on five medicinally significant species of the Acanthaceae family—Justicia adhatoda, Andrographis paniculata, Acanthus ilicifolius, Barleria cristata, and Ruellia tuberosa. The aim is to provide a comprehensive overview of their ethnopharmacological relevance and consolidate current scientific findings regarding their bioactive potential in the aforementioned therapeutic categories.

2. Ethnopharmacological Activities

1. Justicia adhathoda

❖ Anti-inflammatory Activity

Formalin-induced nociception in mice and carrageenan-induced paw edema were two in vivo models used to evaluate Justicia adhatoda's anti-inflammatory properties. The methanolic leaf extract was administered in graded doses (5 mg/kg to 100 mg/kg), and the anti-inflammatory effect was measured by the reduction in paw swelling and pain response. Phytochemical analysis and HPLC profiling revealed high concentrations of gallic acid, quercetin, and rutin, which are known to inhibit inflammatory mediators and oxidative stress pathways[3].

❖ Antimicrobial Activity

The antimicrobial potential was determined using the disc diffusion method against several bacterial and fungal strains. Methanolic extracts of J. adhatoda leaves were tested at different concentrations (50–200 mg/mL) on organisms like Staphylococcus aureus, Pseudomonas aeruginosa, Bacillus subtilis, and Proteus vulgaris. The size of the zone of inhibition was measured after incubation to assess antimicrobial efficacy. The study demonstrated a dose-dependent antimicrobial effect, especially against S. aureus, suggesting strong antibacterial properties linked to its alkaloids and phenolic content[4].

❖ Antioxidant Activity

To evaluate antioxidant potential, multiple in vitro assays were employed, including:

- DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay
- ABTS assay
- Ferric reducing antioxidant power ($FeCl_3$ assay)

The methanolic leaf extract showed a concentration-dependent antioxidant effect, with significant radical scavenging activity. The total phenolic content was quantified using the Folin–Ciocalteu reagent method, supporting the claim that phenolics and flavonoids are the key contributors to its antioxidant activity[5].

❖ Antidiabetic Activity

Antidiabetic activity was evaluated through in vivo experimentation using albino mice induced with streptozotocin (STZ) to simulate diabetes. Experimental groups were treated with methanolic leaf and flower extracts of J. adhatoda (1 mg/kg), and blood glucose levels were monitored using oral glucose tolerance test (OGTT). The efficacy was validated through measurements of fasting blood glucose, random blood sugar, and glycosylated hemoglobin (HbA1c). The results showed a significant

hypoglycemic effect, possibly due to stimulation of insulin secretion and enhanced glucose uptake in tissues[5].

2. Andrographis paniculata

❖ **Anti-inflammatory Activity**

The aqueous leaf extract exhibited strong inhibitory effects on heat-induced protein denaturation, comparable to standard diclofenac sodium. In the membrane stabilization test, it prevented red blood cell (RBC) lysis caused by heat, indicating its ability to stabilize lysosomal membranes. Furthermore, it inhibited proteinase enzymes, which are key contributors to inflammation. These effects were attributed to the presence of terpenoids, flavonoids, and alkaloids, confirmed by phytochemical screening and thin-layer chromatography (TLC)[6].

❖ **Antimicrobial Activity**

The antimicrobial effect of A. paniculata was tested using the well diffusion method and minimum inhibitory concentration (MIC) assay against pathogens like Staphylococcus, Escherichia coli, Shigella, Salmonella typhi, Proteus, and Klebsiella. Salmonella typhi had the highest sensitivity in the concentration-dependent zone of inhibition displayed by the aqueous extract.The MIC values indicated that even low concentrations were effective in bacterial growth inhibition. This activity was linked to bioactive compounds including flavonoids, alkaloids, and terpenoids separated and identified by TLC[6].

❖ **Antioxidant Activity**

Antioxidant activity was measured using assays like the phosphomolybdenum method, estimation of total phenolic content, and enzyme assays for superoxide dismutase (SOD), catalase, and glutathione peroxidase. The aqueous and ethanol leaf extracts showed significant total antioxidant capacity, with phenolic and flavonoid contents contributing to the scavenging of free radicals. In in vivo experiments, ethanol extracts increased antioxidant enzyme levels in streptozotocin-induced diabetic rats, highlighting its role in counteracting oxidative stress[7].

