MIKAILALSYS
Journal of Multidisciplinary Sciences

e-ISSN : 2987-2286
p-ISSN : 2987-3924
Index: Harvard, Boston, Sydney, Copernicus, Sinta 4, Scilit, Semantic, Google, etc

https://doi.org/10.58578/mikailalsys.v4i3.12193

Extension Design for the Application of Balakka Leaf Botanical Pesticide to Control Aphids on Red Chili Plants in Padang Bolak District

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Submitted:	Revised:	Accepted:	Published:
Aug 15, 2026	Sep 12, 2026	Sep 24, 2026	Sep 29, 2026

Abstract

Red chili cultivation in Padang Bujur Village, Padang Bolak District, faces aphid (*Aphis gossypii*) infestation and heavy reliance on synthetic pesticides. Locally abundant balakka leaves (*Phyllanthus emblica* L.) offer a potential botanical pesticide for agricultural extension. This study designed an extension activity, characterized the target farmers, and assessed acceptance and adoption of the proposed innovation. A descriptive quantitative study was conducted from April to May 2026 using interviews and closed questionnaires with 30 red chili farmers; questionnaire responses were analyzed using a Likert scale. The extension components received an acceptance score of 86.18%, classified as highly appropriate. Following the activity, 12 farmers (40.00%) adopted the balakka-leaf botanical pesticide, exceeding the target of 10 farmers (33.33%). These findings support the feasibility of the extension design and illustrate the potential to integrate locally available botanical resources into environmentally friendly pest-management extension.

Keywords: Aphids; Balakka Leaves; Botanical Pesticide; Agricultural Extension; Innovation Adoption

INTRODUCTION

The agricultural sector plays a strategic role in Indonesia's economic development because it provides livelihoods for rural communities while supporting the sustainability of the national food system. Strengthening farmers' welfare requires farming systems that

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integrate competitiveness, community economic interests, and sustainability principles (Rodiaminollah & Qomariyah, 2023). Red chili (*Capsicum annuum* L.) is one of Indonesia's important horticultural commodities because of its high economic value and nutritional content (Irjang et al., 2024). Its utilization extends beyond household consumption, as red chili is also used as a raw material in food and pharmaceutical industries (Talli et al., 2023). Therefore, maintaining red chili production is important not only for farmers' economic interests but also for sustaining the availability of a valuable horticultural commodity. This condition highlights the need for production systems that can respond to biological constraints while making efficient use of locally available agricultural resources.

In North Sumatra, red chili production is also developed in North Padang Lawas Regency, including Padang Bolak District. However, the potential of red chili production in this area is constrained by pest infestation, particularly the cotton aphid (*Aphis gossypii*). The pest causes direct damage by sucking plant sap, thereby disrupting the physiological processes required for normal plant growth (Mumba & Rante, 2020). Severe infestation may cause leaf deformation, curling, chlorosis, leaf loss, and reduced fruit development, ultimately affecting farmers' productivity and economic returns (Jaya et al., 2024). Aphid populations may also increase rapidly during the early dry season when environmental conditions support their development and reproduction (Daud et al., 2025). In addition to direct feeding damage, *Aphis gossypii* can act as a vector for various plant viruses, creating an additional threat to crop health (Syaifudin et al., 2023). These conditions indicate that aphid management requires preventive and curative approaches that are technically feasible for farmers.

The pest problem is closely associated with farmers' reliance on synthetic chemical pesticides. Excessive dependence on chemical pesticides can contribute to pest resistance and generate negative effects on agricultural ecosystems when their use is not properly managed (Dadi, 2021). Such practices may also contribute to environmental pollution and other risks associated with pesticide residues (Sinambela, 2024). Botanical pesticides provide an alternative because they utilize active compounds derived from plant materials and can generally be prepared using relatively simple technologies (Wardana et al., 2021). Their biodegradable characteristics also provide an opportunity to support more environmentally sustainable agricultural practices (Tuhuteru et al., 2019). However, introducing a botanical pesticide as an alternative technology requires more than merely informing farmers about its potential. Farmers need adequate knowledge, practical skills, and confidence to prepare and apply the innovation appropriately within their existing farming practices.

