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Extension Program Design for the Innovation of Plastic Mulch Use to Control Weeds in Upland Rice in Siempat Rube District, Pakpak Bharat Regency

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Abstract

Upland rice production in Siempat Rube District is constrained by weed growth, highlighting the need for appropriate innovations to reduce weed-management burdens and support crop productivity. This study aims to evaluate the effectiveness of an agricultural extension design promoting the use of plastic mulch for weed control in upland rice cultivation. The study was conducted in Siempat Rube District from January to March 2026 using a descriptive survey approach involving 39 rice farmers as respondents. Data were collected through observations, interviews, and questionnaires and analyzed using percentage analysis and a Likert scale. The findings show that farmer adoption of plastic mulch increased from no adopters to 20 farmers, representing 51.28% of the respondents. The extension design, encompassing instructional materials, methods, media, frequency, location, timing, and costs, achieved an acceptance score of 81.42%, corresponding to the strongly agree category. These findings indicate that the extension design was positively received by farmers and supported the adoption of plastic mulch as an innovation for weed control in upland rice cultivation. The study concludes that a systematically designed extension program can facilitate farmer adoption of plastic mulch technology. The findings provide practical implications for agricultural extension services, particularly by emphasizing the importance of continued technical assistance and field demonstrations to strengthen the implementation and adoption of plastic mulch for weed management.

Keywords: Agricultural Extension; Plastic Mulch; Weed Control; Upland Rice; Innovation Adoption

INTRODUCTION

Rice is one of Indonesia's strategic food commodities, and its demand continues to increase along with population growth. National rice production has traditionally relied heavily on lowland rice cultivation, while agricultural land is increasingly exposed to conversion into residential and other non-agricultural uses. This condition indicates that efforts to strengthen food production cannot depend solely on the expansion or intensification of irrigated rice fields, but should also consider alternative production systems that utilize available dryland resources. Upland rice offers such an alternative because it can be cultivated on dryland with a lower dependence on standing water and irrigation systems than conventional lowland rice (Kusbiantoro et al., 2024). The development of upland rice is particularly relevant to sustainable food security because Indonesia continues to face challenges related to dependence on imports of several strategic food commodities and limited technology transfer from formal research institutions to farmers (Chaireni et al., 2020). Accordingly, agricultural innovation and food-source diversification are increasingly important for strengthening food availability while supporting local economic development (Lumbanraja & Fahreza, 2023).

Pakpak Bharat Regency is characterized by hilly landscapes and a predominance of dryland areas, providing considerable potential for upland rice cultivation. According to data from the Central Statistics Agency of Pakpak Bharat Regency in 2023, the upland rice area reached approximately 2,254.50 ha, including about 650 ha in Siempat Rube District. However, the substantial land potential has not yet been accompanied by optimal productivity. Upland rice productivity in the area remains approximately 3–3.5 tons/ha, whereas lowland rice can reach around 5–6 tons/ha. One factor contributing to this productivity gap is weed competition, as weeds compete with cultivated crops for essential growth resources, including water, nutrients, light, and growing space. Weed dynamics are strongly influenced by cultivation practices and environmental conditions, meaning that the intensity of weed competition may vary according to agroecosystem characteristics and land management practices (Magar et al., 2024). Consequently, ineffective weed management can substantially constrain crop growth and yield, emphasizing the need for management strategies that are both effective and sustainable.

Weed management is particularly important in upland rice systems because crop growth is strongly dependent on environmental conditions, especially rainfall and soil moisture. In dryland cultivation, rainfall constitutes the primary source of water for crops, making soil-moisture conditions an important determinant of both rice and weed growth (Santoso et al., 2022). High rainfall can increase soil moisture and create favorable conditions for weed seed germination and vegetative development. Field identification and interviews conducted with agricultural extension officers and farmers in Siempat Rube District indicate that rapid weed growth is one of the major constraints affecting upland rice cultivation and has encouraged some farmers to shift toward other food crops. This situation suggests that the problem is not limited to production potential but also concerns farmers' capacity to access, understand, and adopt appropriate agricultural innovations. Therefore, an extension approach is required to connect farmers' actual needs with technologies that are technically feasible and compatible with local conditions.

