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Medicinal Plants as Therapeutic Agents: Indonesia as a Case Study of Phytopharmaceutical Development

Gibran Rakabuming

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Abstract

Medicinal plants remain important sources of health care, cultural identity, and pharmaceutical discovery. Indonesia provides an especially informative case study because its exceptional biological diversity intersects with a large and culturally diverse population and a long-standing tradition of jamu and other plant-based therapies. Recent synthesis of Indonesian ethnobotanical research identified 791 medicinal plant species across 91 studies, with 3,202 reported medicinal-use records, while also demonstrating substantial geographic and methodological gaps in the evidence base [1]. The therapeutic potential of Indonesian medicinal plants spans anti-inflammatory, antimicrobial, metabolic, cardiovascular, gastrointestinal, dermatological and other indications, but the level of evidence varies markedly from traditional use and laboratory studies to controlled clinical trials. Three representative Indonesian-relevant medicinal plants illustrate this evidence continuum: Andrographis paniculata (sambiloto), Orthosiphon aristatus (kumis kucing), and Curcuma longa (turmeric). A. paniculata has extensive pharmacological literature and clinical evidence for symptom relief in acute respiratory infections, as well as Indonesian clinical research in malaria and metabolic disease [2–5]. O. aristatus contains rosmarinic acid, sinensetin and other bioactive constituents and is traditionally used in urinary and metabolic disorders, although clinical evidence remains less mature [6,7]. Curcuma longa is deeply embedded in Indonesian traditional medicine and food culture, but therapeutic claims require careful distinction between traditional preparations and standardized curcuminoid products [8,9]. Indonesia has also developed a regulatory framework distinguishing empirical traditional medicines (jamu), standardized herbal medicines (Obat Herbal Terstandar; OHT), and phytopharmaceuticals (fitofarmaka). Current BPOM regulations require progressively stronger evidence and product standardization across these categories [10]. The central challenge is therefore not simply to identify plants with biological activity, but to translate ethnomedical knowledge into authenticated, standardized, reproducible, safe and clinically validated therapeutic agents. This review discusses the opportunities and limitations of that translation process and proposes a research and policy framework for Indonesia.

Keywords: medicinal plants; therapeutic agents; Indonesia; jamu; phytopharmaceuticals; ethnopharmacology; herbal medicine

1. Introduction

Medicinal plants have contributed to human therapeutics for centuries and continue to provide molecules, extracts and pharmacological concepts relevant to modern drug discovery. Their contemporary importance, however, should not be reduced to the assertion that 'natural' products are inherently safe or effective. A medicinal plant becomes a credible therapeutic agent only when its identity, composition, dose, quality, pharmacological activity, safety and clinical benefit are sufficiently characterized. The transition from traditional use to evidence-based therapy is consequently a translational process rather than a simple substitution of plants for synthetic drugs.

Indonesia is particularly suitable for examining this process. The country contains extensive plant biodiversity and numerous ethnolinguistic communities whose medicinal knowledge has developed within distinct ecological and cultural settings. A 2026 systematic review of Indonesian ethnobotanical studies synthesized 791 medicinal plant species and 3,202 use-reports from 91 studies. It identified a shared core of 239 species but also found strong geographic concentration of research, especially in Sumatra and Java, with eastern Indonesia comparatively underrepresented [1]. These findings demonstrate both the richness of the Indonesian medicinal-plant resource and the incompleteness of its scientific documentation.

Traditional medicine is also economically and socially relevant. Indonesian herbal medicine is commonly associated with jamu, while national regulation provides pathways toward standardized herbal medicines and phytopharmaceuticals. BPOM's current framework, including Regulation No. 25 of 2023, establishes criteria and registration procedures for natural medicinal products [10]. The Indonesian Ministry of Health has also described a progression from jamu, supported principally by empirical knowledge, to OHT, supported by preclinical evidence and standardization, and to fitofarmaka, for which safety and efficacy are supported by clinical evidence [11].

