

POTENTIAL OF BIOACTIVE COMPOUNDS, STANDARDIZATION OF GACP-WHO CULTIVATION, AND CHALLENGES OF DOWNSTREAM HERBAL PLANTS IN INDONESIA: A LITERATURE REVIEW

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Received: 11/08/2026 | Revised: 23/08/2026 | Accepted: 19/09/2026 | Published: 13/10/2026

Abstract

Indonesia has great potential for developing herbal plants as raw materials for traditional medicine and health products, but the industry still faces challenges in cultivation, standardization, research, and processing. This literature review examines the bioactive compounds and cultivation practices of ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), temulawak (*Curcuma xanthorrhiza*), sambiloto (*Andrographis paniculata*), and gotu gotu (*Centella asiatica*), based on WHO Good Agricultural and Collection Practices (GACP). The findings show that these plants contain bioactive compounds such as gingerol, curcumin, xanthorrhizol, andrographolide, and asiaticoside, which have various potential biological activities. However, limited technology, climate change, lack of standardization, and dependence on imported materials remain major challenges. Strengthening research, cultivation quality, standardization, and processing technology is essential to support the sustainable development of Indonesia's herbal industry.

Keywords: Herbal plants, bioactive compounds, cultivation, WHO GACP, literature review

INTRODUCTION

Background

Indonesia is a tropical archipelagic country with rich biodiversity. Its diverse geographical and climatic conditions create favorable opportunities for the development of medicinal and herbal plants. According to the sources reviewed in this study, around 30,000 plant species have been identified in Indonesia, with approximately 31,000 species considered to have potential as medicinal raw materials. This shows that Indonesia has abundant natural resources that could contribute to reducing dependence on imported medicinal materials. However, the large potential of these natural resources has not been fully followed by the use in the form of standardized herbal products and phytopharmaceuticals. The data used in this study shows that the number of herbal products is much larger than the number of Standardized Herbal Medicines (OHT) and phytopharmaceuticals. These conditions show that there is still a gap between the availability of natural resources, research results, and the development of value-added herbal products.

Several factors contribute to this gap, including limited sustainable research and development, inconsistent standardization of raw materials and products, inadequate processing technology, and limited downstream application of research findings. Therefore, developing herbal plants requires more than simply increasing raw material production. It also requires improvements in cultivation practices, research on bioactive compounds, post harvest processing, and the development of products supported by scientific evidence. The Indonesian herbal industry also has significant economic potential. However, realizing this potential requires improvements in farmers' skills, access to quality planting materials, processing technology, clinical research, and marketing systems. Based on these conditions, research on herbal plant cultivation is important to connect Indonesia's natural resources with the development of high quality herbal products. This study focuses on ginger, turmeric, temulawak, sambiloto, and gotu

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Alfino Dwi Hadi et al

kola because these plants have been widely studied, contain bioactive compounds, and have potential for further development as herbal commodities.

Problem Formulation

1. What is the content of bioactive compounds of herbal plants that are scientifically proven based on research with verified journals?
2. How to optimize herbal plant cultivation techniques according to standards international?
3. What are the economic potential and challenges of herbal plant cultivation in Indonesia Based on the latest official data?

Research Objectives

1. Examine the content of bioactive compounds of herbal plants based only on references with verified journals.
2. Analyze cultivation techniques according to WHO GACP 2003 standards.
3. Evaluate economic potential based on the latest official government data (2024-2026).

RESEARCH METHODS

This research uses the library research method. Literature studies are carried out by collecting, reading, reviewing, and analyzing various literature relevant to the topic of herbal plant cultivation, bioactive compound content, cultivation standards, and the development of the herbal industry. The data used in this study is secondary data obtained from scientific journals, books, research reports, and official publications from related institutions, including the Ministry of Health, the Food and Drug Supervisory Agency (BPOM), the Ministry of Agriculture, the Central Statistics Agency (BPS), and the World Health Organization (WHO). Some of the scientific references used have DOI as the identity of the publication so that it makes it easier to search for sources.

The stages of the research include:

1. Determine the topic and scope of the research.
2. Identify literature relevant to herbal plants, bioactive compounds, cultivation techniques, and the herbal industry.
3. Collect information from scientific journals and official sources.
4. Classify information based on plant type, bioactive compound content, cultivation techniques, economic potential, and development challenges.
5. Compare and synthesize results from various sources.
6. Compile the results of the study in the form of a systematic discussion.