❖ **Antidiabetic Activity**

The antidiabetic activity of A. paniculata was demonstrated in two separate models—glucose-loaded hyperglycemic rats and alloxan- or streptozotocin-induced diabetic rats. In both models, oral administration of hot water or ethanol extracts led to a significant reduction in blood glucose levels, comparable to standard antidiabetic drugs like glibenclamide. Additionally, the ethanol extract improved body weight, kidney markers (serum creatinine, urea), and restored islet cell integrity in the pancreas, as confirmed by histopathological studies[7,8].

3.Acanthus ilicifolius

❖ **Anti-inflammatory Activity**

In vivo models were used to assess Acanthus ilicifolius's anti-inflammatory properties. A methanolic leaf extract was tested using the carrageenan-induced paw edema method in rats, where it showed significant inhibition of edema when administered before and after inflammation induction. The extract showed efficacy similar to that of BW755C, a well-known inhibitor of both lipoxygenase (LOX) and

cyclooxygenase (COX). The mechanism is suggested to involve inhibition of COX-1, COX-2, LOX enzymes, and suppression of pro-inflammatory cytokines, along with free radical scavenging properties[9].

❖ **Antimicrobial Activity**

The antimicrobial potential of A. ilicifolius was studied using the agar well diffusion method. Leaf extracts prepared in different solvents (aqueous, petroleum ether, diethyl ether, and acetone) were tested against bacteria such as Staphylococcus aureus, Bacillus thuringiensis, and Escherichia coli. The petroleum ether extract exhibited the strongest antibacterial effect, showing measurable zones of inhibition. The antimicrobial action was attributed to the presence of flavonoids, alkaloids, steroids, and tannins, which act through disruption of bacterial membranes and protein synthesis[10].

❖ **Antioxidant Activity**

The antioxidant activity of the aqueous extract from the above-ground parts of A. ilicifolius was assessed through several in vitro assays, including:

- DPPH and ABTS free radical scavenging assays
- Ferric reducing antioxidant power (FRAP)
- Total antioxidant capacity (TAC)
- The DPPH assay showed strong free radical scavenging with an IC_{50} of 208.59 µg/mL, comparable to ascorbic acid. The activity was attributed to high levels of polyphenols, flavonoids, and alkaloids, which were quantified using standard protocols such as the Folin–Ciocalteu method and $AlCl_3$ colorimetric assay[11.]

❖ **Antidiabetic Activity**

By measuring the inhibition of the enzymes α-amylase and α-glucosidase, in vitro antidiabetic efficacy was evaluated. The aqueous extract inhibited these enzymes significantly, with EC_{50} values of 136.35 µg/mL for α-amylase and 49.81 µg/mL for α-glucosidase, showing comparable efficacy to acarbose, a standard antidiabetic drug. Additionally, an in vivo study using glucose-loaded Swiss albino mice demonstrated that methanolic leaf extract reduced blood glucose levels in a dose-dependent manner, with effects similar to glibenclamide at the highest tested dose (400 mg/kg)[11–12].

4.Barleria cristata

❖ **Anti-inflammatory Activity**

Several in vivo models were used to assess Barleria cristata's anti-inflammatory capabilities, including:

- Carrageenan-induced paw edema in rats
- Prostaglandin-induced diarrhea in mice
- Acetic acid-induced vascular permeability

Graded dosages of the leaf aqueous extract (BCW) were given (125, 250, and 500 mg/kg).
In the paw edema model, BCW significantly inhibited inflammation in a dose-dependent manner, with the 500 mg/kg dose showing 55.08% inhibition, close to the standard drug indomethacin (62.5%). In the prostaglandin inhibition model, BCW reduced castor oil-induced diarrhea, indicating prostaglandin

synthesis inhibition. It also reduced vascular permeability induced by acetic acid, confirming its anti-inflammatory action. These effects are linked to the plant's flavonoids and alkaloids[13].

❖ **Antimicrobial Activity**

The antibacterial activity of Barleria cristata was assessed using the agar well diffusion method. Methanolic and aqueous extracts of the leaves were tested against Streptococcus pyogenes (Gram-positive) and Escherichia coli (Gram-negative). Methanolic extract showed stronger activity than aqueous extract. At 500 µg/mL, the zone of inhibition reached 21.4 mm for Streptococcus and 18.6 mm for E. coli, compared to 25.7 mm and 21.8 mm with standard streptomycin. The results support its traditional use in treating skin and wound infections[14].

❖ **Antioxidant Activity**

Antioxidant potential was measured through in vitro assays:

- DPPH radical scavenging
- Ferric Reducing Antioxidant Power (FRAP)

Ethanolic extracts demonstrated higher radical scavenging activity than petroleum ether extracts, with DPPH inhibition reaching 76.01% at 100 µg/mL. FRAP results showed a significant, dose-dependent increase in reducing power. These effects were attributed to flavonoids, phenolics, and tannins identified through phytochemical screening[15].