Balakka (*Phyllanthus emblica* L.) represents a locally available plant resource with potential for development as a botanical pesticide. The plant is recognized as a non-timber forest product that has social and economic value for local communities in southern North Sumatra. Its natural availability and adaptability to local environmental conditions make balakka a potentially accessible source of raw material for agricultural innovation (Idami, 2024). Phytochemical analysis has indicated that balakka leaves contain secondary metabolites, including alkaloids and flavonoids, which have biological activity against insect pests (Harahap, 2023). These compounds have also been reported to possess repellent and antifeedant functions that may interfere with aphid feeding activity (Nasuha et al., 2025). Other findings indicate that plant-derived bioactive compounds can affect insect digestive and nervous systems, providing a biological basis for their use in pest management (Hasanah & Sutrisno, 2021). The availability of this local resource therefore creates an opportunity to connect indigenous plant potential with a more accessible pest-control innovation for red chili farmers.

The main challenge is that the existence of a potentially useful local resource does not automatically lead to its utilization by farmers. Agricultural extension is required as a learning process that can strengthen farmers' knowledge, attitudes, skills, and capacity to apply agricultural innovations (Rusdy & Sunartomo, 2020). The competence of extension workers is also an important factor in facilitating behavioral transformation and supporting farmers' adoption of appropriate technologies (Rangkuti et al., 2025). Extension therefore needs to be positioned not merely as a process of delivering technical information, but as an educational intervention that facilitates farmers' ability to understand, practice, and make decisions regarding innovations (Wibowo et al., 2023). The formulation of extension objectives should consequently be specific, measurable, achievable, realistic, and time-bound, while also clearly defining the target audience, expected behavior, conditions, and degree of achievement. These principles provide a systematic basis for developing an extension design that corresponds to farmers' actual needs and capacities.

The selection of extension targets is equally important because the effectiveness of an extension activity depends partly on the compatibility between farmers' characteristics, information needs, and the innovation being introduced. Farmer education can encourage changes in perspectives and promote greater openness toward agricultural innovations (Faisal, 2020). Identification of regional potential is therefore necessary to ensure that extension planning reflects actual human resources, natural resources, social conditions, and

agricultural problems in the target area (Ruspianda et al., 2019). Identification of Regional Potential also functions as a strategic basis for preparing extension programs that are applicable to the needs of farmer groups and local agribusiness activities (Sutisna, 2019). In this study, Rapid Rural Appraisal (RRA) is used to obtain contextual information through field observation, interviews, and discussions with farmers and relevant stakeholders. Such participatory identification enables local problems and available resources to be understood from actual field conditions, thereby supporting a more targeted extension design (Purnamasari et al., 2024).

Research Gap in this study concerns the limited development of an integrated extension design that specifically connects locally available balakka leaves with aphid control on red chili through a systematic agricultural extension framework in Padang Bolak District. Previous studies have demonstrated that agricultural extension can contribute to changes in farmers' knowledge, attitudes, skills, and behavior toward agricultural innovations (Yakub et al., 2020). However, there remains a need to integrate local problem identification, farmer characteristics, SMART- and ABCD-based objectives, and the selection of extension components into a single design that is directly applicable to the specific conditions of farmers. Farmer behavior is not transformed through information alone because knowledge develops through cognitive processes that influence subsequent responses and decisions (Darsini et al., 2019). The adoption of agricultural innovation is also influenced by how farmers perceive the innovation's relative advantage, compatibility, complexity, and trialability (Rogers, 2003). Accordingly, an extension design for botanical pesticides should provide not only conceptual information but also opportunities for farmers to observe, practice, and evaluate the innovation in relation to their own farming conditions.

The Novelty of this study lies in the development of an extension design for applying balakka-leaf botanical pesticide that integrates actual farmer problems, local resource potential, target characteristics, and SMART and ABCD principles into a structured extension framework. The design combines material on botanical pesticide preparation and application with demonstration methods, discussion, and farm visits, supported by folders and actual learning objects. Such an approach is relevant because farmers' technical skills develop through observation, practice, repetition, and learning experiences rather than through verbal information alone (Ellyta et al., 2019). Innovation adoption is likewise understood as a behavioral process in which individuals move from awareness and knowledge toward actual implementation of an innovation. The extension design therefore

seeks to create a practical learning pathway through which farmers can understand the potential of balakka, practice its processing and application, and consider its use for aphid management. This integration distinguishes the study from approaches that discuss botanical pesticides or agricultural extension separately.