The data obtained was analyzed in a qualitative descriptive manner to obtain an overview of the potential of herbal plants as a source of health raw materials and factors that affect their quality and development.

This study has limitations because it does not conduct direct observations in the field or laboratory experiments. Therefore, information on the content of bioactive compounds and pharmacological activities is completely dependent on the results of previous research. The results of research derived from in vitro or experimental animals cannot be directly equated with effectiveness in humans.

RESULTS AND DISCUSSION

Nutritional Content and Benefits of Herbal Plants

Bioactive Compound Content Based on Verified Scientific Evidence

1. Jahe (*Zingiber officinale*)

Based on research by Dugasani et al. (2010) published in the Journal of Ethnopharmacology (DOI: 10.1016/j.jep.2009.10.004), ginger contains [6]-gingerol, [8]-gingerol, [10]-gingerol, and [6]-shogaol which have strong antioxidant and anti-inflammatory activity.

Further research by Ayustaningwarno et al. (2024) in Frontiers in Nutrition (DOI: 10.3389/fnut.2024.1364836) showed that gingerol and shogaol work through activation of the Nrf2 pathway for antioxidants, and inhibition of Akt and NF- κ B for anti-inflammatory.

2. Kunyit (*Curcuma longa*)

Hewlings & Kalman (2017) in Foods (DOI: 10.3390/foods6100092) show curcumin is the main bioactive compound that gives turmeric its yellow color with proven antioxidant, anti-inflammatory, and health effects.

Kocaadam & Şanlıer (2017) in Critical Reviews in Food Science and Nutrition (DOI: 10.1080/10408398.2015.1077195) concluded that curcumin has a multi-target effect on various chronic diseases.

3. Temulawak (*Curcuma xanthorrhiza*)

Devaraj et al. (2010) in the Journal of Medicinal Plants Research proved the hepatoprotective activity of standardized temulawak ethanol extract in rats with liver damage.

Rahmat et al. (2021) in Evidence-Based Complementary and Alternative Medicine (DOI: 10.1155/2021/9960813) comprehensively reviewed the ethnobotany, phytochemistry, and pharmacological activity of temulawak

4. Sambiloto (*Andrographis paniculata*)

Wang et al. (2010) in Acta Pharmacologica Sinica (DOI: 10.1038/aps.2009.205) showed that andrographolide has immunomodulatory activity in macrophages through the NF- κ B/MAPK suppression mechanism.

Naik & Hule (2009) in Planta Medica (DOI: 10.1055/s-0029-1185398) proved the immunostimulant activity of andrographolide extract on antibody responses and delayed type hypersensitivity.

Puri et al. (1993) in the Journal of Natural Products (DOI: 10.1021/np50097a002) showed that pure ethanol and andrographolide extracts from sambiloto stimulate antibody responses and slow-type hypersensitivity in mice.

5. Pegagan (*Centella asiatica*)

Shukla et al. (1999) in the Journal of Ethnopharmacology (DOI: 10.1016/S0378-8741(98)00141-X) proved that Asiaticosides have significant wound healing activity in guinea pig models and diabetic rats. Bylka et al. (2014) in Phytotherapy Research (DOI: 10.1002/ptr.5110) reviewed the role of asiaticosides and madecassosides in dermatology. This scientific evidence is very important because it provides "academic legitimacy" for herbal plants that have often been considered "pseudoscience" or myths. However, what needs to be realized is that validation at the preclinical level (in vitro and experimental animals) is not enough. The majority of the cited research is still in the preclinical stage. To achieve phytopharmaceutical status, phase I-III clinical trials in humans are needed. This is why out of ~20,000 herbal medicine distribution permits, only 20 have successfully upgraded to phytopharmaceuticals. This figure shows that the main "bottleneck" is not the shortage of raw materials, but the limitations of clinical research and financing.

Herbal Plant Cultivation Techniques

WHO (2003) has published the Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants which is an international standard for the cultivation of medicinal plants. These guidelines include: (1) Identification and authentication of botanically verified species; (2) Seeds and propagation materials from identified sources; (3) Tillage without heavy metal contamination; (4) Priority fertilization of composite organic fertilizers; (5) Pest control with minimum doses of registered pesticides; (6) Harvest and post-harvest with complete documentation.

