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Design a model strategy for regulations on the use of tobacco biopesticide as a substitute for hazardous pesticides

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ABSTRACT

Food security constitutes a pillar of national stability according to Law No. 18/2012, yet agricultural productivity is frequently threatened by pests. Chemical pesticides classified as Hazardous and Toxic Materials (B3) are effective but pose risks to health and the environment, induce pest resistance, and impose management burdens as stipulated in Government Regulation No. 22/2021. Tobacco possesses potential for utilization as a biopesticide due to the insecticidal properties of nicotine and its non-B3 classification. Through an empirical research approach integrating legal, agricultural, and environmental analyses, this study employed observation, interviews, regulatory analysis, literature review, and field effectiveness trials. The findings demonstrate that chemical pesticides require stringent management, which is frequently neglected; tobacco biopesticide is recognized under Minister of Agriculture Regulation No. 43/2019 and exhibits regulatory advantages; field trials reduced pest populations by up to 60% within four weeks after planting; implementation remains constrained by technological and research limitations. The utilization of tobacco biopesticide has the potential to reduce costs, mitigate B3 hazards, and support sustainable food security while empowering local farmers through principles of economic circularity, technological self-reliance, income diversification, ecosystem protection, and community empowerment aligned with food sovereignty.

INTRODUCTION

Food security is crucial for national stability and welfare. It ensures that communities have access to nutritious, safe, and affordable food that supports health and productivity, while reducing malnutrition, price volatility, and import dependence. The importance of a nation's food self-sufficiency has been comprehensively regulated in Article 1 paragraph (3) of the Republic of Indonesia Law Number 18 of 2012 concerning Food, which stipulates that food requirements can be met from the national to individual levels through domestic production, reducing dependence on imports that are vulnerable to global fluctuations by leveraging natural, human, social, economic resources, and local wisdom in a dignified manner (Martínez et al., 2024).

Maintaining food security also aligns with Sustainable Development Goal 2, which aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. However, Indonesia's current dependence on food imports remains high, with one contributing factor being the limited domestic pesticide industry. This increases agricultural production costs and makes farmers vulnerable to price fluctuations and pesticide availability.

Nevertheless, the use of imported pesticides is not as efficient as it appears, as many Indonesian farmers still apply pesticides excessively or inappropriately due to a lack of knowledge. This actually damages soil ecosystems, kills natural pest predators, and causes pest resistance, resulting in decreased long-term productivity. While the initial

intention is to enhance food production, this lack of knowledge unfortunately harms multiple parties, including humans and the environment.

Chemical pesticides are popular among farmers due to their rapid effectiveness. However, their excessive and improper use brings serious impacts on the environment and human health (Parven et al., 2025). Pesticide residues in harvested crops can accumulate in the body when consumed long-term, causing various health problems. Direct exposure during spraying can trigger acute disorders such as skin/eye/respiratory irritation, nausea, dizziness, and even fatal poisoning. Long-term exposure to pesticides is associated with risks of cancer, neurological disorders (e.g., Parkinson's disease), hormonal disruption, reproductive issues (infertility, miscarriage, birth defects), and immune system decline. Farmers and their families constitute the most vulnerable group due to direct and intense exposure.

There is a need for continuous review of more effective solutions that still empower local farmers, such as reducing the use of imported chemical pesticides. This can be achieved through the development of local biological or organic pesticides, particularly in strengthening the domestic agrochemical industry. The development of local pesticide use in Indonesia can be implemented following the provisions of Government Regulation No. 22 of 2021. As hazardous and toxic chemical materials (B3), both imported and local pesticides require special management that includes distribution permits, storage according to safety standards, use of personal protective equipment (PPE), strict documentation, and management of used packaging as B3 waste (Buonsenso, 2025).

Tobacco extract contains nicotine, which is effective as a natural nerve toxin for insects. This opens significant opportunities for developing environmentally friendly botanical biopesticides as an alternative to chemical pesticides, including developing local products to compete with imported pesticide products. This is supported by several studies conducted by Saminathan et al (2025) and Nurhidayah et al (2022), which demonstrate that tobacco is proven effective in protecting corn crops from pest attacks. The content of active compounds such as alkaloids and terpenoids functions as pest control agents, making this biopesticide equivalent to synthetic pesticides but more environmentally friendly.

Based on this research, the potential of tobacco to be developed as a local pesticide to reduce imported products is feasible; however, it certainly requires prior examination from a regulatory perspective regarding mechanisms for tobacco formulation if it is to be used as a pesticide, particularly provisions concerning its production and application. Thus, through an interdisciplinary approach, this research not only examines the effectiveness of tobacco-based biopesticides but also addresses aspects of legal regulation, regional policies, community empowerment, and strategies for strengthening national food security through sustainable local innovation. This makes the research more comprehensive and applicable compared to previous studies, so that the effectiveness of tobacco use as a pesticide can be maximized from social, environmental, and regulatory benefit perspectives (Vero et al., 2023).

METHODS

This research originates from the identification of crucial problems related to the use of chemical pesticides that generate multilayered negative impacts, such as environmental degradation, human health risks, increased agricultural production costs, and structural dependence on imported products that threaten national food sovereignty. In the context of research sampling conducted in Sinjai Regency, as one of the largest tobacco production centers in South Sulawesi with a land area of 993-1500 hectares, there exists strategic potential for utilizing local resources that has not been optimized.

Tobacco, which has only been viewed as a commodity of the cigarette industry, actually contains nicotine that is proven effective as a natural insecticide. This potential opens opportunities for developing environmentally friendly botanical biopesticides that are economical and support sustainable utilization of local resources. However, transforming this potential into an applicable solution requires comprehensive analysis that focuses not only on technical-agronomic aspects but also addresses dimensions of legal regulation, public policy, and farmer community empowerment.

