

Downstreaming nanoemulsion-based botanical insecticides: Enhancing competitiveness and sustainability of organic horticulture for KWT Kayu Gadang

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Abstract

Dependency on chemical pesticides is a major hurdle in achieving competitive and safe organic horticultural cultivation. This community service program aims to implement nanoemulsion-based botanical insecticide innovation as an eco-friendly pest control solution for the Kayu Gadang Women Farmer Group (KWT) in Sawahlunto. The methodology employed a participatory approach involving technology transfer, digital financial management mentoring, and product branding strategies. Evaluation results demonstrated significant impacts across three key pillars: an 80% reduction in chemical pesticide use per planting season, improved quality of residue-free horticultural products, and a 25% increase in business turnover. Additionally, marketing effectiveness rose, with sales volume growing by 50%. This program successfully transformed KWT Kayu Gadang into a self-sufficient and competitive horticultural business unit that supports green technology-based sustainable agriculture.

Keywords: Botanical insecticide nanoemulsion; Organic horticulture; Pest management; Sustainable agriculture; Women farmer group

Hilirisasi inovasi nanoemulsi insektisida nabati untuk eskalasi daya saing hortikultura organik di KWT Kayu Gadang

Abstrak

Ketergantungan pada pestisida kimia menjadi hambatan utama dalam mewujudkan budidaya hortikultura organik yang kompetitif dan aman. Program pengabdian masyarakat ini bertujuan menerapkan inovasi nanoemulsi insektisida nabati sebagai solusi pengendalian hama ramah lingkungan di Kelompok Wanita Tani (KWT) Kayu Gadang, Sawahlunto. Metode pelaksanaan menggunakan pendekatan partisipatif melalui transfer teknologi, pendampingan manajemen keuangan digital, serta strategi branding produk. Hasil evaluasi menunjukkan dampak signifikan pada tiga pilar utama: penurunan penggunaan pestisida kimia hingga 80% per musim tanam, peningkatan kualitas produk hortikultura yang bebas residu, serta pertumbuhan omzet usaha sebesar 25%. Selain itu, efektivitas pemasaran meningkat dengan kenaikan volume penjualan mencapai 50%. Program ini berhasil mentransformasi KWT Kayu Gadang menjadi unit usaha hortikultura yang mandiri, berdaya saing, dan mendukung sistem pertanian berkelanjutan berbasis teknologi hijau.

Kata Kunci: Nanoemulsi insektisida nabati; Hortikultura organik; Pengendalian hama; Pertanian berkelanjutan; Kelompok wanita tani

Contributions to
SDGs

2

ZERO
HUNGER



12

RESPONSIBLE
CONSUMPTION
AND PRODUCTION



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1. Introduction

Horticultural farming at the rural community level, particularly among women farmer groups, faces serious challenges due to its high dependence on chemical pesticides. This situation not only results in high levels of chemical residues in products, which reduces food quality and safety, but also threatens soil fertility and environmental health. The Kayu Gadang Women Farmers Group (KWT) in Sawahlunto is one of the partners that still relies on conventional cultivation systems with synthetic pesticide inputs. In addition to facing production problems, this group also faces limitations in business management knowledge and marketing strategies. The horticultural products produced are not yet competitive in terms of quality, packaging, and market access, so their selling value is relatively low. Another challenge faced is the lack of structured financial records and skills in utilising digital technology for product promotion and distribution ([Lina et al., 2021](#)).

In view of these problems, innovation in environmentally friendly horticultural cultivation is needed to increase economic added value for the community. The application of plant-based insecticide nanoemulsion is offered as a solution to reduce dependence on chemical pesticides. This innovation is not only effective in controlling pests, but also safer for the environment and supports the creation of organic horticultural products. Through a participatory approach, this community service programme is designed to strengthen the capacity of partners in three main aspects, namely environmentally friendly technology-based production, structured business management, and product marketing through branding and digitalisation strategies ([Nguyen et al., 2025](#)).