Group I: Rhizome Plants (Ginger, Turmeric, Temulawak)

This plant is propagated through parent rhizomes with buds. Requirements generally include an altitude of 0–1,500 m above sea level, rainfall of 1,500–3,500 mm/year, a temperature of 23–35°C, and loose soil with a pH of 5.5–7.0. Planting is carried out at the beginning of the rainy season with a distance of 25–40 cm and a depth of 5–10 cm. Basic fertilization uses manure composed of 15–25 tons/ha plus NPK according to specific needs. Pest control prioritizes biological agents such as *Trichoderma harzianum* and *Bacillus thuringiensis*. The harvest age ranges from 8–12 months with a yield of 15–30 tons/ha. Post-harvest is a critical factor: ginger requires 2–3 days of curing, turmeric is boiled for 45–60 minutes to maintain color and curcumin, and curcuma is steamed 30 minutes before drying.

Group II: Leaf Plants (Sambiloto, Pegagan)

The plant is propagated through seeds (sambiloto) and cuttings (pegagan). Generally requirements include altitude of 0–2,500 m above sea level, rainfall of 1,000–3,000 mm/year, temperature 20–35°C, and loose soil with good drainage and pH of 5.0–6.5. Planting uses a distance of 20–30 cm with a depth of 1–5 cm. Fertilization is lighter (compost 10–15 tons/ha + NPK 150–300 kg/ha). The main advantage is that the harvest cycle is very short (3–4 months) which allows 2–3 harvests per year with a yield of 10–20 tons/ha. However, post-harvest is very critical because the main bioactive compounds (andrographolide in sambiloto and asiaticoside in sorghum) are very sensitive to heat and UV rays. Drying should be done in the shade with a temperature of 30–40°C, not in direct sunlight.

Based on the above comparison, there is an interesting pattern: plants with shorter harvest cycles (sambiloto and pegagan) actually have bioactive compounds that are more sensitive to heat. This creates the dilemma, sambiloto and gotu gotu can be harvested 2–3 times per year (high economic potential), but post-harvest requires special

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Alfino Dwi Hadi et al

handling (low-temperature drying in the shade) that traditional farmers often do not have. This is why many Indonesian farmers prefer to cultivate ginger and turmeric even though the harvest cycle is longer, post-harvest is more "forgiving" (tolerant). However, from a pharmacognosy perspective, sambiloto and gotu gotu actually have a greater potential for the phytopharmaceutical market because the mechanism of action of andrografolide and asiaticoside has been clinically tested. The solution is to invest in low-tech drying units such as solar dryers that can maintain a temperature of 35–40°C at an affordable cost for smallholders. In addition, the 2003 GACP-WHO standard requiring the identification of botanically verified species is often a barrier. Many farmers do not have access to herbariums or taxonomists. Thus, simple DNA barcoding technology needs to be socialized to the level of farmer cooperatives. With increasingly affordable costs, DNA barcoding can be a more accurate "certificate of identity" of herbal plants than traditional morphological identification.

Potential of Plant Cultivation

Based on BPOM data in February 2026, there are ~20,000 herbal medicine distribution permits with industrial growth of 6% per year. The projected market of Rp 23 trillion in 2025

Data on the Indonesian Herbal Medicine Industry

February 2026

Indicator	Data Valid
● Herbal medicine distribution permit	● ~20,000
● Standardized herbal medicine (OHT)	● 71 products
● Phytopharmacy	● 20 Products
● Market potential	● IDR 350 trillion
● Actual economic value (2025)	● ~Rp 2 trillion
● Market Projections (2025)	● IDR 23 trillion
● Industry growth	● 6% per annum

Source: Indonesian Herbal Medicine Industry Data, February 2026

(Euromonitor) shows increasing demand. The five herbal plants studied (ginger, turmeric, temulawak, sambiloto, pegagan) have high cultivation potential because: (1) There is already strong scientific validation, (2) Wide domestic and export markets, (3) Ease of agroclimatic adaptation in Indonesia, (4) Competitive economic value per hectare compared to conventional crops. However, this potential can only be realized if it is followed by increased farmer capacity, access to quality seeds, and stable marketing guarantees.