❖ **Antidiabetic Activity**

Both in vitro and in vivo models were used to assess antidiabetic activity:

In vitro: Inhibition of α-amylase and α-glucosidase enzymes. At 100 µL, the ethanol extract demonstrated 67.1% and 47.7% inhibition, respectively, suggesting delayed absorption of glucose and digestion of carbohydrates.

In vivo: Streptozotocin (STZ)-induced diabetic rats were treated with 400 mg/kg of ethanolic extract for 45 days. Results showed significant reduction in blood glucose, HbA1c, and increase in insulin and C-peptide levels. Tissue antioxidant enzymes (SOD, CAT, GPx) were also restored to near-normal levels. The extract improved organ weights, protein levels, and protected tissues from oxidative stress, suggesting dual action in glycemic control and oxidative defense[15–16].

5.Ruellia tuberosa

❖ **Anti-inflammatory Activity**

Lipopolysaccharide (LPS)-stimulated RAW 264.7 macrophage cells were used in an in vitro model to assess the anti-inflammatory properties of Ruellia tuberosa extracts.
Ethanol, methanol, and ethyl acetate fractions of the extract significantly suppressed nitric oxide (NO) production and reduced the expression of proinflammatory cytokine IL-6 in a dose-dependent manner. Cell viability was confirmed using the CCK-8 assay, and cytokine levels were measured using ELISA. Key anti-inflammatory compounds like hispidulin, physalin D, and physalin E were isolated using column chromatography and showed potent IL-6 inhibition without cytotoxicity[17].

❖ **Antimicrobial Activity**

Although the current studies primarily focused on anti-inflammatory and antidiabetic effects, previous literature reports on R. tuberosa suggest that its ethyl acetate and methanolic extracts possess antibacterial activity. The proposed mechanism involves flavonoids and triterpenoids which are known to disrupt microbial membranes. However, specific agar diffusion methods or MIC assays were not detailed in the documents provided and may need confirmation through additional literature review or empirical validation.

❖ **Antioxidant Activity**

The antioxidant activity of Ruellia tuberosa extracts was measured using DPPH and ABTS radical scavenging assays. The ethyl acetate fraction exhibited the strongest effect, with IC_{50} values of 12.69 µg/mL (DPPH) and 14.70 µg/mL (ABTS), close to the effects of standard compounds like Vitamin C and Trolox. The antioxidant activity correlated with high levels of polyphenols (259.12 mg GAE/100g) and flavonoids (56.07 mg QE/100g), quantified via Folin–Ciocalteu and aluminum chloride methods[17].

❖ **Antidiabetic Activity**

Ruellia tuberosa showed strong antidiabetic activity through several approaches:

In vitro α-amylase inhibition: Using the starch-iodine method, the n-hexane fraction of methanolic extract (HFME) showed a dose-dependent inhibition with an IC_{50} of 0.14 mg/mL[18].

In vivo studies: In MLD-STZ-induced diabetic rats and alloxan-induced diabetic rabbits, oral administration of extracts significantly reduced blood glucose levels. The ethyl acetate fraction (100 mg/kg) reduced glucose by 28.64%, comparable to tolbutamide (34.31%)[19].

In silico modeling: Docking studies revealed that betulin, isolated from the HFME, binds noncompetitively to α-amylase, suggesting it as a potent enzyme inhibitor involved in glycemic regulation[18].

3. CONCLUSION

The present review highlights the rich ethnopharmacological and therapeutic value of five medicinally important species from the Acanthaceae family—Justicia adhatoda, Andrographis paniculata, Acanthus ilicifolius, Barleria cristata, and Ruellia tuberosa. All five plants have demonstrated promising pharmacological effects, particularly in the domains of anti-inflammatory, antimicrobial, antioxidant, and antidiabetic activities. These effects are largely attributed to the presence of diverse bioactive compounds such as flavonoids, alkaloids, phenolics, and terpenoids, many of which have been scientifically validated through in vitro, in vivo, and even in silico studies.

Each plant exhibits a unique combination of activities that support its traditional use and potential as a source of phytotherapeutic agents. This review reinforces the importance of the Acanthaceae family as a valuable reservoir for natural product-based drug discovery and underscores its relevance in addressing global health challenges such as infections, inflammation, oxidative stress, and diabetes mellitus.

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