To realize effective and sustainable tobacco-based biopesticide innovation, this research

employs an interdisciplinary approach that integrates four main aspects:

1. Legal Aspect: Analysis of the regulatory framework governing the formulation, production, and use of botanical pesticides based on Indonesian legislation, including Law No. 18/2012 on Food, Law No. 39/2014 on Plantations, Minister of Agriculture Regulation No. 43/2019 on Pesticide Registration, and regulations related to the management of Hazardous and Toxic Materials (B3).
2. Agricultural Aspect: Evaluation of the effectiveness of tobacco biopesticide application for pest control on food crops, its impact on agricultural productivity, and the potential for reducing dependence on synthetic chemical pesticides.
3. Environmental Aspect: Assessment of the ecological impacts of tobacco biopesticide use in the context of ecosystem protection, biodiversity conservation, and sustainability of agricultural systems.

Public Policy Aspect: Analysis of existing policy implementation and formulation of strategies for farmer community empowerment in biopesticide utilization to strengthen national food security.

Through this integrative approach, the research is expected to generate concrete recommendations that are not only technically applicable in nature but can also be implemented within the framework of sustainable agricultural development policy. The expected impacts include: (1) reduction of chemical pesticide imports and strengthening of the national biopesticide industry; (2) reduction of agricultural production costs through utilization of local inputs; (3) protection of ecosystems and public health from exposure to hazardous chemicals; and (4) improvement of farmer productivity and income.

Thus, the ultimate objective of this research is not merely to produce biopesticide technological innovation, but to contribute to the strengthening of food sovereignty through the application of economic circularity principles in tobacco utilization, enhancement of farmer self-reliance in production input management, empowerment of local communities, and development of a sustainable and sovereign agricultural system.

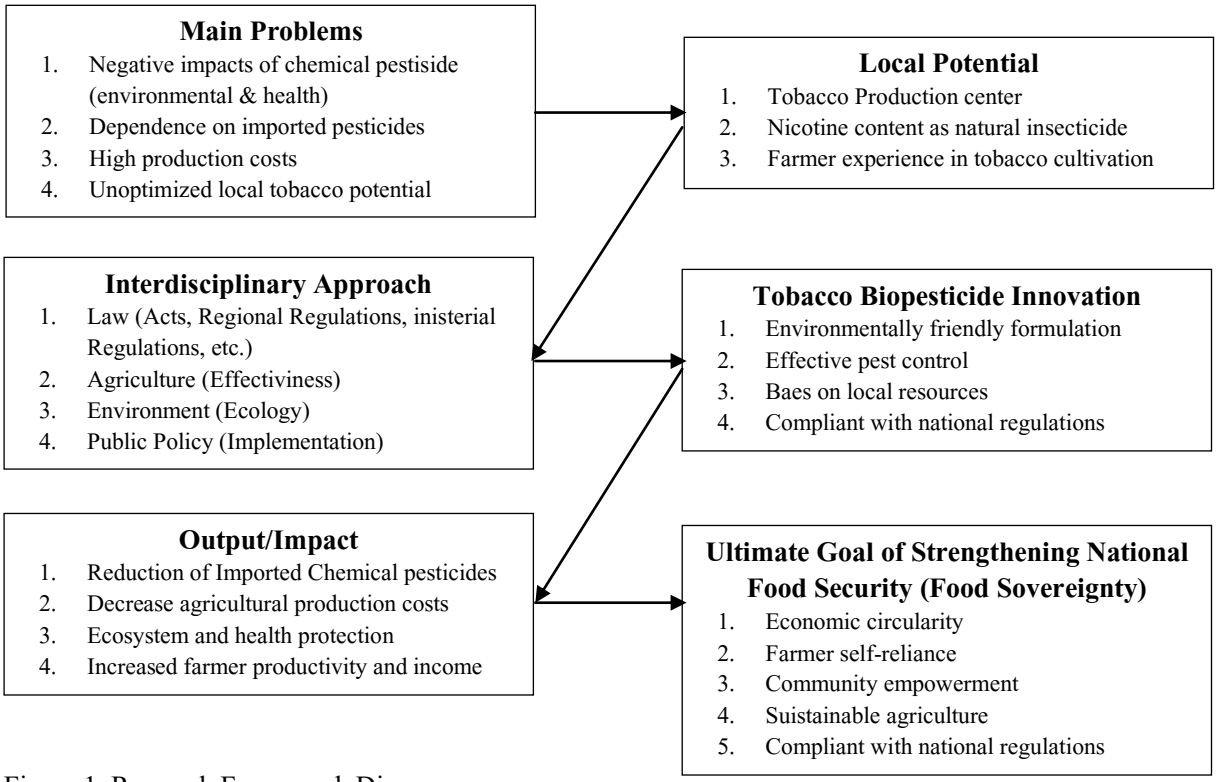

Figure 1. Research Framework Diagram

This research employs an interdisciplinary qualitative research design. An empirical approach was selected to obtain factual and comprehensive data from actual field conditions, including farmer practices, biopesticide effectiveness, and policy implementation challenges. The framework design in formulating the discussion uses an interdisciplinary approach that will be integrated

throughout the study, combining perspectives from Legal Science (analysis of regulations and policies related to pesticides and food security), Agricultural Science (technical assessment of biopesticide effectiveness and cultivation practices), Environmental Science (evaluation of ecological impacts and sustainability of agricultural systems), and Public Policy (implementation strategies and policy recommendations). Data were collected through:

1. Primary Data

Primary data collection was conducted through three methods: (1) field observation to monitor tobacco cultivation practices and management by farmers; (2) in-depth interviews with key informants (farmers and village heads) to explore perceptions and experiences related to tobacco utilization; and (3) analysis of regulations on tobacco potential as a biopesticide and testing of its effectiveness on food crops.

2. Secondary Data

Secondary data collection was conducted through three sources of policy and regulatory documents (food security policies, biopesticide policies, national and regional regulations, and pesticide use regulations), then strengthened with scientific literature (tobacco chemical composition, biopesticide processing, effectiveness on food crops, and environmental impacts).

3. Research Location and Time

Batubelerang Village, Batu Belerang, Sinjai Borong District, Sinjai Regency, South Sulawesi 92662.