Academically, the use of botanical insecticides has been extensively researched as a sustainable alternative for pest control. A study by [Lina et al. \(2021\)](#) showed that *Tephrosia vogelii* extract has synergistic insecticidal activity against the main pest of cabbage (*Crociodolomia pavonana*). Recent research also confirms that nanoemulsion formulations from plant-based materials can increase insecticide effectiveness, extend stability, and reduce application doses without leaving harmful residues ([Lina et al., 2023](#)). These findings reinforce the urgency of applying nanotechnology in organic horticulture ([Tama et al., 2024](#)). Thus, this community service activity aims to: 1) introduce and implement plant-based insecticide nanoemulsion technology on partner land; 2) improve business management capacity through simple financial record-keeping, and 3) expand market access through branding and digitalisation. The expected outcomes are increased productivity, product quality, and economic empowerment for KWT Kayu Gadang, while supporting the achievement of sustainable development goals (SDGs No. 2 and No. 12).

2. Method

The community service activity was conducted over a six-month period, starting from June to December 2025. The programme took place in Kayu Gadang Village, Sawahlunto City, an area with significant potential for horticultural development managed by local farmer groups. The participants of this activity were members of the Kayu Gadang Women Farmers Group (Kelompok Wanita Tani/KWT Kayu Gadang), who served as the main partners in the implementation of the programme. These participants were

actively involved throughout all stages of the activity, including planning, training, technology application, monitoring, and evaluation, to ensure the sustainability and relevance of the interventions to their local context.

The method of implementing this community service activity uses a participatory approach, in which partners are actively involved in every stage of the programme, from planning, training, implementation, to evaluation. The implementation stage begins with an initial survey and programme socialisation to identify existing conditions, problems faced, and the priority needs of KWT Kayu Gadang. This is followed by training and technology transfer, which includes the production and application of plant-based insecticide nanoemulsions, simple manual and digital financial record-keeping, and digital marketing strategies through the use of social media. The language used in the training is Indonesian, with technical terms adjusted to be easily understood by partners.

The next stage was the direct application of technology in the partners' horticultural fields, where KWT members practised the use of plant-based insecticide nanoemulsions, the application of standard operating procedures (SOPs) for cultivation and post-harvesting, and product branding strategies. The tools used include plant-based raw materials, simple nanoemulsion formulation devices, digital financial recording applications (SiAPIK), printed promotional media (stickers and packaging), and online marketing platforms. To ensure the effectiveness of the activities, regular assistance and monitoring are carried out for six months through field visits, group discussions, and achievement evaluations. The evaluation was conducted using pre-test and post-test methods to measure improvements in knowledge and skills, direct observation of practices in the field, and analysis of financial records and product marketing. The monitoring data was analysed using descriptive statistics, such as the percentage reduction in the use of chemical pesticides, increased sales, and the level of technology adoption by KWT members.

3. Results and Discussion

The implementation of training activities and technology application has been running well according to plan. The entire training series was actively attended by members of KWT Kayu Gadang, with an average attendance rate of 90%. The enthusiasm of the participants was evident from their involvement in discussions, hands-on practice, and willingness to try new technologies in their horticultural businesses.

3.1. Production aspects

The implementation of activities in the production aspect focused on reducing dependence on chemical pesticides through the application of nanoemulsion technology for plant-based insecticides and strengthening the organic horticulture cultivation system (Figure 1). During the assistance period, members of the Kayu Gadang Women Farmers Group (KWT) were given training in the manufacture of nanoemulsion-based plant-based insecticides and immediately practised their application on horticultural land. Monitoring results show that the use of chemical pesticides can be reduced by up to 80% in one planting season.

Based on the monitoring results shown in Table 1, it can be seen that the community service programme has had a significant impact on the efficiency of chemical pesticide

use. The number of chemical pesticide applications, which originally reached 8 times in one planting season, can be reduced to only 2 times, which means a reduction of 80%. This decrease shows that the application of nanoemulsion-based botanical insecticides is quite effective in controlling pests on horticultural crops, thereby reducing the need for chemical pesticides. This is in line with the findings of [Priyono \(2019\)](#), who stated that botanical insecticides are quite effective in suppressing pest populations when used appropriately and sustainably.