This review therefore examines medicinal plants as potential therapeutic agents using Indonesia as a case study. It focuses on the evidence-development pathway from ethnobotany to phytochemistry, pharmacology, toxicology, clinical research, regulation and health-system integration. The aim is not to catalogue every medicinal plant used in Indonesia, but to develop a scientifically defensible framework for identifying plants with the greatest potential for therapeutic development.

2. Scope and Review Approach

This is a narrative review informed by contemporary systematic reviews, Indonesian ethnobotanical literature, pharmacological and phytochemical studies, clinical trials, and Indonesian regulatory documents. Priority was given to evidence directly relevant to medicinal plants used in Indonesia or Southeast Asia and to plants for which there is a plausible pathway from traditional use to therapeutic development.

The review emphasizes three illustrative species — Andrographis paniculata, Orthosiphon aristatus and Curcuma longa—because they represent different stages and challenges of medicinal-plant development. A. paniculata provides a relatively strong example of transition from traditional use to standardized extracts and human clinical research. *O. aristatus* illustrates the importance of phytochemical standardization and the gap between promising pharmacology and clinical validation. *C. longa* illustrates the need to distinguish traditional preparations from modern standardized curcuminoid formulations and to avoid extrapolating evidence from one preparation to another.

The review does not claim that these plants are established substitutes for approved conventional medicines. Where evidence is based mainly on in vitro, animal or ethnomedical research, this limitation is explicitly stated.

3. Indonesia's Medicinal-Plant Heritage

Indonesia's medicinal-plant knowledge is embedded in a wide range of local traditions. Jamu is the best-known national expression of this heritage, but ethnomedicinal practice varies substantially among islands and ethnic communities. The recent systematic review by Febriyanti and colleagues found that 91 primary ethnobotanical studies collectively documented 791 medicinal species and 3,202 use-reports, while identifying important deficiencies in geographic coverage, taxonomic verification, ethics reporting and standardized disease classification [1].

These methodological limitations matter because a medicinal-use record is not equivalent to evidence of clinical efficacy. A community may consistently use a plant for a particular condition, but the reported plant may be taxonomically ambiguous, the preparation may vary by household, the dose may be unknown, and the outcome may be subjective. Nevertheless, consistent traditional use can be a valuable starting point for hypothesis generation, prioritization of species, and identification of biologically active plant fractions.

An additional opportunity is the integration of ethnobotany with biodiversity conservation. If particular species become commercially successful, poorly controlled harvesting may threaten wild populations. Conversely, cultivation and value-chain development can provide incentives for conservation if they are designed with community participation and benefit sharing. Therapeutic development should therefore be linked to sustainable sourcing rather than treated as an isolated pharmaceutical activity.

4. From Medicinal Plant to Therapeutic Agent

The development pathway can be conceptualized as six connected stages:

- Ethnomedical identification: document species, plant part, preparation, dose, route, indication, population and cultural context.
- Botanical authentication: confirm scientific identity, deposit voucher specimens, and document geographical origin and cultivation or harvesting conditions.
- Phytochemical characterization: identify marker compounds and, where appropriate, broader chemical fingerprints; define batch-to-batch specifications.
- Pharmacological and toxicological evaluation: investigate plausible mechanisms using validated in vitro and in vivo models and characterize exposure-response relationships.
- Clinical evaluation: determine safety, pharmacokinetics, efficacy, clinically meaningful outcomes, dose and interactions using appropriately designed trials.
- Regulatory and health-system translation: manufacture consistently, establish pharmacovigilance, obtain the appropriate registration category, and determine where the product fits within clinical practice.

A major advantage of medicinal plants is chemical diversity. A whole extract may contain multiple constituents that act on several biological pathways. This can be pharmacologically useful but creates a major challenge for standardization. If the active therapeutic principle is not a single molecule, quality control must rely on a combination of botanical identity, manufacturing specifications, chemical fingerprints and validated marker compounds.