Plastic mulch represents one technological option with potential for addressing these challenges. Mulch is a material applied to cover part or all of the soil surface, thereby modifying the microenvironment surrounding the crop root zone. Its application can reduce soil evaporation, conserve moisture, moderate soil-temperature fluctuations, and suppress weed emergence. Plastic mulch may also increase the reflection of Photosynthetically Active Radiation (PAR) toward the crop canopy, potentially improving the availability of solar radiation for plant growth (Setioputra & Suryanto, 2025). Research by Ilmam et al. (2025) demonstrated that different mulch types could affect energy-conversion efficiency and yield in upland rice. Another study found that black plastic mulch significantly increased root volume compared with an unmulched treatment, suggesting an improvement in the root-zone environment under upland rice cultivation (Kusbiantoro et al., 2024). These findings indicate that plastic mulch may provide benefits beyond weed suppression by contributing to moisture management and improving growing conditions for upland rice under dryland environments.

Nevertheless, the availability of an agricultural technology does not automatically result in farmers' adoption of that technology. The effectiveness of an innovation is closely associated with how information is communicated, its compatibility with the target group, and farmers' capacity to understand and implement the recommended practice. Agricultural extension serves as a learning process through which farmers can improve their knowledge, attitudes, and skills in addressing farming-related problems (Wibowo, 2020). Extension materials should therefore be developed according to farmers' needs so that technological information is relevant to their actual circumstances (Frasisca et al., 2024). At the same time, the selection of extension methods needs to consider farmers' social and cultural characteristics, field conditions, and intended behavioral outcomes because no single method is universally appropriate for every target group ((Bachtiar et al., 2025). Thus, introducing plastic mulch in Siempat Rube should be embedded within a systematic agricultural extension design rather than treated merely as the delivery of technical information.

An effective extension design should integrate the selection of materials, methods, media, activity volume, timing, location, and target characteristics. Appropriate extension methods may include group discussions, method demonstrations, result demonstrations, field visits, and demonstration plots, allowing farmers to acquire not only information but also practical experience with the proposed innovation. The use of appropriate communication media can further clarify technical messages and improve farmers' attention and comprehension during the learning process (Gusmadevi & Hendrita, 2024). Extension media can also transform technical information into accessible messages that facilitate improvements in farmers' knowledge, attitudes, and practical skills (Rofy et al., 2024). Accordingly, extension activities should be designed not merely to increase farmers' awareness of plastic mulch but also to facilitate the transition from knowledge acquisition to actual implementation in farming practices.

The research gap addressed by this study arises from the discrepancy between the growing body of research concerning the agronomic benefits of plastic mulch in upland rice and the limited integration of such technological evidence into farmer-oriented extension planning at the local level. Previous studies have primarily examined the effects of mulch on crop growth, root development, energy-use efficiency, soil microclimate, and yield. Research on plastic-film mulching in non-flooded rice systems has also reported improvements in early soil temperature, root development, and yield stability. However, these studies have not specifically integrated the technological evidence into an agricultural extension design that accounts for the characteristics, needs, and readiness of upland rice farmers in Siempat Rube District. Therefore, a practical research gap remains concerning how an empirically supported agricultural innovation can be translated into an operational extension program that is responsive to local socio-agroecological conditions.

The novelty of this study lies in the development of an agricultural extension design for plastic-mulch innovation specifically aimed at suppressing weeds in upland rice based on local potential assessment and farmer characteristics in Siempat Rube District. The novelty is not limited to the technological object itself but lies in integrating local agricultural potential, weed-related constraints, target-group characteristics, and a comprehensive extension strategy involving materials, methods, media, activity volume, timing, location, and costs. The extension objectives are formulated using the SMART and ABCD principles to ensure that the expected behavioral changes are specific, measurable, and clearly directed toward the target farmers. Theoretically, this approach is grounded in the view that knowledge constitutes an important foundation for technology adoption and that improved knowledge should be accompanied by the development of favorable attitudes and practical competencies (Latif et al., 2024). This study therefore conceptualizes innovation adoption as a behavioral process that needs to be supported through structured learning and evaluated according to farmers' responses and ability to implement the recommended technology.