4. Data Analysis Techniques

The collected data were subjected to interdisciplinary analysis by combining perspectives and data from various disciplines, namely Legal Science, Agricultural Science, Environmental Science, and Public Policy, thereby enabling holistic answers to research questions. From the legal perspective, analysis focused on applicable regulations, including Laws, Regional Regulations, and sectoral policies related to food, biopesticides, and environmental protection.

From the agricultural perspective, this research examines the potential utilization of tobacco as a biopesticide and its effective impact on food productivity, as well as the potential for reducing dependence on chemical pesticides.

Meanwhile, in the public policy domain, this research evaluates existing policy implementation and formulates improvement recommendations so that the utilization of tobacco-based biopesticides can proceed effectively, sustainably, and support the goals of food self-sufficiency while maintaining environmental sustainability.

RESULTS AND DISCUSSION

Regulatory Mechanisms for Formulation, Production, and Use of Tobacco as a Pesticide under Indonesian Legislation

The legal foundation for food administration and plant protection in Indonesia places collective responsibility on the Central Government, Regional Governments, and business actors. The Republic of Indonesia Law Number 18 of 2012 on Food in Articles 2 and 3 emphasizes that food administration is conducted to fulfill basic human needs that provide benefits fairly, equitably, and sustainably based on Food Sovereignty, Food Independence, and Food Security.

In line with this, the Republic of Indonesia Law Number 39 of 2014 on Plantations, particularly Articles 33 to 37, stipulates that plantation crop protection is a shared responsibility to prevent and control attacks by Plant Pest Organisms (PPO). The national development context reinforces this, where Presidential Regulation of the Republic of Indonesia Number 12 of 2025 on the National Medium-Term Development Plan (RPJMN) for 2025-2029 designates one region in Indonesia, namely Sulawesi, to be developed as a "Supporting Superhub for the Archipelago Economy and Natural Resource-Based Industry", with agriculture and plantation sectors as priority potentials that must be managed sustainably (RPJMN IV., 2025).

In the operationalization of plant protection, pesticides play a crucial role. However, the use of imported chemical pesticides classified as Hazardous and Toxic Materials (B3) presents a complex dilemma (Buonsenso, 2025). Their B3 status based on Government Regulation of the Republic of Indonesia Number 22 of 2021 on the Management of B3 Waste requires clear special management, ranging from licensing, storage, use of Personal Protective Equipment (PPE), to the management of used packaging as B3 waste (Ahmadi et al., 2025).

The formulation of tobacco raw materials in pesticide production is a critical stage that determines the effectiveness and safety of the final product. Although there is no specific regulation explicitly governing tobacco formulation as a pesticide ingredient, the applicable legal framework can be traced through several related laws and regulations.

Minister of Agriculture Regulation Number 43 of 2019 on Pesticide Registration in Article 5, paragraph (2) letter b classifies botanical pesticides (including tobacco extract) as metabolite pesticides, namely pesticides whose active ingredients are derived from secondary compounds of living organisms. This classification provides a legal basis for using tobacco as a pesticide raw material, but it still requires standardization of active ingredient composition (Jalal & Bondarenko, 2025).

Reviewing the formulation context, Article 17, paragraph (1) of Permentan 43/2019 emphasizes that every pesticide to be registered must clearly and measurably state the composition of ingredients contained in the pesticide. This provision also applies to tobacco biopesticides, where the concentration of nicotine as the main active ingredient must be established within a certain range to ensure efficacy against plant pest organisms (PPO) while minimizing toxicity risks to humans and the environment.

Furthermore, National Food Agency Regulation Number 15 of 2024 on Maximum Residue Limits (MRL) of Pesticides in Agricultural Products stipulates that pesticide residues in food products must not exceed established thresholds. Although tobacco is classified as a biopesticide with low toxicity to mammals, proper formulation is still required to ensure that nicotine residues in agricultural products remain within safe consumption limits. Article 4, paragraph (2) of Perbapanas 15/2024 states that MRL determination is based on health risk assessment considering Acceptable Daily Intake (ADI).

From the researcher's practical field perspective, research results indicate that tobacco extract with a nicotine concentration of 0.5–2% is effective in controlling pests such as Spodoptera frugiperda (fall armyworm) and Grapholita molesta (oriental fruit moth) without causing phytotoxicity to plants (Bezabih et al., 2022). This formulation standard becomes an important reference for tobacco biopesticide producers to formulate products in accordance with Good Agricultural Practices (GAP) principles as mandated in Law Number 18 of 2012 on Food (Nurhidayah et al., 2022).

The production process of tobacco-based pesticides in Indonesia must comply with strict regulations aimed at ensuring product quality, safety, and effectiveness. Minister of Agriculture Regulation Number 43 of 2019 on Pesticide Registration serves as the main foundation governing all production stages, from formulation to packaging.

Article 8 paragraph (1) of Permentan 43/2019 stipulates that every person intending to produce pesticides must register their product with the Minister through the Pesticide Commission. This registration process includes comprehensive technical requirements, as regulated in Article 17, namely: (a) Identity of applicant and producer; (b) Pesticide trademark; (c) Composition of contained ingredients; (d) Pesticide formulation; (e) Pesticide use; (f) Method and dosage of use; (g) Efficacy data; (h) Toxicological and ecotoxicological data; and (i) Label and packaging.

Specifically for tobacco biopesticides, Article 19, paragraph (2) provides simpler requirements compared to synthetic chemical pesticides. Botanical biopesticides are not required to submit detailed acute oral, dermal, and inhalation toxicology data, provided the active ingredient is derived from plant extracts that have been proven traditionally safe. However, producers are still obligated to submit Material Safety Data Sheets (MSDS) and efficacy test results in laboratory and field settings to prove product effectiveness against target PPO (Gudeta et al., 2021).