Based on this background, this study focuses on developing an agricultural extension design for applying botanical pesticide derived from balakka leaves to control aphids on red chili plants in Padang Bolak District, North Padang Lawas Regency. The study aims to identify local agricultural problems and potentials, formulate extension objectives using SMART and ABCD principles, determine the appropriate target based on farmers' characteristics, and develop extension components covering material, methods, media, volume, location, time, and cost. It also examines farmers' acceptance of the proposed extension design and identifies the number of farmers who subsequently apply the balakka-leaf botanical pesticide innovation. Theoretically, the study draws on farmer behavioral change and innovation diffusion concepts to explain the process through which farmers receive and implement agricultural innovations. Practically, the resulting design is expected to provide an applicable reference for agricultural extension workers in developing interventions that respond to pest problems, utilize local plant resources, and encourage more sustainable pest-management practices.

METHODS

This study employed a descriptive assessment with a quantitative approach to develop and evaluate an agricultural extension plan concerning the application of botanical pesticide derived from balakka leaves (*Phyllanthus emblica* L.) for controlling aphids (*Aphis gossypii*) on red chili plants (*Capsicum annuum* L.). The quantitative approach was used to measure farmers' acceptance of the proposed extension plan, while the descriptive approach was applied to systematically portray field conditions and assess the suitability of the planned extension components to the target farmers' needs (Afif et al., 2023). The study was conducted from April to May 2026 in Padang Bujur Village, Padang Bolak District, North Padang Lawas Regency. The study site was selected purposively because the area is characterized by red chili cultivation, aphid infestation, and the absence of prior extension activities concerning the use of balakka leaves as a botanical pesticide.

The research design focused on seven indicators of the agricultural extension plan: extension materials, methods, media, volume, location, timing, and cost. The objectives of the extension plan were formulated using the SMART principles—Specific, Measurable, Actionary, Realistic, and Time Frame—and the ABCD framework—Audience, Behaviour, Condition, and Degree. Problem identification employed a Rural Rapid Appraisal (RRA) approach through field observation, interviews, and discussions to identify farmers' conditions, the causes of the pest-control problem, and priority extension needs. The intended behavioural change was defined as an increase in the number of farmers willing to produce and apply balakka-based botanical pesticide, from an initial baseline of zero farmers to 10 farmers, representing 33.3% of the target group.

The study population comprised 72 red chili farmers distributed across seven farmer groups in Padang Bujur Village. A sample of 30 farmers was selected based on predetermined criteria, including active participation in red chili cultivation, land ownership ranging from 0.04 to 1 ha, exposure to aphid infestation, no previous participation in botanical-pesticide training, and access to balakka leaves as the primary raw material. Sample allocation across the seven farmer groups was conducted proportionally to ensure representation according to the size of each group. Primary data were collected from farmers through interviews and questionnaires, while secondary data were obtained from the 2024 Padang Bolak District Statistics publication and the 2024 Extension Program of the Padang Bolak Agricultural Extension Center. The primary research instrument was a closed-ended questionnaire using a Likert scale to assess farmers' acceptance of the seven extension-plan indicators (Sugiyono, 2021).

Instrument quality was assessed through Pearson Product Moment validity testing and Cronbach's Alpha reliability testing. The instrument trial involved 20 respondents, with a Pearson r critical value of 0.444 at the 5% significance level. Ninety-eight statements were declared valid, whereas 12 invalid statements were excluded from the analysis. All measured indicators produced Cronbach's Alpha coefficients exceeding 0.60, indicating that the instrument was reliable. Data were subsequently tabulated and converted into percentages to determine farmers' acceptance of each extension-plan indicator. The resulting scores were interpreted using five categories: very inappropriate (0–20%), inappropriate (21–40%), moderately appropriate (41–60%), appropriate (61–80%), and highly appropriate (81–100%). These results were used to evaluate the overall suitability of the proposed agricultural extension plan in relation to farmers' needs and field conditions.