Tabel 1. Results of chemical pesticide use monitoring

No	Parameters	Before programme	After programme	Percentage Reduction
1	Amount of chemical pesticide application	8 time/season	2 time/season	80%
2	Volume of chemical pesticides used	5 litre/season	1 litre/season	80%
3	Cost of purchasing chemical pesticides	IDR 500,000/season	IDR 100,000/season	80%

In addition, the volume of chemical pesticides used also decreased dramatically from 5 litres to 1 litre per planting season. This had a direct impact on the cost of purchasing pesticides, which was originally IDR 500,000 per season, but could be reduced to IDR 100,000, or a saving of 80%. This reduction in input costs provides tangible economic benefits for farmers, especially members of KWT Kayu Gadang, who on average have limited capital for cultivation activities. The use of plant-based pesticides can reduce farmers' dependence on external inputs and reduce production costs by more than 50%.



Figure 1. Demonstration plot/organic horticultural garden

In terms of production sustainability, the use of nanoemulsion-based botanical insecticides supports a more environmentally friendly organic horticultural cultivation system. Not only does it reduce soil and water pollution from chemical pesticide residues, but this technology also contributes to improving the quality of horticultural products that are healthier and safer for consumption. According to [Singh et al. \(2021\)](#), nanoemulsion formulations can increase the stability of plant-based pesticide active ingredients and improve their effectiveness in pest control with lower doses. This is in line with the increasing market demand for organic horticultural products ([Food and Agriculture Organization, 2020](#)). Thus, success in this aspect of production is an

important foundation for increasing the competitiveness of horticultural products and the welfare of farmers in the future.

From an environmental perspective, reduced use of chemical pesticides has positive implications for soil quality and ecosystems. Excessive chemical pesticide residues can reduce soil fertility, contaminate water, and harm non-target organisms. With the application of plant-based nanoemulsion technology, these risks can be reduced. [Singh et al. \(2021\)](#) emphasise that nanoemulsion technology can increase the stability of plant-based insecticide active ingredients, broaden the spectrum of pest control, and optimise application doses. This allows farmers to achieve pest control results that are equivalent to or even better than those achieved with synthetic chemical pesticides.

In addition to reducing the use of chemical pesticides through the application of nanoemulsion-based plant-based insecticides, members of the Kayu Gadang KWT have also begun to apply other environmentally friendly pest control methods, such as installing insect traps (sticky traps, light traps) and utilising natural enemies ([Figure 2](#)). This step is in line with the principles of Integrated Pest Management (IPM), which emphasises pest control by utilising natural ecological interactions. According to [Isman \(2020\)](#), the combination of botanical insecticides and IPM methods can increase the effectiveness of pest control while maintaining the sustainability of the agroecosystem.



[Figure 2](#). Plant based insecticide nanoemulsion has been applied

The implementation of standard operating procedures (SOPs) in cultivation and post-harvest also contributes significantly to improving crop quality ([Osei-Kwarteng et al., 2024](#)). SOPs cover technical aspects ranging from land preparation, planting, maintenance, harvesting, to post-harvest handling. With SOPs in place, KWT members are able to maintain consistent quality in horticultural products, resulting in more uniform harvests. This is evident from the fact that 85% of horticultural products meet the criteria for good quality according to the established indicators. In line with [Sutanto \(2018\)](#), the implementation of SOPs in organic cultivation can improve product quality and market value because consumers are assured of clear quality standards.

In addition to improving product quality, the implementation of environmentally friendly methods and SOPs also has implications for increased market confidence. Horticultural products free from chemical pesticide residues have a greater chance of penetrating the premium and organic market segments. According to [Willer & Lernoud \(2019\)](#), global consumers are increasingly concerned about food safety and

environmental sustainability when choosing agricultural products. This presents a significant opportunity for farming communities to increase the added value of their products through broader marketing. Thus, the application of plant-based insecticide nanoemulsion technology, combined with environmentally friendly pest control methods and the implementation of cultivation and post-harvest SOPs, not only increases production efficiency but also ensures the quality and competitiveness of horticultural products. This combination of strategies is an important foundation in building a sustainable horticultural production system that can provide economic benefits while preserving the environment (Kusumayanti et al., 2025).

3.2. Business management aspects

Participants attended training on simple financial record-keeping using manual cash books (Figure 3). A total of 75% of participants were able to compile simple reports on business income and expenditure. The implementation of digital financial record-keeping through smartphone-based applications began to be adopted by some younger KWT members, with 50% of participants successfully operating the record-keeping application.