Another important aspect is the obligation of business actors to implement a quality assurance system in the production process. Article 25 of Permentan 43/2019 stipulates that pesticide factories must meet Good Manufacturing Practice (GMP) standards, which include: (1) Cleanliness and sanitation of production facilities; (2) Calibration of measuring and weighing instruments; (3) Production batch recording; (4) Quality control of raw materials and finished products; and (5) Traceability system from raw materials to distribution.

From the technical production perspective, nicotine extraction from tobacco leaves can be performed through several methods, including: (a) Solvent extraction (ethanol, methanol, or water); (b) Steam distillation; or (c) Enzymatic extraction. Recent research demonstrates that extraction using 70% ethanol solvent produces optimal nicotine concentration (1.2–1.8%) with high purity levels and low solvent residue. This process continues with filtration, evaporation, and formulation into ready-to-use dosage forms such as spray solutions, emulsions, or granules (Higgins, 2025).

Government Regulation Number 22 of 2021 on the Implementation of Environmental Protection and Management is also relevant in the context of pesticide production. Article 408, paragraph (1) requires every production activity generating B3 waste to possess waste management permits. However, tobacco biopesticides have significant advantages here because they are not classified as Hazardous and Toxic Materials (B3) as defined in PP No. 22 of 2021. This status exempts producers from complex B3 waste management obligations, thereby substantially reducing cost and administrative burdens.

Finally, Law Number 18 of 2012 on Food in Article 118 provides a strategic foundation for developing the national biopesticide industry. This article mandates that food research and development be directed toward creating competitive products by accelerating the breeding of superior varieties resistant to pest organisms. In the context of Sinjai Regency as a tobacco center, this provision becomes a legal basis for Regional Governments to promote applied research and technology transfer from research institutions to local industries, thereby creating a self-reliant and sustainable biopesticide production ecosystem (Sinjai Info., 2025).

The use of tobacco pesticides at the farmer level is regulated through Integrated Pest Management (IPM) principles as mandated in Law Number 39 of 2014 on Plantations (Ali & Zhou, 2025). Article 33, paragraph (1) of the Plantation Law states that plantation protection is conducted through prevention, monitoring, and control of Plant Pest Organisms (PPO) attacks by prioritizing environmentally friendly methods (Oguh, 2019).

Furthermore, Article 36 of Law 39/2014 requires plantation business actors to implement an IPM system comprising: (a) Use of pest-resistant varieties; (b) Land sanitation; (c) Crop rotation; (d) Use of natural enemies; and (e) Wise and limited use of pesticides. In this context, tobacco biopesticides meet the criteria for environmentally friendly pesticides because they are biodegradable and do not leave persistent residues in soil or water.

National Food Agency Regulation Number 15 of 2024 on Maximum Residue Limits (MRL) of Pesticides in Agricultural Products regulates in detail the permissible residue thresholds in food commodities. Article 5, paragraph (1) states that every person using pesticides must ensure harvested agricultural products meet MRL standards. Although tobacco biopesticides have a safer toxicological profile compared to synthetic pesticides, excessive use can still result in nicotine residue accumulation in horticultural products such as vegetables and fruits (Sakadzo et al., 2020).

The recommended application dose based on field research results is 10–15 ml of tobacco extract per liter of water with a spraying frequency of 1–2 times per week during the vegetative growth period of plants. Research by Nurhidayah et al. (2022) demonstrates that tobacco extract application at 1.5% concentration effectively reduces corn stem borer populations by up to 78% without causing physiological damage to plants. This finding aligns with Good Agricultural Practices (GAP) principles that emphasize minimal input use for maximum results (Sarker & Lim, 2018).

Occupational safety aspects are also an important concern. Although tobacco biopesticides are not classified as B3, the Ministry of Manpower Regulation Number 5 of 2018 on Occupational Safety and Health in the Work Environment still requires farmers to use minimum Personal Protective Equipment (PPE) in the form of gloves, masks, and boots during application. Article 13, paragraph (2) of Permenaker 5/2018 states that every worker exposed to chemicals must use PPE appropriate to the type of hazard faced.

From the supervision and guidance perspective, Article 51 of Government Regulation Number 6 of 1995 on Plant Protection stipulates that the Fertilizer and Pesticide Supervisory Commission (KPPP) at provincial and district/city levels has the authority to supervise pesticide production, distribution, and use. KPPP is authorized to conduct sudden inspections, sample

collection for laboratory analysis, and impose administrative sanctions in the form of written warnings, suspension of distribution permits, and permit revocation for violators.

Additionally, Law Number 18 of 2012 on Food in Article 96 regulates a food safety assurance system that requires every business actor to implement good and safe production methods. In the context of pesticide use, this means farmers must record every pesticide application (type, dose, application time, and target plants) as part of a traceability system that enables product safety verification from upstream to downstream.

Finally, the implementation of tobacco pesticide use regulations is also closely related to agricultural extension programs. Law Number 16 of 2006 on the Agricultural, Fisheries, and Forestry Extension System (SP3K) in Article 14 mandates that extension materials must include technical cultivation aspects, including sustainable pest and disease management. The Regional Government of Sinjai Regency, through the Department of Agriculture, needs to strengthen the capacity of field extension workers in providing education to farmers about proper formulation methods, application doses, and spraying times for tobacco pesticides, so that technology adoption can proceed effectively and safely.

Although the regulatory framework governing the formulation, production, and use of tobacco pesticides is sufficiently comprehensive, its field implementation still faces several structural and cultural challenges. First, the complexity of pesticide registration procedures as regulated in Permentan 43/2019 becomes an obstacle for small and medium-scale business actors, including farmer groups wishing to commercialize tobacco biopesticides. Requirements for efficacy and toxicology data necessitate adequate laboratory facilities and substantial testing costs, which are often beyond farmers' reach.

Second, limited human resource capacity at both producer and user levels becomes a serious constraint. Many farmers do not yet understand correct biopesticide formulation principles, so independently made products often fail to meet effective active ingredient concentration standards (Kumar et al., 2025). On the other hand, the scarcity of extension workers trained in biopesticide technology causes knowledge transfer from research institutions to farmers to proceed slowly.