5. Regulatory Landscape in Indonesia

Indonesia's regulatory system provides a useful model for graded evidence requirements. BPOM Regulation No. 25 of 2023 establishes criteria and procedures for registration of natural medicinal products and replaced earlier registration provisions [10]. Indonesian regulatory information distinguishes jamu, OHT and fitofarmaka according to the level of supporting evidence and standardization [10,11].

Category	Core evidence concept	Development implication
Jamu	Primarily empirical/traditional evidence and established traditional use	Useful for cultural health practice and hypothesis generation; does not by itself establish clinical efficacy for a specific indication.
Obat Herbal Terstandar (OHT)	Preclinical safety/efficacy data plus standardized raw material and finished product	Requires stronger analytical and experimental control than traditional jamu.
Fitofarmaka	Scientific demonstration of safety and efficacy including clinical evidence, with standardized materials/products	Closest Indonesian regulatory category to an evidence-supported phytopharmaceutical.

BPOM has also emphasized the need for preclinical pharmacodynamic evidence when developing traditional medicines toward higher evidence categories [12]. The policy direction is important because it encourages movement from empirical use toward reproducible products without requiring every traditional preparation to be treated as a conventional pharmaceutical at the outset.

6. Representative Indonesian Medicinal Plants

6.1 Andrographis paniculata (Sambiloto)

Andrographis paniculata is widely distributed in South and Southeast Asia and is used in Indonesian traditional medicine. Its principal studied diterpenoid is andrographolide, accompanied by related diterpenoids and other constituents. Pharmacological studies have reported anti-inflammatory, antimicrobial, immunomodulatory and other biological activities [2,3].

The clinical evidence for A. paniculata is more developed than for many medicinal plants. A systematic review and meta-analysis of 33 randomized trials involving 7,175 patients found that A. paniculata improved cough and sore throat symptoms in acute respiratory tract infections compared with placebo, although the methodological quality of many trials was limited [4]. This distinction is important: evidence for symptom relief in acute respiratory illness is not equivalent to proof of efficacy for all diseases for which the plant is traditionally used.

Indonesia-specific clinical research has also been conducted. In a clinical trial among malaria patients in North Sumatra, an ethanolic A. paniculata extract was administered at 250 mg three times daily for five days and the investigators reported high apparent efficacy without observed adverse effects during the study [5]. However, such findings should not be interpreted as establishing A. paniculata as a replacement for standard antimalarial therapy. Malaria treatment requires validated regimens and disease-specific regulatory and clinical oversight.

An Indonesian randomized crossover study also investigated A. paniculata in normal and prediabetic subjects, examining GLP-1 and DPP-4-related outcomes [13]. This illustrates the growing tendency to investigate traditional plants using modern metabolic endpoints, but mechanistic biomarker changes should not be equated automatically with clinical benefit.

6.2 Orthosiphon aristatus (Kumis Kucing)

Orthosiphon aristatus is a Southeast Asian medicinal plant widely known as cat's whiskers or kumis kucing. It is associated particularly with traditional urinary and diuretic applications and has attracted research into metabolic, antioxidant and anti-inflammatory activities. Phytochemical studies identify rosmarinic acid, sinensetin, eupatorin and related phenolic and terpenoid constituents among its important chemical components [6,7].

A review of Asian medicinal herbs identified O. aristatus as a plant rich in polar bioactive constituents and emphasized the relationship between extraction method and recovery of compounds such as rosmarinic acid [6]. This is highly relevant to therapeutic development because the biological activity of an extract depends on the plant material, extraction solvent, temperature, duration, drying process and subsequent formulation.

Recent Indonesian ethnobotanical synthesis also identified O. aristatus among the culturally prominent medicinal plants used across multiple communities [1]. Nevertheless, the clinical evidence base is less mature than the ethnomedical popularity of the plant might suggest. Future research should prioritize standardized extracts, pharmacokinetics, clinically relevant endpoints and well-designed randomized trials.

6.3 Curcuma longa (Turmeric)

Curcuma longa is deeply embedded in Indonesian culinary and medicinal traditions and is a major source of curcuminoids, particularly curcumin. Curcumin has been studied extensively for anti-inflammatory, antioxidant and other biological effects, but the translation of these findings into consistent clinical benefit is complicated by low systemic bioavailability, formulation differences and heterogeneity among commercial preparations [8,9].