NO	TANGGAL	URAIAN	UANG MASUK (Rp)	UANG KELUAR (Rp)	SALDO (Rp)
22	15-2025	Salek Alim Alim			
		Pengeluaran Bakti	Rp. 4.000		Rp. 4.000
		Pengeluaran Sayur	Rp. 4.000		Rp. 8.000
	24-2025	Pengeluaran Sayur	Rp. 8.000		Rp. 16.000
	26-2025	Pengeluaran Sayur	Rp. 9.000		Rp. 25.000
	28-2025	Pengeluaran Sayur	Rp. 26.000		Rp. 51.000
	30-2025	Pengeluaran Sayur	Rp. 28.000		Rp. 79.000
	31-2025	Pengeluaran Sayur	Rp. 35.000		Rp. 114.000
	02-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 146.000
	04-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 178.000
	06-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 210.000
	08-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 242.000
	10-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 274.000
	12-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 306.000
	14-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 338.000
	16-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 370.000
	18-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 402.000
	20-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 434.000
	22-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 466.000
	24-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 498.000
	26-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 530.000
	28-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 562.000
	30-2025	Pengeluaran Sayur	Rp. 32.000		Rp. 594.000
	31-2025	Jumlah Rp. Alim Alim			Rp. 2.378.000

NO	TANGGAL	URAIAN	UANG MASUK (Rp)	UANG KELUAR (Rp)	SALDO (Rp)
1	15-2025	Pendapatan Sayur			Rp. 981.000
2	16-2025	Pengeluaran Sayur 28 kg			Rp. 919.000
3	17-2025	Pengeluaran Sayur 1 kg			Rp. 921.000
4	18-2025	Sayur 1 kg			Rp. 924.000
5	19-2025	Sayur 2 kg			Rp. 933.000
		Jumlah Rp. Alim Alim Juni 2025			Rp. 933.000

Waga Gudang, 30 Juni 2025
Pemeriksaan Buku Regangan
Potensial
(WAGU)
(TUNEM)

Figure 3. The Women group has been keeping financial records

The training results show that simple financial recording methods using manual cash books are still relevant for most participants, especially those who are older and not yet familiar with digital technology (Novianto et al., 2025). As many as 75% of participants were able to compile simple reports on business income and expenditure. This proves that manual methods are relatively easy to understand, practical, and can be directly applied in daily business activities. Manual recording provides a basic understanding of cash inflows and outflows, which is very important for the management of small and medium-sized enterprises (SMEs). According to Kasmir (2015), good financial recording, even if simple, can help business actors monitor business development and determine business strategies.

On the other hand, the adoption of digital financial recording is beginning to be seen among younger KWT members. As many as 50% of participants successfully operated smartphone-based applications for financial recording. This phenomenon shows the potential for digital transformation in business management, although the level of adoption is still limited. The younger generation tends to adapt more quickly to technology, making them pioneers in the application of digital innovation. The use of smartphone-based recording applications not only facilitates the recording process but

also provides additional benefits such as ease of financial analysis, reduced risk of data loss, and financial transparency (Putra & Supriyanto, 2020).

However, the main challenge in implementing digital technology is the limited digital literacy of some members, especially the elderly. Age and education level affect the ability of micro-entrepreneurs to adopt digital financial technology. Therefore, further training and intensive mentoring are needed so that all members can make optimal use of this technology. The integration of manual and digital recording can be an effective transition strategy, so that participants not only understand the basics of recording but can also develop towards a more modern system. Thus, the success of 75% of participants in manual recording and 50% of participants in digital recording shows significant progress in improving financial literacy. In the future, this community service programme can be directed towards continuous mentoring and the provision of more applicable training modules in the use of digital financial applications, so that all KWT members can achieve financial independence and efficiency in business management.

3.3. Marketing aspects

During the marketing training, participants were taught how to create accounts on the WhatsApp social media e-commerce platform. Seventy per cent of participants successfully created active accounts and began marketing horticultural products online. The branding strategy for organic horticultural products was implemented through the creation of simple logos, more attractive packaging designs (Figure 4), and an emphasis on environmental friendliness and the use of chemical-free products (Rauf & Nazli, 2024). Following the activity, there was a 40% increase in the number of customers in the first two months of online marketing.