RESULTS

The findings indicate that Padang Bujur Village, Padang Bolak District, North Padang Lawas Regency has considerable potential for red chili cultivation but continues to face challenges in pest management, particularly aphid (*Aphis gossypii*) infestation. Field observations, interviews, discussions, and secondary data indicated that aphid infestation was one of the main problems affecting red chili cultivation in the study area. Farmers were also found to rely heavily on synthetic pesticides for pest control, while the locally available balakka plant (*Phyllanthus emblica* L.) had not been optimally utilized as a botanical pesticide resource. These conditions provided the basis for developing an agricultural extension design introducing balakka leaf botanical pesticide for aphid control in red chili cultivation.

The extension program targeted 30 red chili farmers in Padang Bujur Village. Most respondents were within the productive-age group, female, had completed senior high school, had farming experience, and cultivated their own land. These characteristics were considered in determining the extension materials, methods, media, activity volume, location, timing, and cost. The extension design was formulated using the SMART and ABCD approaches. The initial adoption level of balakka leaf botanical pesticide was 0%, while the target was set at 10 farmers, equivalent to 33.3%. The extension materials covered the introduction and benefits of balakka leaf botanical pesticide, preparation procedures, formulation, and application techniques for controlling aphids on red chili plants. The methods included lectures, discussions, method demonstrations, and farm visits, while folders and real objects were used as supporting media.



Figure 1. Documentation of Red Chili Plants

Figure 1. Documentation of Red Chili Plants shows the red chili plants and the field context in which the extension activities were conducted. The documentation illustrates the agricultural conditions that served as the basis for introducing and demonstrating the use of balakka leaf botanical pesticide for aphid control.

The assessment of the extension design showed a high level of acceptance across all evaluated components, namely materials, methods, media, volume, location, timing, and cost.

Table 1. Acceptance of the Agricultural Extension Design Components

Component	Obtained Score	Maximum Score	Percentage	Category
Materials	2,332	2,700	86.37%	Highly Appropriate
Methods	3,203	3,750	85.41%	Highly Appropriate
Media	2,590	3,000	86.43%	Highly Appropriate
Volume	878	1,050	83.62%	Highly Appropriate
Location	1,051	1,200	87.58%	Highly Appropriate
Timing	1,299	1,500	86.60%	Highly Appropriate
Cost	1,315	1,500	87.67%	Highly Appropriate
Total	12,668	14,700	86.18%	Highly Appropriate

Source: Compiled by the researcher (2026)

Table 1. Acceptance of the Agricultural Extension Design Components shows that all components of the extension design obtained percentages above 80% and were categorized as highly appropriate. The cost component recorded the highest percentage at 87.67%, followed by location at 87.58% and timing at 86.60%. The media component reached 86.43%, materials 86.37%, methods 85.41%, and volume 83.62%. Overall acceptance of the extension design reached 86.18%.

The material component achieved an acceptance rate of 86.37%. The assessment covered the relevance of the material to aphid problems, information about balakka leaf botanical pesticide, its benefits, preparation procedures, formulation, and application techniques. The results indicate that the material component was highly appropriate for the target farmers and the agricultural problem addressed by the extension program.

The method component achieved 85.41%, while the media component reached 86.43%. The extension activities used method demonstrations, discussions, and farm visits. The demonstration activities provided direct opportunities for farmers to observe the preparation and application of balakka leaf botanical pesticide. Discussions facilitated interaction between farmers and the extension facilitator, while farm visits provided opportunities to observe conditions directly in the farmers' fields. The extension media consisted of folders and real objects, including balakka leaves, botanical pesticide extract, aphid-affected red chili plants, and spraying equipment.

The volume component achieved 83.62%. The extension activities were conducted through two meetings. The first meeting focused on explaining the material, demonstrating the preparation and application of balakka leaf botanical pesticide, and conducting discussions. The second activity involved visits to individual farmers' fields to observe farmers' willingness to practice the innovation. The results indicate that the volume of the extension activities was categorized as highly appropriate, although it recorded the lowest percentage among the seven evaluated components.

The location component recorded an acceptance rate of 87.58%. The extension activities were conducted in locations directly related to red chili cultivation, including the village meeting hall and farmers' fields. The location was assessed based on accessibility, relevance to the extension material, and the availability of facilities supporting the activities. The results show that the selected locations were highly appropriate for the extension activities.