Consequently, a manuscript describing turmeric as a therapeutic agent should distinguish between turmeric rhizome, traditional turmeric-containing preparations, crude extracts, standardized curcuminoid extracts, and enhanced-bioavailability formulations. Evidence for one preparation cannot automatically be transferred to another. This principle applies broadly to medicinal plants and is central to regulatory-quality phytopharmaceutical development.

7. Therapeutic Domains

Plant / preparation	Traditional or investigated use	Key evidence level	Main development issue
Andrographis paniculata	Respiratory symptoms, fever, infections; Indonesian use includes malaria-related applications	Human clinical trials and systematic reviews available	Standardize andrographolide content; define indication and dose; avoid overgeneralization.
Orthosiphon aristatus	Urinary/diuretic, metabolic and inflammatory applications	Ethnobotanical, phytochemical and preclinical evidence; limited clinical validation	Extract standardization, pharmacokinetics and clinical endpoint validation.
Curcuma longa / curcuminoids	Inflammatory and digestive indications; extensive traditional use	Large pharmacological and clinical literature, heterogeneous by formulation	Bioavailability, product equivalence and formulation-specific evidence.
Blumea balsamifera (Sembung)	Cough, sinusitis, flu, diuretic and other traditional uses	Ethnopharmacological and phytochemical literature	Clinical validation and standardized preparations remain limited.
Dendrophthoe spp.	Traditional use for inflammatory, infectious and other disorders	Phytochemical, in vitro and animal evidence; some traditional use in Indonesia	Toxicology, dose definition and clinical evidence.

8. Pharmacological Mechanisms and Bioactive Constituents

Medicinal plants may act through multiple pharmacological pathways. Phenolic compounds can influence oxidative and inflammatory signaling; flavonoids may modulate enzymes, receptors and redox pathways; terpenoids can interact with inflammatory and metabolic pathways; alkaloids can affect neuronal, cardiovascular or infectious processes; and polysaccharides may influence immune responses. However, mechanistic plausibility is only one component of therapeutic evidence.

For A. paniculata, andrographolide is a major mechanistic focus and has been associated with anti-inflammatory and immunomodulatory effects [2,3]. For O. aristatus, rosmarinic acid and flavonoids such as sinensetin and eupatorin have received attention [6,7]. For Curcuma longa, curcuminoids are central to pharmacological investigation [8,9].

A critical methodological issue is that concentrations producing biological effects in vitro may be substantially higher than concentrations achieved safely in humans. Drug-development studies should therefore connect in vitro potency to achievable plasma or tissue exposure and, ideally, to pharmacodynamic biomarkers in humans.

9. Safety, Toxicology and Herb–Drug Interactions

The assumption that medicinal plants are intrinsically safe is scientifically unjustified. Toxicity may arise from the plant itself, contamination, adulteration, misidentification, excessive dose, chronic exposure, or interactions with conventional medicines. Risk may also vary with age, pregnancy, renal function, hepatic function and coexisting disease.

Safety evaluation should include botanical authentication, microbial and heavy-metal testing where relevant, pesticide and contaminant controls, stability testing, acute and repeated-dose toxicology, reproductive and genotoxicity assessment when indicated, and pharmacovigilance after marketing. For products with concentrated extracts, the safety profile may differ substantially from the traditional food or decoction form.

Herb–drug interactions deserve particular attention. Plants or their constituents may affect cytochrome P450 enzymes, transporters, platelet function, blood pressure, glycaemia or central nervous system activity. Clinical development should therefore include interaction assessment when there is a plausible pharmacological basis or when the target population is likely to use multiple medicines.

10. Standardization and Quality Control

Standardization is one of the most important barriers between ethnomedicine and reproducible therapeutics. A medicinal plant product should ideally be traceable from species and cultivar through cultivation or collection, harvest time, processing, extraction, formulation and final packaging.