Third, the suboptimal supervisory function of the Fertilizer and Pesticide Supervisory Commission (KPPP) at the regional level. Budget and personnel limitations cause field inspection activities and sample collection for laboratory analysis to be rarely conducted (Mawcha et al., 2025). Consequently, unregistered (illegal) tobacco biopesticide products circulate in the market, which not only harms consumers but also damages the reputation of biopesticides themselves.

Fourth, from the criminal law perspective, Article 103 of Law Number 32 of 2009 on Environmental Protection and Management threatens imprisonment of at least 1 year and a fine of at least IDR 1 billion for actors managing Hazardous and Toxic Materials (B3) without permits. Although tobacco biopesticides are not classified as B3, business actors producing pesticides without distribution permits can still be subject to administrative sanctions in the form of written warnings, administrative fines, or business license revocation according to Article 112 of Permentan 43/2019.

To address these challenges, strategic measures involving multisectoral coordination are required. The Central Government, through the Ministry of Agriculture, needs to simplify botanical biopesticide registration procedures by providing a special fast track for products whose active ingredients have been recognized as traditionally safe. The Regional Government of Sinjai Regency, as a tobacco production center, can facilitate the establishment of a Tobacco Biopesticide Production Center equipped with testing laboratories, shared production facilities, and training programs for farmers and MSME actors.

Additionally, institutional strengthening of KPPP at the district level through budget increases and technical personnel additions becomes an urgent need. Effective supervision will not only ensure the safety and quality of circulating biopesticide products but also provide legal protection for consumers and producers compliant with regulations.

Finally, revision or harmonization of regulations more responsive to biopesticide technology development is required. Permentan 43/2019, currently in force, still adopts a relatively

uniform regulatory approach between chemical pesticides and biopesticides. However, the safer and more environmentally friendly characteristics of biopesticides should allow for more flexible regulation implementation without sacrificing safety aspects. This aligns with the mandate of Law Number 18 of 2012 on Food, which promotes the creation of a sovereign, independent, and sustainable food system (Ali & Zhou, 2025).

Design Strategies for Empowering Farmer Communities in the Utilization of Tobacco-Based Biopesticides to Strengthen National Food Security

National food security is a condition of food fulfillment for the state to individuals, reflected in adequate food availability in terms of both quantity and quality. Food sovereignty encompasses a broader scope, including farmers' rights and access to all agricultural resources, including land, water, production inputs, technology, and marketing (Vargas-Chaves, 2026).

Indonesia, as the fourth-largest tobacco producer in the world, possesses significant potential that has not been maximally optimized. The tobacco agribusiness sector absorbs millions of workers, from farmers and farm laborers to factory workers, making it an important commodity supporting rural livelihoods (Zhang, 2025). This makes tobacco an important commodity that sustains the lives of many rural communities.

One of the largest tobacco-producing locations in South Sulawesi is Sinjai Regency, with tobacco plantation areas of approximately 993-1500 hectares, constituting one of the tobacco production centers. Experienced farmers earn IDR 30-60 million per year from selling tobacco as traditional cigarette material. However, dependence on the single cigarette industry makes farmers vulnerable to market demand fluctuations (Prasetya et al., 2025). In fact, with broader awareness, tobacco benefits are quite extensive, with other potential utilizations that can be considered for development, including:

1. Biopesticide, Tobacco extract contains nicotine that is effective as a natural nerve toxin for insects, opening opportunities for developing environmentally friendly botanical pesticides as an alternative to chemical pesticides (Lekhsmi et al., 2025).
2. Pharmaceuticals and Health: Nicotine and other compounds in tobacco are being researched for vaccine and pharmaceutical production, for instance, for neurological diseases such as Alzheimer's (Fu et al., 2025).
3. Bioenergy: Tobacco seeds can be processed into more environmentally friendly biofuel (Nikolova et al., 2025)
4. Textile and Composite Products: Fibers from tobacco plants have potential for use in textile industries and composite materials, such as those used in automotive parts (Sriariyanun et al., 2025).
5. Non-Cigarette Consumption Products, Tobacco is also utilized in premium cigar production and other alternative nicotine products (Whitney et al., 2026).

Focusing on food development, the use of tobacco as a pesticide is highly effective because tobacco leaves naturally contain various chemical compounds that play important roles in plant self-defense mechanisms. The main compound contained therein is nicotine, an alkaloid that functions as a natural nerve toxin effective against insects, thus potentially utilized as a biopesticide ingredient (Wahyuni et al., 2025). Besides nicotine, tobacco leaves also contain other alkaloids such as nornicotine and anabasine that contribute to toxic effects. Essential oil content in tobacco leaves provides a distinctive aroma while possessing antibacterial properties and functioning as a pest repellent. Flavonoid compounds contained therein function as antioxidants and can act as nerve toxins for pest organisms. Meanwhile, the presence of sugars and organic acids influences the taste and acidity level of tobacco products.

Based on experiments on chili plants at various Weeks After Planting (WAP) following treatment with tobacco boiled water, the following results were obtained:

Table 1. Chili Plant Pest Population at Various WAP Following Tobacco Decoction Treatment

Plant Age (DAP)	Number of Pests Without Treatment	Number of Pests With Tobacco Boiled Water	Reduction Percentage (%)
1 WAP	25 Tail	12 Tail	52%
2 WAP	40 Tail	18 Tail	55%
3 WAP	60 Tail	25 Tail	58%
4 WAP	75 Tail	30 Tail	60%

WAP= Weeks After Planting

Data demonstrate a consistent reduction in pest population with increasing effectiveness over time, reaching 60% in the fourth week. This indicates the cumulative effect of the active compounds in pest control. Additionally, the effectiveness of tobacco biopesticides is supported by several studies:

1. Shoaib et al. (2026) stated that metamorphosis can fail due to active compounds such as alkaloids, terpenoids, saponins, flavonoids, and papain enzymes that can affect physiological systems regulating pest development. Furthermore, the high content of nicotine in tobacco leaves can increase mortality due to its higher toxicity level (Haris et al., 2023).
2. Benchararki et al. (2025) stated that secondary metabolite compounds (nicotine, terpenoids, flavonoids, etc.) contained in tobacco leaf extract can affect the central nervous system. Therefore, it is suspected that the cause of pupae having abnormal forms is due to disruption of the pupal nervous system by the influence of secondary metabolite compounds contained in tobacco leaf extract.
3. Kanluang et al. (2025) stated that abnormal imagoes are characterized by defects with imperfect wing forms, inability to fly to search for food, and typically surviving only 1-3 days. This causes the life cycle of the fall armyworm to not continue or cease.