Challenges and Obstacles to Cultivating Herbal Plants

1. Agronomic and Technical Challenges

Based on the LAKIP of the Directorate General of Horticulture of the Ministry of Agriculture (2024), there are technical problems in the cultivation of medicinal plants: (1) The ability to adopt the latest cultivation technology is still limited; (2) The implementation of GAP/SOP cultivation is not optimal so that productivity is low; (3) The limited availability of quality medicinal plant seeds that meet the 7 right (type, variety, quality, quantity, place, time, price); (4) The price of quality seeds is relatively expensive; (5) The use of pesticides that is too high results in soil damage and high residues; (6) The use of environmentally friendly plant pest organism controls (OPT) is not optimal.

2. Climate Change Challenges

According to research published by Kompas (2024), more than half of medicinal plants in Indonesia will reduce their population due to the loss of 80 percent of their distribution area due to the climate crisis. BRIN and

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Alfino Dwi Hadi et al

University College London (UCL) have collaborated on medicinal plant research to answer the challenge of climate change, as deforestation is the main factor that has an impact on the availability of medicinal plant raw materials.

3. Standardization and Downstream Challenges

According to the Head of BPOM, Prof. Taruna Ikrar (2025), there are four main challenges: (1) Standardization - from the quality of raw materials to the identification of active substances still faces technical obstacles; (2) Lack of interest from researchers in developing herbal research in a sustainable manner - many research stops at publication without proceeding to industrial products; (3) Obstacles in research financing to commercialization; (4) Limited products that are upgraded - out of 18,600 herbal medicines licensed for distribution, only 71 become OHT and 20 become phytopharmaceuticals. The minor difference between standard research data (76 products) and BPOM's active distribution permit data (71 products) indicates that there are downstream research constraints, where some scientifically certified products have not been or are no longer commercially produced by the pharmaceutical industry.

4. Market Chain and Economic Challenges

Based on official data: (1) Dependence on imported raw materials - 25% of Indonesia's herbal medicine raw materials are still imported due to limited local cultivation; (2) Downstream technology - Indonesia is still dependent on the import of processing machinery from Germany and the Netherlands; (3) Price and market uncertainty - the absence of a price stabilization system makes farmers vulnerable to market fluctuations.

The dependence on imports of raw materials and processing technology is an indicator that Indonesia is still at the weak downstream end of the global value chain. This is similar to the paradox of the "resource curse", rich in natural resources, but unable to process them. The solution is not only to increase local cultivation, but also to develop the domestic processing machinery industry. The government needs to provide fiscal incentives for the agricultural machinery tool industry (alsintan) that focuses on herbal processing. In addition, price stabilization systems such as the "Government Purchase Price" (HPP) for strategic herbal crops need to be considered to protect farmers from market fluctuations.

This finding is very worrying because it threatens national medicinal sovereignty. If Indonesia loses its natural habitat for medicinal plants, we will not only lose economic resources, but also the heritage of indigenous knowledge. The strategy that must be prioritized is ex situ and in situ conservation that is integrated with commercial cultivation. BRIN and UCL need to develop superior climate-resilient varieties and indoor/vertical farming systems for high-value herbal plants. This is not only a matter of adaptation, but also of future agricultural innovation.

Conclusion

- Indonesian herbal plants contain bioactive compounds that are scientifically proven through research with verified DOIs: gingerol/shogaol (ginger), curcumin (turmeric), xanthorrhizole (temulawak), andrografolida (sambiloto), and asiaticoside (pegagan).
- The WHO GACP 2003 cultivation standard provides a valid technical framework for the production of quality herbal crops.
- The large economic potential (Rp 350 trillion) has not been optimally realized (only Rp 2 trillion in 2025), with a market projection of Rp 23 trillion in 2025 based on Euromonitor data quoted by BPOM. The latest data (February 2026) shows that there are ~20,000 herbal medicine distribution permits, 71 OHTs, and 20 phytopharmaceuticals.
- The main challenges include: limited technology adoption, climate change that threatens the diversity of medicinal plants, suboptimal standardization and downstreaming, and dependence on imported raw materials.

Suggestions

- For the Government: Accelerate the implementation of GACP-WHO through integrated counseling programs and subsidies for quality seeds; develop national herbal clinical trial facilities; provide tax incentives for the herbal processing industry.
- For Researchers: Focus research on phase II-III clinical trials to accelerate upgrading from herbal medicine to phytopharmaceuticals; develop climate-resistant varieties.
- For Farmers: Take GACP training and organic certification; form cooperatives to increase bargaining power and market access.

For Industry: Invest in downstream domestic processing technology; build a farming contract system with farmers to ensure supply stability.

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