Quality domain	Recommended control
Botanical identity	Voucher specimen, authenticated taxonomy, macroscopic/microscopic confirmation and DNA-based methods where useful.
Raw material	Geographic origin, cultivation/harvesting method, moisture, foreign matter and contaminant testing.
Chemical profile	Validated chromatographic fingerprint and quantitative marker compounds.

Manufacturing	Controlled extraction parameters, validated processes and batch records.
Finished product	Assay, uniformity, microbial limits, contaminants, stability and packaging controls.
Clinical consistency	Use the same or demonstrably equivalent standardized preparation in confirmatory trials.
Traceability	Document suppliers, lots, processing dates and distribution.

11. From Traditional Knowledge to Clinical Evidence

Traditional knowledge should be treated as a valuable source of hypotheses rather than as a substitute for clinical evidence. A rational development program can use ethnobotanical frequency, cross-cultural agreement, chemical plausibility, preliminary pharmacology, safety signals and disease burden to prioritize candidate plants.

The 2026 Indonesian systematic review found that acute conditions sometimes showed high agreement around particular plants, whereas chronic conditions such as hypertension involved more diverse plant selections [1]. This suggests that consensus measures can help identify candidates for research, but they should not be mistaken for clinical effectiveness estimates.

Clinical trials should use standardized preparations, prespecified outcomes, adequate sample sizes, appropriate comparators and transparent reporting of adverse events. Where the therapeutic claim concerns symptom relief, validated symptom scales may be appropriate; for chronic diseases, trials should prioritize outcomes that matter to patients, such as blood pressure, glycaemic control, exacerbations, hospitalization or quality of life, rather than relying only on laboratory biomarkers.

12. Indonesia as a Model for Translational Phytomedicine

Indonesia offers a potentially powerful translational model because it possesses all the major components required for medicinal-plant development: extensive biodiversity, established traditional knowledge, universities and research institutions, pharmaceutical manufacturing capacity, a national regulatory authority, and a large domestic population with experience using herbal products.

The major weakness is fragmentation. Ethnobotanical data are unevenly distributed; taxonomic verification is inconsistent; many pharmacological studies use non-standardized extracts; clinical studies vary in methodological quality; and pharmacovigilance remains less developed than for conventional medicines. The recent national ethnobotanical synthesis specifically identified weaknesses in ethics reporting, voucher documentation and standardized reporting [1].

A national research strategy could therefore prioritize a limited number of high-potential plants rather than attempting to commercialize hundreds of species simultaneously. Each candidate could progress through a standardized pipeline of authentication, phytochemistry, toxicology, pharmacology, formulation, clinical testing and regulatory assessment.

13. Proposed Research and Development Framework

Phase	Primary question	Key output
Ethnobotany	What is consistently used, by whom, for what condition and how?	Prioritized candidate list and documented traditional-use dossier.
Authentication	Is the plant correctly identified and traceable?	Voucher specimen and validated identity.
Phytochemistry	What compounds or chemical fingerprints define the product?	Marker compounds, fingerprint and specifications.
Preclinical pharmacology	Is there a plausible therapeutic effect at achievable exposure?	Mechanistic and efficacy evidence.
Toxicology	Is the candidate sufficiently safe for human testing?	Nonclinical safety package.
Phase I / early clinical	What dose, exposure and short-term safety profile are acceptable?	Human PK/PD and tolerability data.
Controlled efficacy trial	Does the standardized product improve clinically meaningful outcomes?	Confirmatory efficacy and safety evidence.
Regulatory translation	Does the product meet the relevant Indonesian registration pathway?	OHT/fitofarmaka or other appropriate regulatory submission.
Post-market surveillance	Does safety remain acceptable in real-world use?	Pharmacovigilance and benefit-risk reassessment.

14. Sustainability, Intellectual Property and Benefit Sharing

Commercial development of medicinal plants creates ethical obligations. Traditional knowledge may belong to communities rather than individual investigators, and commercially valuable species may be associated with local ecological knowledge. Research should therefore incorporate appropriate consent, attribution, benefit sharing and compliance with applicable biodiversity and access-and-benefit-sharing requirements.