Based on these considerations, this study focuses on designing an agricultural extension program for the use of plastic mulch to suppress weeds in upland rice cultivation in Siempat Rube District, Pakpak Bharat Regency. The study aims to identify local agricultural problems and potential, formulate extension objectives based on the SMART and ABCD principles, determine the target group according to demographic, social, and economic characteristics, establish appropriate extension materials, methods, media, activity volume, timing, location, and costs, and determine the extent to which farmers implement the plastic-mulch innovation following the extension activities. The resulting design is expected to provide a technically relevant and locally responsive framework for agricultural extension while supporting behavioral change and strengthening farmers' capacity to manage weeds in upland rice production.

METHODS

This study employed a quantitative evaluative design using a descriptive approach to assess farmers' acceptance of an agricultural extension plan introducing plastic mulch as a weed-control innovation for upland rice cultivation in Siempat Rube District, Pakpak Bharat Regency, North Sumatra. The quantitative approach was used to obtain measurable data concerning farmers' responses to the proposed extension components, while the descriptive approach was applied to systematically portray the conditions and level of acceptance identified in the field (Creswell & Creswell, 2024). The study was conducted from January to May 2025 in Siempat Rube District. The study site was selected purposively because the area has considerable potential for upland rice production and farmers had not previously received extension activities concerning the use of plastic mulch for weed management.

The research design focused on developing and evaluating an agricultural extension plan consisting of seven components: extension materials, methods, media, volume, location, timing, and cost. The formulation of extension objectives followed the SMART principles—Specific, Measurable, Actionary, Realistic, and Time Frame—and the ABCD framework, Audience, Behaviour, Condition, and Degree as stipulated in Minister of Agriculture Regulation No. 47/Permentan/SM.010/9/2016. The extension material addressed the use of plastic mulch to control weeds in upland rice cultivation. The proposed methods comprised method demonstrations, plot demonstrations, group discussions, and farm visits, supported by folders and real objects as extension media. The remaining components addressed the frequency of extension activities, the suitability of the location, the timing of implementation, and the required costs. The selection of extension methods also referred to Minister of Agriculture Regulation No. 52/Permentan/OT.140/12/2009, taking into account farmers' characteristics, innovation adoption stages, available resources, local conditions, and relevant agricultural policies.

The study involved 39 participants representing 13 farmer groups in two villages affiliated with the Agricultural Extension Center of Siempat Rube District. Participants consisted of farmer-group administrators and selected members who met the predetermined criteria. A census or total sampling technique was employed, whereby the entire defined population was included as the research sample (Sugiyono, 2022). Participants were selected because they were involved in upland rice farming, belonged to active farmer groups, and represented the target population requiring information concerning the proposed plastic-mulch innovation.

Data were collected through observation, interviews, questionnaires, and documentation. Primary data were obtained directly from upland rice farmers and farmer-group administrators, whereas secondary data were obtained from the 2024 Siempat Rube in Figures, the 2024 Siempat Rube Extension Program, and the 2024 Agricultural Extension Work Plan for Siempat Rube District. The principal research instrument was a closed-ended Likert-scale questionnaire comprising 65 statements covering the seven extension-plan components. Instrument validity was examined using the Pearson Product Moment correlation with 20 respondents outside the main research sample at a 5% significance level.

All items produced calculated r values exceeding the critical r value of 0.444 and were therefore retained. Reliability was assessed using Cronbach's Alpha, with 0.60 established as the minimum criterion. All components exceeded this threshold, indicating that the instrument demonstrated acceptable internal consistency.

Data were analyzed descriptively by calculating farmers' acceptance scores for each component of the extension plan. The obtained score was calculated as the ratio between the observed score and the maximum possible score and subsequently expressed as a percentage. The results were interpreted using five categories: strongly disagree (0–20%), disagree (21–40%), moderately agree (41–60%), agree (61–80%), and strongly agree (81–100%). This analysis was used to determine farmers' level of acceptance of the proposed extension materials, methods, media, volume, location, timing, and costs, and subsequently served as a basis for evaluating and refining the agricultural extension plan prior to its implementation.