Pest control using local inputs becomes an important strategy in realizing food sovereignty. Farmers can utilize tobacco leaves and tobacco waste to be processed into effective biopesticides, protecting food crops from pest attacks (Hartanto, 2025). This utilization of local resources directly reduces dependence on imported chemical pesticides controlled by large corporations, thereby reducing farmers' production cost burdens while strengthening their self-reliance. With the ability to independently manage agricultural production inputs, farmers have full control over the cultivation process, aligning with food sovereignty principles that emphasize the rights of local communities to determine production methods and food management independently and sustainably.

The development of tobacco-based biopesticides using tobacco samples in Sinjai Regency provides dual benefits for the environment and health. Compared to chemical pesticides, tobacco biopesticides are more environmentally friendly because they can maintain soil fertility, protect biodiversity, and reduce exposure to hazardous materials that pose risks to farmer health (Fenibo & Matambo, 2025).

This practice not only provides ecological benefits but also supports the creation of sustainable agricultural systems. This principle aligns with the food sovereignty concept that emphasizes the importance of ecological sustainability as a primary requirement in achieving long-term food self-sufficiency, where food production must not damage the environment that sustains it (Venker et al., 2025).

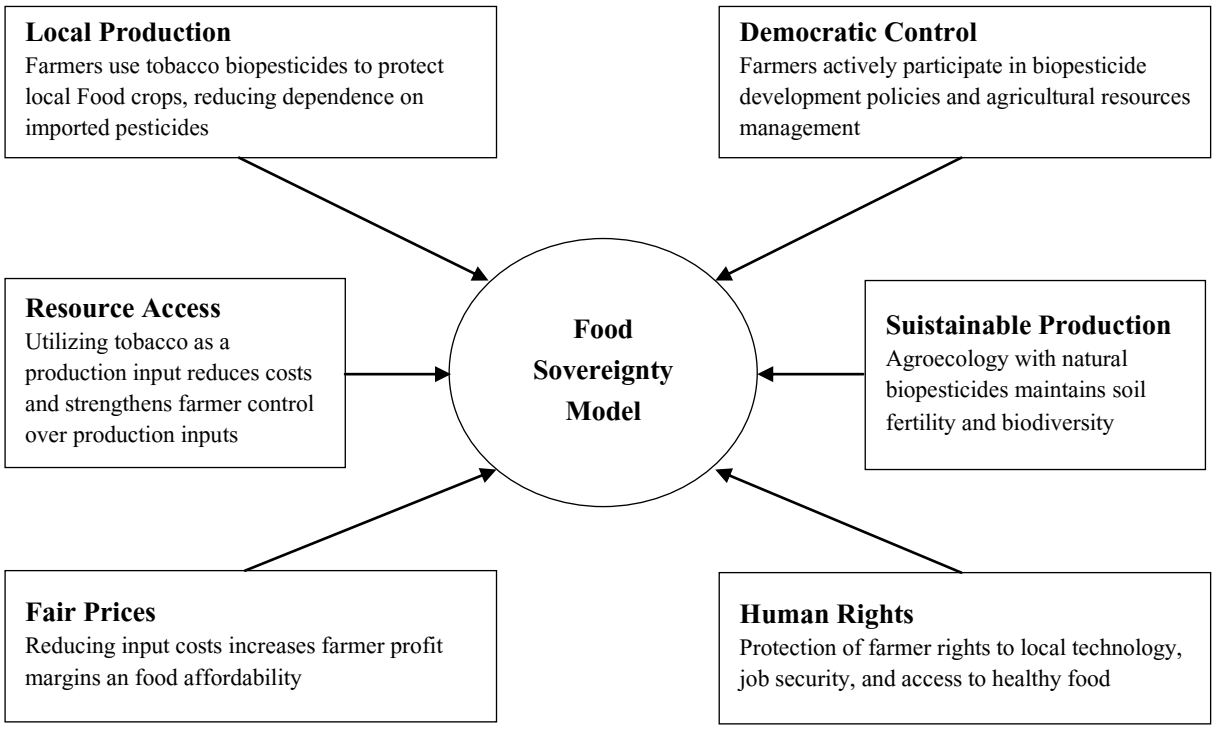

Figure 2. Ideal Food Sovereignty Model Based on Research Findings (Personal Document)

The principles of food sovereignty affirm that food systems must prioritize local communities with several key points relevant to tobacco farmer empowerment (Carter., 2026):

1. Local Food Priority
   Producing food for local community needs with local inputs (tobacco biopesticides), reducing dependence on imported chemical pesticides, and preserving environmentally friendly traditional agricultural practices.
2. Democratic Control
   Farmers and consumers actively participate in decision-making regarding food policies with transparent distribution systems. Farmer groups have a voice in determining prices, quality standards, and biopesticide distribution mechanisms.
3. Access and Control of Resources
   Farmers have full access and control over agricultural resources such as tobacco land, water, biopesticide production technology, and local knowledge, enabling them to be self-reliant in farm management.
4. Sustainable Production Methods
   Implementation of agroecology through utilization of local inputs (tobacco biopesticides), environmental conservation by reducing the use of hazardous chemicals, and rejection of agricultural systems that damage ecosystems.
5. Fair Prices
   Establishment of biopesticide prices that benefit producers (tobacco farmers), are affordable for consumers (horticulture farmers), and protect local markets from imported product domination.
6. Respect for Human Rights
   Protection of the rights of farmers, farm laborers, and indigenous communities in accessing agricultural resources, gender equality in farmer group participation, and the right to healthy and nutritious food produced without hazardous pesticide residues.