The timing component achieved 86.60%. The extension activities were conducted in the morning based on an agreement with the farmers and adjusted to their availability. The timing was arranged to allow farmers to participate in the extension activities without substantially interfering with their regular farming activities. The results indicate that the timing of the activities was highly appropriate.

The cost component obtained the highest acceptance rate at 87.67%. The extension activities used a self-financing approach involving contributions from the farmer group and researcher. The main raw material, balakka leaves, was obtained directly from the surrounding environment without additional purchasing costs. Expenditure was mainly allocated to supporting equipment required for the preparation and application process. The results indicate that the cost arrangement was highly appropriate and affordable for the farmers.

Table 2. Number of Farmers Applying Balakka Leaf Botanical Pesticide

Description	Number (farmers)	Percentage (%)
Prepared and applied balakka leaf botanical pesticide	12	40.0
Prepared but had not yet applied	12	40.0
Did not prepare and did not apply	6	20.0
Total respondents	30	100

Source: Compiled by the researcher (2026)

Table 2. Number of Farmers Applying Balakka Leaf Botanical Pesticide shows that 24 farmers, or 80.0% of the respondents, had reached the preparation stage of the botanical

pesticide, while 12 farmers, or 40.0%, had progressed to actual application in their red chili fields. The number of farmers who applied the innovation exceeded the initial target of 10 farmers, or 33.3%, by two farmers. Meanwhile, 12 farmers had already prepared the botanical pesticide but had not yet applied it, and six farmers had not participated in either the preparation or application stage.

Overall, the results show that the agricultural extension design achieved an acceptance rate of 86.18%, categorized as highly appropriate. The adoption of balakka leaf botanical pesticide reached 40.0%, exceeding the initial target of 33.3%. The findings demonstrate that the extension activities generated different levels of farmer response, with some farmers progressing to actual field application, some reaching only the preparation stage, and a smaller group not yet adopting the innovation.

DISCUSSION

The overall acceptance score of 86.18% indicates that the extension design was highly compatible with the needs and conditions of the target farmers. This finding is important because the design did not merely provide technical information about botanical pesticides; it integrated the learning material with appropriate methods, media, location, timing, activity volume, and financing arrangements. Hendrita (2024) argues that acceptance of agricultural extension is associated with the suitability of extension components and the ability of extension workers to adapt innovation delivery to the needs of the target group. The present finding supports this perspective, as all seven components were classified as highly appropriate.

Among the seven components, cost obtained the highest score at 87.67%. This result can be explained by the characteristics of the innovation, which uses locally available balakka leaves as the primary raw material. Consequently, the main financial requirement was not the purchase of active ingredients but the provision of supporting household-scale equipment that was not already available to farmers. This finding suggests that the economic value of the innovation lies not only in its relatively low implementation cost but also in its potential to reduce dependence on externally purchased inputs. Bachtiar (2024) emphasize that efficient cost allocation is important for supporting the implementation of agricultural programs. In the present study, such efficiency was reflected through self-financing and the utilization of locally available resources.

Nevertheless, cost was not the only component associated with farmers' acceptance. Location received 87.58% and media 86.43%, suggesting the importance of conducting extension activities in settings that are accessible to farmers and using learning resources that can facilitate understanding. The method component obtained 85.41%, whereas activity volume recorded the lowest score at 83.62%. The relatively lower score for activity volume may indicate that the number and duration of extension sessions still need to accommodate farmers' time constraints and field responsibilities. This finding highlights the importance of balancing comprehensive learning opportunities with flexibility in agricultural extension scheduling.

The suitability of the extension design should also be interpreted alongside the characteristics of the respondents. Most farmers were within the productive-age group, had completed secondary education, and cultivated their own land. These characteristics may provide a supportive context for innovation adoption because farmers have greater autonomy in making decisions concerning their farming practices. Gusti et al. (2022) found that education can be associated with farmers' ability to receive, process, and apply information. However, these characteristics should not be interpreted as sole determinants of acceptance or adoption because innovation decisions are also shaped by farming experience, perceived benefits, existing practices, and specific production conditions.