RESULTS

The findings indicate that Siempat Rube District, Pakpak Bharat Regency has considerable potential for upland rice cultivation but still faces challenges in adopting agricultural technologies, particularly for weed management. Regional potential and problem identification conducted through field observations, interviews, discussions, and secondary data indicated that agricultural activities in the study area are relatively well developed, particularly in food crops, horticultural crops, and plantation commodities. However, the adoption of agricultural innovations among farmers remains limited. Weed occurrence was identified as one of the problems affecting upland rice cultivation. This condition provided the basis for designing an agricultural extension program introducing plastic mulch as an innovation for weed control in upland rice cultivation.

The extension program targeted 39 farmers from 13 farmer groups in Traju Village and Siempat Rube 2 Village. Most respondents were 38–45 years old, male, had completed senior high school, had 5–11 years of farming experience, and cultivated 0.5–1 hectare of land. All respondents cultivated their own land. These characteristics were considered in adjusting the materials, methods, media, implementation volume, location, timing, and cost of the extension program to the conditions of the target farmers.

The extension design was developed based on the initial conditions of the target farmers and formulated using the SMART and ABCD approaches. The initial level of plastic mulch adoption was set at 0%, while the target adoption rate was established at 50%. The extension materials focused on plastic mulch innovation for weed control in upland rice cultivation, including the definition and benefits of plastic mulch, its function in suppressing weed growth, installation procedures, and practical application in upland rice fields. The methods included lectures, discussions, method demonstrations, field practice, and demonstration plots. Folders, real objects, and supporting media were used to facilitate farmers' understanding of the innovation and its application process.

Figure 1. Documentation of Upland Rice Planting

Figure 1. Documentation of Upland Rice Planting shows the upland rice planting conditions that provided the field context for the research and the application of plastic mulch innovation. The documentation illustrates the actual upland rice cultivation conditions at the research site in relation to the implementation of the extension activities.

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	1,633	1,950	83.74%	Strongly agree
Methods	3,706	4,485	82.63%	Strongly agree
Media	1,781	2,145	83.03%	Strongly agree
Volume	959	1,170	84.12%	Strongly agree
Location	825	975	84.61%	Strongly agree
Timing	810	975	83.07%	Strongly agree
Cost	810	975	83.07%	Strongly agree
Total	10,524	12,675	83.02%	Strongly agree

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 strongly agree. The location component recorded the highest percentage at 84.61%, while the method component recorded the lowest at 82.63%. Overall acceptance of the extension design reached 83.02%.

The material component achieved an acceptance rate of 83.74%. The assessment covered the relevance of the material to farmers' needs, knowledge improvement, innovation benefits, ease of application, potential reduction in labor requirements, additional costs, compatibility with existing farming practices, environmental considerations, and social conditions. The method component achieved 82.63%, while the media component reached 83.03%. The methods and media were designed to support information delivery while providing farmers with direct experience in understanding the application of plastic mulch.

The volume component achieved 84.12%. This assessment covered the suitability of the amount and intensity of the activities to farmers' needs. The location component recorded 84.61%. The extension activities were conducted in upland rice fields belonging to farmer-group administrators in Traju Village and Siempat Rube 2 Village. The location was assessed in terms of accessibility, relevance to the extension materials, strategic suitability, availability of tools and materials, and supporting facilities.

The timing component achieved 83.07%. The extension activities were conducted in the morning beginning at 10:00 a.m. and continuing until the activities were completed. The schedule was determined through agreement with the farmers and adjusted to their availability. The cost component achieved 83.07%. The total cost used to support the demonstration plot and method demonstration activities for plastic mulch installation was Rp1,500,000.

The adoption results showed that some farmers had applied plastic mulch to their upland rice fields after the extension activities. Of the 39 respondents, 20 farmers had applied the innovation, while 19 farmers had not. Overall, the findings show that the extension design achieved an acceptance rate of 83.02%, while the adoption of plastic mulch reached 51.28%. These findings indicate that the extension design, consisting of materials, methods, media, volume, location, timing, and cost, was highly accepted by the target farmers, while innovation adoption reached the target established in the extension design.