The ideal farmer empowerment model with tobacco implementation as a biopesticide depicts a holistic and sustainable system integrating six main pillars:

1. Economic Circularity: Transforming tobacco into valuable input for food agriculture, creating an efficient circular economy. Farmers no longer view tobacco merely as cigarette material but as a high -value resource.
2. Technological Self-Reliance: Farmers in Sinjai Regency can develop simple nicotine extraction technology using local equipment, reducing dependence on imported technology and high production costs.

3. Income Diversification: Besides selling tobacco as cigarette material, farmers can process low-quality leaves and waste into biopesticides, creating stable additional income sources.
4. Ecosystem Protection: Replacing chemical pesticides with biodegradable natural biopesticides, maintaining soil fertility and biodiversity in the long term.
5. Community Empowerment: Creating networks among farmers who mutually support each other in food production and local resource management through cooperatives or farmer groups.
6. Supportive Policies: Regional government support in the form of regulations, subsidies, and development programs for program sustainability.

This empowerment model has significant potential to be replicated in other tobacco-producing provinces in Indonesia, such as East Java, Central Java, and West Nusa Tenggara. South Sulawesi, as one of the tobacco production centers, can serve as a pilot for implementing food sovereignty-based empowerment strategies that can be adapted according to each region's local context. The success of this model will contribute significantly to strengthening national food security through increased agricultural productivity, reduced production costs, and sustainable farmer economic empowerment.

CONCLUSION

This research yields three main findings regarding tobacco utilization as a biopesticide in strengthening national food security, encompassing regulatory aspects, effectiveness, and farmer empowerment. From the regulatory perspective, the national legal framework has opened space for tobacco biopesticide development through various laws and regulations, with the advantage of tobacco not being classified as B3 waste, although its implementation remains constrained by administrative procedures and weak regional supervision.

From the technical aspect, field trials demonstrate that tobacco decoction application can suppress pest populations, supported by nicotine content and other active compounds that function as natural nerve toxins. Meanwhile, farmer empowerment strategies based on six pillars of food sovereignty can promote farmer self-reliance, reduce production costs, decrease dependence on chemical pesticides, and maintain environmental sustainability. Overall, tobacco biopesticides possess strategic potential to support sovereign, independent, and sustainable national food security, with policy recommendations including regulatory simplification, institutional strengthening, and integration into regional and national development programs.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

REFERENCES

Ahmadi, A., Idris, I., Tahrim, N., Nisa, N. A., & Alifah, N. F. (2025). Health promoting university programs as a strategy for reducing tuberculosis stigma and enhancing environmental. *Asian Journal of Toxicology, Environmental, and Occupational Health*, *2*(2), 98–114.

Ali, H., & Zhuo, Z. (Eds.). (2025). Integrated Pest Management: Emerging Technologies and Sustainable Approaches.

Bencharki, B., Chaachouay, N., Azeroual, A., & Baidani, A. (2025). Cultivated Tobacco (Nicotiana tabacum L. Cannabaceae). In *Comprehensive Guide to Hallucinogenic Plants* (pp. 333-348). CRC Press.

Bezabih, G., Satheesh, N., Workneh Fanta, S., Wale, M., & Atlabachew, M. (2022). Reducing postharvest loss of stored grains using plant-based biopesticides: A review of past research efforts. *Advances in Agriculture*, *1*, 1–16.

Buonsenso, F. (2025). Scientific and regulatory perspectives on chemical risk assessment of pesticides in the European Union. *Journal of Xenobiotics*, *15*(5), 173.

Carter, A. L. (2026). *Seeds of Sovereignty: Critical Public Health, Radical Sisterhood, and the Fight for Agricultural Justice*. Oxford University Press.

Fenibo, E. O., & Matambo, T. (2025). Biopesticides for sustainable agriculture: feasible options for adopting cost-effective strategies. *Frontiers in Sustainable Food Systems*, *9*, 1657000.

Fu, C., Li, X., Liu, X., Zheng, Y., Ma, X., Zhang, B., ... & Zou, G. (2025). Psychoactive substances: novel molecular insights and therapeutic potential for Alzheimer's disease. *Translational Neurodegeneration*, *14*(1), 1-22.

Gudeta, B., Solomon, K., & Ratnam, V. M. (2021). Bioinsecticide production from cigarette wastes. *International Journal of Chemical Engineering*, *1*, 1–15.

Hartanto, S. (2025). Sustainable Agriculture in The Tobacco Industry: Future Trends and Challenges. *ASA: Agribusiness and Sustainable Agriculture*, *1*(1). 1-10.

Higgins, M. (n.d.). *Scientists found nicotine a useful pesticide*. Stanford Chemicals. https://www.stanfordchem.com/scientists-found-nicotine-a-useful-pesticide.html

Jalal, M. A., & Bondarenko, S. (2025). Agrochemicals: Definition and regulation. In *Radiochemical analysis of agrochemicals: Environmental Fate and Metabolism* (pp. 1-50). Cham: Springer Nature Switzerland.

Kumar, S., Bhattacharya, D., & Banerjee, M. (2025). Bridging behavioral theories and government initiatives: understanding the drivers of biopesticide adoption among farmers in India. *Renewable Agriculture and Food Systems*, *40*(21), 1-17.

Kunluang, S., Yasanga, T., & Manaboon, M. (2025). Wing abnormalities and morphological differences in the edible moth Omphisa fuscidentalis (Lepidoptera: Crambidae) from northern Thailand. *International Journal of Tropical Insect Science*, 1-14.