An important finding is the distinction between acceptance of the extension design and actual innovation adoption. An overall acceptance score of 86.18% did not mean that all farmers immediately adopted the technology. Among the 30 respondents, only 12 farmers (40.0%) had both prepared and applied the botanical pesticide. Another 12 farmers had prepared the product but had not yet applied it, while six farmers had neither prepared nor applied it. This pattern demonstrates that acceptance of an extension design and the decision to adopt an innovation are related but distinct processes. According to Rogers (2003), innovation adoption develops through stages of knowledge, persuasion, decision, implementation, and confirmation. Farmers who had already prepared the botanical pesticide but had not applied it may therefore be understood as having progressed toward implementation without yet fully incorporating the innovation into their farming practices.

The realization of 12 adopters compared with the initial target of 10 farmers indicates that the quantitative objective of the extension activity was achieved. This finding is consistent with Sofia et al. (2022), who reported that acceptance of an agricultural extension

design can contribute to farmers' willingness and motivation to implement agricultural innovations. Nevertheless, the 40.0% adoption rate should not be interpreted as evidence of long-term adoption effectiveness because the present study primarily assessed implementation within the specific period and context of the extension activity. Continued use during subsequent planting seasons, consistency of application, and comparative pest-control performance against synthetic pesticides were not directly measured.

The study contributes to the agricultural extension literature by demonstrating how a locally grounded extension design can connect available natural resources with farmers' immediate pest-management needs. Rather than focusing solely on the dissemination of information about botanical pesticides, the design integrates problem identification, target-farmer characteristics, SMART and ABCD objectives, selection of extension components, assessment of farmer acceptance, and observation of innovation implementation. The principal contribution therefore lies in developing an operational and context-specific extension design for introducing balakka leaves as a locally available botanical pesticide resource.

Practically, the findings provide a basis for extension workers to develop low-cost activities that utilize local materials and emphasize hands-on demonstration. Theoretically, the findings suggest that the suitability of extension components can create supportive conditions for innovation adoption but does not automatically result in adoption among all target farmers. Methodologically, the study also demonstrates the importance of distinguishing between acceptance indicators and behavioral adoption indicators so that extension evaluation does not rely solely on participants' perceptions.

Several limitations should be acknowledged. First, acceptance was assessed using questionnaire responses from 30 farmers, meaning that the findings primarily represent the context of red chili farmers in Padang Bujur Village and should not be directly generalized to other agricultural communities. Second, adoption was assessed during the period following the extension activity and therefore does not establish whether the innovation would be sustained over subsequent planting seasons. Third, the study did not directly measure the biological effectiveness of balakka leaf extract through comparisons of aphid infestation before and after application or against a control treatment. Future studies should therefore examine the continuity of adoption, pest-control effectiveness, and changes in farmers' reliance on synthetic pesticides across multiple planting seasons.

CONCLUSION

This study demonstrates that the main challenge in red chili cultivation in Padang Bujur Village is aphid infestation accompanied by farmers' high dependence on synthetic chemical pesticides and the limited utilization of balakka leaves as a botanical pesticide due to insufficient technical knowledge. In response to these conditions, an agricultural extension design based on SMART and ABCD principles was successfully developed to support changes in farmers' knowledge, attitudes, and skills in applying balakka-leaf botanical pesticides. The design, comprising extension materials, methods, media, volume, location, timing, and cost, achieved an overall acceptance rate of 86.18%, categorized as highly appropriate. The evaluation also indicated increased innovation adoption, from an initial 0% to 12 farmers (40.00%), exceeding the predetermined target of 10 farmers (33.33%). These findings address the research objectives by demonstrating that an extension design aligned with farmers' characteristics and local needs can facilitate the application of a locally based agricultural innovation.

Practically, this study contributes an extension design that can serve as a reference for agricultural extension workers in introducing botanical pesticide technology based on locally available resources. Its key contribution lies in integrating field-based problem identification, target-farmer characteristics, measurable extension objectives, and farmer acceptance assessment into a structured and measurable extension framework. The findings imply that balakka leaves can be further incorporated into locally responsive pest-management extension practices. For continued implementation, extension workers and relevant institutions are encouraged to utilize the proposed design in areas with comparable agricultural conditions. Follow-up extension activities should include a result demonstration on the fields of the 12 farmers who have adopted the innovation to strengthen farmer-to-farmer learning and encourage wider adoption. Future research should examine the implementation and sustainability of the innovation across subsequent growing seasons and broader farmer groups.

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