DISCUSSION

The central problem underlying the extension design was the limited adoption of agricultural technology for weed management in upland rice cultivation. Weeds compete with upland rice plants for water, nutrients, light, and growing space, potentially reducing crop growth and productivity. In this context, plastic mulch represents a relevant technological alternative because its function extends beyond weed suppression to creating a more favorable soil environment. Kusbiantoro et al. (2024) found that mulch use affected root development and root volume in upland rice, while Setioputra & Suryanto (2025) reported that black-silver plastic mulch improved plant growth, tiller number, leaf area, and dry weight compared with cultivation without mulch. The selection of plastic mulch in this study was therefore directly connected to the agronomic problem identified in the study area rather than being introduced as a technology without contextual justification.

The overall acceptance rate of 83.02% indicates that farmers responded positively to the extension design as a whole. This score was generated by seven interconnected components: materials, methods, media, volume, location, timing, and cost. The material component reached 83.74%, suggesting that farmers considered the information relevant to their needs and practical conditions. This finding indicates that extension materials should not merely transfer information but should explain how the proposed innovation addresses problems that farmers actually encounter. The inclusion of technical, economic, and social dimensions strengthened the relevance of the material because farmers could evaluate the innovation in terms of how it works, what benefits it may provide, and how compatible it is with their existing practices. This finding is consistent with the emphasis placed on relevance and appropriateness of extension materials by Nurfathiyah & Rendra (2020) and Irdiana et al. (2024).

The acceptance rates for methods and media were 82.63% and 83.03%, respectively. These results indicate that an extension approach combining information delivery, discussion, and practical demonstration was positively received. Because plastic mulch is a technical innovation, verbal explanation alone may be insufficient to develop the skills required for implementation. Demonstrations and field practice therefore play an important role by allowing farmers to observe installation procedures and connect the information provided with actual field conditions. Supporting media can further make technical information more concrete and easier to understand. The integration of methods and media thus strengthens the learning process by combining information, observation, and practice. This interpretation is consistent with findings reported by Fatchiya et al. (2025), Gusmadevi & Hendrita (2024), Yanfika et al. (2025), and Anwarudin et al. (2019), who emphasized the importance of appropriate communication components in agricultural extension.

Location received the highest acceptance score at 84.61%. This finding is important because the extension location functioned not merely as a physical venue but also as part of the learning strategy. Conducting the activities directly in upland rice fields allowed farmers to relate the extension material to their everyday production conditions. Farmers could observe field characteristics, the positioning of the mulch, and the tools and materials required for implementation. The high acceptance of the location therefore suggests that the proximity between the learning environment and the production environment was one of the strengths of the extension design. Strategic and accessible locations can facilitate farmer participation, particularly when the extension topic requires direct practice (Rosiana & Cahyani, 2024). Madawu et al. (2024) similarly emphasized the importance of selecting locations that correspond to local conditions and farmer-specific problems.

Timing and cost both received acceptance scores of 83.07%. The positive response to timing suggests that scheduling the activities through agreement with farmers helped minimize conflicts between extension participation and farming activities. Farmer participation depends not only on interest in the subject but also on whether the activity can be attended without substantially disrupting productive work. This consideration is consistent with Bachtiar et al. (2025), Fauziah et al. (2024), and Irdiana et al. (2023). The cost result also indicates that the implementation cost of the extension activity was generally acceptable. However, the cost of conducting the extension and demonstration plot should be distinguished from the affordability of plastic mulch as a recurring production input. The Rp1,500,000 reported in this study represents the cost of implementing the extension activity and demonstration plot and should not be interpreted as evidence that repeated purchase of plastic mulch would necessarily be affordable for every farmer. This distinction is important because perceived economic benefits and communication conditions may influence farmers' decisions to adopt agricultural innovations.

The adoption result showed that 20 of the 39 farmers, or 51.28%, applied plastic mulch. This figure slightly exceeded the predetermined target of 50%. The result indicates a practical connection between the positively received extension design and the emergence of innovation adoption among more than half of the targeted farmers. However, the 51.28% adoption rate should not be interpreted as causal evidence that the extension program alone produced the adoption outcome. Rather, it represents the observed proportion of farmers who adopted the innovation after the extension design was implemented. Appropriate extension methods and media can increase farmers' knowledge and facilitate acceptance of innovations, as reported by Sirajuddin et al. (2021). Farmers' attitudes toward extension activities may also be associated with innovation implementation (Sinaga, 2024), while demonstration plots, training, and direct practice can strengthen farmers' knowledge and practical skills (Muhdiar et al., 2025).