Lekshmi, P. S., Premalatha, K., Suganya Kanna, S., Shanmugam, P. S., Guruswami, K., Prithiva, J. N., & Boruah, S. (2025). Botanical Insecticide and Entomopathogenic Fungi in Termite Management: a Comprehensive Review. *Applied Ecology and Environmental Research*, *23*(6), 10671-10689.

Martínez, S., Benítez, G. A., Galvez, R. J., & Rivera, C. C. (2024). Socioecological systems approach to assessing family food sovereignty. *Food Studies*, *14*(1), 79–131.

Mawcha, K. T., Kyampaire, D., Marciale, C., Simiyu-Wafukho, S., Chinyama, C., Babalola, O. O., ... & Ndolo, D. (2025). An overview of biopesticide regulatory frameworks in selected countries in Southern Africa. *Frontiers in Sustainable Food Systems*, *9*, 1522526.

Nikolova, V., Nikolov, N., Petrova, T., Popova, V., Petkova, Z., Ruskova, M., & Teneva, O. (2025). Phytonutrients and Bioactive Compounds in Oriental Tobacco (Nicotiana tabacum L.) Seeds A New Perspective for the Food Industry. *Seeds*, *4*(4), 53.

Nurhidayah, N., Abdullah, T., Sholehah, H., & Safhira, F. (2022). Tobacco extract-based biopesticide from cigarette butt waste for corn plants (*Zea mays* L.). *Jurnal Pijar MIPA*, *17*(6), 787–792.

Oguh, E., Okpaka, C. O., Ubani, C. S., Okekeaji, U., Joseph, P. S., & Amadi, E. U. (2019). Natural pesticides (biopesticides) and uses in pest management: A critical review. *Asian Journal of Biotechnology and Genetic Engineering*, *2*(3), 1–18.

Parven, A., Meftaul, I. M., Venkateswarlu, K., & Megharaj, M. (2025). Herbicides in modern sustainable agriculture: environmental fate, ecological implications, and human health concerns. *International Journal of Environmental Science and Technology*, *22*(2), 1181-1202.

Prasetya, B., Adinugroho, T. P., Mulyono, A. B., Tampubolon, B. D., & Wahono, D. R. (2025). Tobacco's social and economic issues in Indonesia from 1992 to 2023–a review to address product development. *International Journal of Innovative Research and Scientific Studies*, *8*(2), 80-102.

Republik Indonesia. (2025). *Lampiran IV Peraturan Presiden Republik Indonesia Nomor 12 Tahun 2025 tentang Rencana Pembangunan Jangka Menengah Nasional Tahun 2025–2029*.

Sakadzo, N., Makaza, K., & Chikata, L. (2020). Biopesticidal properties of aqueous crude extracts of tobacco (*Nicotiana tabacum* L.) against fall armyworm (*Spodoptera frugiperda* J.E. Smith) on maize foliage (*Zea mays* L.) diets. *Agricultural Science*, *2*(1), 47–55.

Saminathan, N., Subramanian, J., Sankaran Pagalahalli, S., Theerthagiri, A., & Mariappan, P. (2025). Entomopathogenic

fungi: translating research into field applications for crop protection. *Arthropod-Plant Interactions*, *19*(1), 8.

Sarker, S., & Lim, U. T. (2018). Extract of *Nicotiana tabacum* as a potential control agent of *Grapholita molesta* (Lepidoptera: Tortricidae). *PLoS One*, *13*(8), 1–15.

Shoaib, S., Jahan, R., Alomary, M. N., Barkat, M. A., Alghamdi, S., & Ansari, M. A. (2026). Medicinal and Nutritional Importance of Nicotiana spp. in Human Health. In *Medicinal Plants and their Bioactive Compounds in Human Health: Volume 2* (pp. 17-30). Singapore: Springer Nature Singapore.

Sinjai Info. (n.d.). 25 Pelaku usaha tembakau di Sinjai dilatih tingkatkan kualitas produksi. *Sinjai Info*. https://sinjai.info/25-pelaku-usaha-tembakau-di-sinjai-dilatih-tingkatkan-kualitas-produksi/

Sriariyanun, M., Koppiahraj, K., Baranitharan, P., Venkatesh, S., Rajeshkumar, K., & Kavimani, V. (2025). Manufacturing and mechanical characterization of alkali-treated Borassus fruit natural fiber with cellulose acetate synthetic fiber reinforced polymer composite: Selection of optimum configuration using CRITIC-integrated EDAS soft computing techniques. *Journal of Material Cycles and Waste Management*, *27*(2), 880–897.

Vargas-Chaves, I., López-Oliva, J., & Luna-Galván, M. (2026). Governance of Genetic Resources and Traditional Agricultural Knowledge in Colombia: A Food Sovereignty Approach. *Pensamiento Americano*, *19*(39).

Venker, N. T., Lee, K. J., Lauber, T. B., & Fiorella, K. J. (2025). Food sovereignty across borders: Fishing among Myanmar refugees in Upstate New York. *Geoforum*, *162*(6), 1–10.

Vero, S., Garmendia, G., Allori, E., Sanz, J. M., Gonda, M., Alconada, T., ... & Wisniewski, M. (2023). Microbial biopesticides: diversity, scope, and mechanisms involved in plant disease control. *Diversity*, *15*(3), 457.

Wahyuni, S. N., Sudarmawan, A. A., & Sudantha, I. M. (2025). Potential of tobacco stem insecticide as pest control in crops. *Jurnal Biologi Tropis*, *25*(1), 689–698.

Whitney, M. A., Gammon, D. G., Nonnemaker, J., Henriksen, L., Andersen-Rodgers, E., Colonna, R., & Rogers, T. (2026). Changes in Cigarette Availability and Sales Associated with California's Statewide Flavored Tobacco Sales Restriction: A Synthetic Control Analysis. *American Journal of Preventive Medicine*, 108286.

Zhang, L., Jia, J., & Cai, X. (2025). The Impact of China's Outward Foreign Direct Investment on the External Risk Exposure of Industrial Chains in Countries Along the Belt and Road. *Sustainability*, *17*(21), 9547.