Sustainability is equally important. Wild harvesting of a medicinal species can increase pressure on natural populations, particularly when roots, bark or whole plants are harvested. Cultivation, propagation protocols, community-based supply chains and quality-controlled agricultural systems can reduce ecological pressure while improving chemical consistency.

15. Challenges and Limitations

First, the evidence for Indonesian medicinal plants is heterogeneous. Many studies are observational, ethnobotanical, in vitro or animal-based, and relatively few provide high-quality randomized clinical evidence. Second, different preparations of the same plant may not be pharmacologically equivalent. Third, publication bias may favour positive pharmacological results. Fourth, traditional knowledge may be incompletely documented, particularly in remote regions, and current research is geographically skewed [1]. Fifth, regulatory categories should not be conflated with proof of efficacy for every individual indication.

This review is also limited by its narrative design and selective emphasis on representative plants rather than a systematic quantitative assessment of all Indonesian medicinal plants. It should therefore be viewed as a framework for research and policy rather than a clinical guideline.

16. Future Directions

- Establish a national, interoperable medicinal-plant research database linking ethnobotanical, taxonomic, chemical, pharmacological and clinical data.

- Prioritize high-burden diseases in Indonesia for phytopharmaceutical development, while requiring clinically meaningful outcomes.
- Develop shared national standards for botanical authentication, voucher deposition, extraction methods and chemical fingerprinting.
- Increase multicentre randomized clinical trials of standardized Indonesian herbal products.
- Strengthen pharmacovigilance and systematic reporting of herb–drug interactions and adverse events.
- Develop sustainable cultivation and community-based supply chains for high-value medicinal species.
- Expand research into eastern Indonesia and other underrepresented biocultural regions.
- Promote collaborations among ethnobotanists, pharmacists, pharmacologists, clinicians, regulators, agricultural scientists and Indigenous/local communities.

17. Discussion

Indonesia demonstrates why medicinal plants should be approached as a continuum of evidence rather than as a binary choice between 'traditional' and 'modern' medicine. A plant can simultaneously be a food, a cultural medicine, a source of bioactive molecules, a standardized herbal product and a candidate pharmaceutical. The scientific task is to determine which therapeutic claims can be supported at each level.

The strongest opportunity is to preserve the information contained in traditional knowledge while applying rigorous modern methods to identity, chemistry, pharmacology, safety and clinical evaluation. A. paniculata demonstrates that traditional plants can reach human clinical investigation, while O. aristatus illustrates the continuing need to bridge phytochemical promise and clinical evidence. Curcuma longa demonstrates another lesson: evidence is formulation-specific and should not be generalized from purified compounds to every traditional preparation.

Indonesia's regulatory progression from jamu toward OHT and fitofarmaka provides an institutional pathway for this translation [10,11]. The long-term goal should not be to replace conventional medicines indiscriminately, but to identify plant-derived therapies that provide demonstrable benefits, acceptable safety, reproducible quality and appropriate cost-effectiveness.

18. Conclusions

Medicinal plants represent a major therapeutic-development opportunity for Indonesia, but their value depends on the quality of the evidence supporting a specific preparation and indication. Indonesia's extraordinary ethnobotanical diversity provides a rich source of therapeutic hypotheses, while its jamu tradition supplies a large body of empirical knowledge. Contemporary science can add botanical authentication, chemical standardization, pharmacology, toxicology, clinical trials and pharmacovigilance.

The most promising strategy is a selective, evidence-based translational pipeline. Candidate plants should be prioritized according to therapeutic need, ethnomedical consistency, biological plausibility, safety, sustainability and feasibility of standardization. Regulatory progression from traditional products toward OHT and fitofarmaka should be accompanied by progressively stronger evidence. If these elements are integrated, Indonesia can serve not merely as a reservoir of medicinal plants but as a model for the responsible development of culturally grounded, scientifically validated phytotherapeutics.

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