The fact that 19 farmers, or 48.71%, had not adopted the innovation is equally important. It demonstrates that high acceptance of the extension design does not automatically result in adoption among all participants. From the perspective of Rogers' diffusion of innovations, farmers may occupy different stages in the adoption process, including knowledge, persuasion, decision, implementation, and confirmation. Thus, some farmers may already understand the innovation but have not yet progressed to implementation. Factors such as increases in plastic mulch prices, additional capital requirements, planting schedules, and limited opportunities to test the innovation may plausibly influence adoption decisions. These factors, however, were not measured directly in this study and therefore should be regarded as possible explanations rather than established causal determinants.

The findings imply that extension activities introducing plastic mulch should not end after a single intervention. Farmers who have already adopted the innovation require reinforcement to sustain their practice, while non-adopters may need additional opportunities to observe results and gain practical experience. Follow-up activities through demonstrations, demonstration plots or demonstration farms, field visits, group discussions, and continuous assistance may help strengthen the transition from acceptance to implementation. For farmers with limited financial resources, alternative organic mulches such as rice straw, leaves, or onion waste may also be introduced as locally available options. The main contribution of this study therefore lies not only in producing an extension design with high acceptance but also in demonstrating the importance of integrating local problem identification, innovation selection, practical learning, and separate measurement of acceptance and adoption.

Theoretically, the findings reinforce the view that extension outcomes should be assessed through more than one indicator. The 83.02% acceptance rate indicates that the design was considered appropriate by the target farmers, while the 51.28% adoption rate indicates that part of the target group progressed toward actual implementation. Practically, the findings provide a basis for extension practitioners to design more context-specific interventions for upland rice farmers in Siempat Rube. Methodologically, distinguishing acceptance from adoption provides a more cautious interpretation of extension outcomes because high acceptance should not automatically be equated with causal effectiveness. The study is limited by its relatively small sample of 39 farmers from selected farmer groups in two villages, the absence of a comparison group, the use of perception-based questionnaires for acceptance measurement, and the lack of long-term measurements of upland rice productivity, weed suppression, and continued mulch use. In addition, the reasons why 19 farmers did not adopt the innovation were not measured directly. Future research should therefore examine adoption longitudinally, compare conditions before and after plastic mulch application, and directly measure changes in weed intensity and upland rice productivity.

CONCLUSION

This study demonstrates that Siempat Rube District has considerable potential for upland rice development, supported by suitable land conditions, while weed growth remains a major constraint to crop performance. This condition highlights the need for weed-management alternatives that can reduce the burden of field sanitation and support the sustainability of upland rice farming. Accordingly, an agricultural extension design promoting the use of plastic mulch was developed by considering local conditions and the characteristics of the target farmers.

The findings indicate that the extension objective of encouraging farmers to adopt plastic mulch was achieved, as the number of farmers willing to implement the innovation increased from none to 20 farmers, representing 51.28% of the target. The extension program involved 39 farmers who were predominantly of productive age, members of farmer groups, experienced in farming, and generally cultivated their own land with an average area of at least 1 ha. The proposed extension design, comprising extension materials, methods, media, frequency, location, timing, and costs, obtained an overall acceptance rate of 81.42%, categorized as strongly agreed. This finding indicates that the proposed design was generally aligned with the characteristics of the target farmers and the extension needs identified in the study area.

Practically, this study contributes an extension design that can serve as a reference for agricultural extension workers in introducing innovative weed-management practices for upland rice. Its implementation implies the need for continuous extension activities, technical assistance, and field-based demonstrations to strengthen farmers' understanding, attitudes, and practical skills. Farmers may also reduce implementation costs by reusing plastic mulch previously applied to other crops or considering organic mulch derived from agricultural residues. Future research should further examine the effectiveness of plastic mulch in controlling weeds and improving upland rice productivity under the specific conditions of Siempat Rube District.

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