Figure 4. More attractive packing design innovation

KWT horticultural products have been successfully marketed online, with a significant increase in the number of customers. This shows that digital marketing training has had a positive impact on market access and business development for the group. Overall, the training and technology implementation activities have succeeded in increasing the production capacity, business management, and digital marketing capabilities of KWT Kayu Gadang members. Assistance and monitoring are carried out regularly to ensure the successful implementation of technology and the sustainability of community service activities. The mentoring process was carried out through field visits, group discussions, and direct technical guidance. Evaluations were conducted to assess the

extent to which the programme achieved its objectives and to identify sustainability measures. The group successfully developed product branding and increased sales by 50% with a $\pm 25\%$ increase in turnover.

The success of KWT Kayu Gadang in marketing horticultural products online shows that digital marketing training plays an important role in expanding market reach. The significant increase in the number of customers proves that digital media can be an effective means of introducing products, establishing communication with consumers, and increasing sales. This is in line with the findings of [Kotler & Keller \(2016\)](#), who state that digital marketing can increase business competitiveness due to its wide accessibility, relatively low promotional costs, and faster interaction with consumers.

The implementation of digital marketing at the women's farmer group (KWT) level also reflects a shift in consumer behaviour patterns, which are increasingly relying on digital platforms for their daily needs. According to [Aprilianti \(2020\)](#), the use of social media as a marketing tool can increase brand awareness and expand the market network for micro and small businesses. In the context of KWT Kayu Gadang, this success not only increases the added value of horticultural products but also strengthens the group's position in the agricultural supply chain ([Waliyanti et al., 2025](#)).

In addition to marketing aspects, regular mentoring and monitoring activities play a major role in maintaining the sustainability of the programme. The assistance provided through field visits, group discussions, and technical guidance has proven to help participants solve problems that arise in a practical and contextual manner. According to [Supriyadi \(2019\)](#), intensive assistance is the key to the success of community empowerment programmes because it provides moral support, knowledge, and technical skills on an ongoing basis. Evaluations conducted at each stage of the activity also enable the measurement of programme achievements and serve as a basis for improvement in the next stage.

Thus, the success of KWT Kayu Gadang in adopting digital marketing and increasing customer numbers demonstrates a significant transformation in the group's business management. The combination of training, technology application, and continuous mentoring is an effective strategy to ensure business sustainability and improve the welfare of members ([Bilderback, 2024](#)). Going forward, capacity building in digital literacy, product innovation, and online market diversification needs to be continuously improved so that KWT can adapt to the increasingly competitive market dynamics.

4. Conclusion

This community service initiative has successfully achieved its core objectives, primarily by enhancing the capacity and productivity of organic horticulture partners through the integration of innovative nanobubble-based botanical insecticide technology. Beyond gaining a theoretical understanding of eco-friendly pest control, partners have acquired critical technical skills and technological infrastructure that ensure long-term operational sustainability. Furthermore, intensive mentoring and monitoring have fortified the partners' management and marketing frameworks, directly fostering greater business independence.

The development of a comprehensive sustainability roadmap now provides a strategic foundation for partners to scale their operations from a personal production level

toward full-scale commercialization. Consequently, this activity has delivered a tangible impact by reinforcing environmentally friendly business systems while unlocking significant opportunities for sustainable economic growth.

To ensure the program's enduring success, it is recommended that partners continue to optimize the use of nanoemulsion-based botanical insecticides by expanding their application across diverse horticultural commodities. Strategic independence should be pursued by developing internal cultivation of raw materials to guarantee supply chain stability. Moving forward, strengthening institutional networks with academia, government, and the private sector will be vital to support the downstreaming of these products toward the commercial market. Additionally, continuous R&D is encouraged to refine insecticide formulations, ensuring their effectiveness remains at the cutting edge. Through these coordinated steps, the partners' businesses are poised to contribute significantly to both regional economic prosperity and environmental conservation.

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Author Contribution

All authors contribute to, activity implementation, article preparation, analysis of service impact, presentation of service results, and article revision.

Conflict of Interest

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