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Strengthening Farmer Capacity through Participatory Agricultural Innovation: Evidence from Hybrid Rice Demonstration

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Abstract

Smallholder rice farmers in Sidemen, Karangasem Regency, Bali, face low productivity, limited access to improved rice technologies, and insufficient capacity to evaluate agricultural innovations. This community service program aimed to strengthen farmers' knowledge, confidence, and technology adoption through a participatory hybrid rice demonstration plot. The program involved 10 smallholder farmers as the primary beneficiaries, supported by the *Subak* organization, village agricultural authorities, local farmer youths, university students from Universitas Bali Internasional Muhammadiyah (BIM University), experts from Universitas Brawijaya, and Microgene China as the technology partner. Community empowerment was implemented through demonstration plots, continuous field mentoring, experiential learning, technical discussions, and participatory evaluation during the 2025 rice cultivation season. The activities improved farmers' understanding of hybrid rice cultivation, pest and disease management, varietal evaluation, and evidence-based decision-making for technology adoption. Farmers became more confident in assessing hybrid rice performance under local conditions while strengthening collaboration among community members, universities, government, and the private sector. Agronomic evaluation showed that all hybrid varieties outperformed the local control, with V1 producing 6.79 t ha^{-1} (302% higher yield) and demonstrating the most stable performance. The program demonstrates that participatory demonstration plots effectively enhance farmer capacity, strengthen institutional partnerships, and provide a sustainable model for community-based agricultural innovation and technology adoption.

Keywords: farmer empowerment; participatory; hybrid rice; innovation capacity; technology adoption.

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Introduction

Rice (*Oryza sativa* L.) remains Indonesia's primary staple crop and constitutes the backbone of rural livelihoods in Bali [1]. In Karangasem Regency, particularly in Sidemen District, rice farming is the dominant economic activity for many households. Despite its strategic importance, local farmers continue to face persistent production challenges, including stagnant productivity, increasing production costs, pest pressures, and limited access to improved rice technologies [2], [3]. Most farmers continue cultivating conventional rice varieties with relatively low productivity, while opportunities to evaluate new technologies under local farming conditions remain limited [4]. These conditions reduce farm profitability and weaken the long-term sustainability of rice-based livelihoods.

Field observations conducted prior to the program, together with discussions with local farmer groups and agricultural stakeholders, identified several practical constraints faced by the community. Farmers had limited knowledge of hybrid rice cultivation techniques, lacked confidence in evaluating the performance of new varieties, and were reluctant to adopt hybrid seeds due to perceived production risks, higher seed costs, and insufficient technical assistance [5], [6], [7]. Furthermore, although Bali possesses a strong agricultural institution through the Subak system, the introduction of new agricultural technologies requires collective understanding and community acceptance before adoption decisions can be made [8], [9], [10]. Consequently, strengthening farmers' knowledge and decision-making capacity became a priority need identified by the community and partner institutions.

These conditions highlight the urgency of community empowerment activities that move beyond one-way technology dissemination toward participatory learning [11], [12]. Rather than simply introducing hybrid rice varieties, farmers require practical opportunities to observe crop performance directly, compare varieties under local conditions, interact with technical experts, and discuss potential benefits and challenges collectively [13], [14]. Such participatory approaches are particularly relevant in Bali, where agricultural decisions are strongly influenced by social interactions and collective institutional arrangements within the Subak system [8], [15].

Hybrid rice technology, developed on the principle of heterosis, has consistently demonstrated yield advantages of approximately 15–30% over conventional inbred varieties across many Asian rice production systems [16], [17], [18]. However, previous studies emphasize that successful adoption depends not only on the technology's superiority but also on farmers' capacity to understand, evaluate, and trust the innovation within their socioeconomic and cultural contexts [19], [20], [21]. Agricultural innovation therefore requires the integration of technological advancement with local institutional capacity and effective community engagement [22], [23].

To respond to these identified community needs, Universitas Bali Internasional Muhammadiyah (BIM University), in collaboration with Microgene China and local farmer groups, implemented a participatory hybrid rice demonstration program in Sidemen, Karangasem. The community service activity was designed not merely as a technology demonstration but as a capacity-building initiative in which farmers actively observed, evaluated, and discussed the performance of hybrid rice under local farming conditions [14]. Through demonstration plots, technical mentoring, and interactive discussions, the program sought to reduce uncertainty surrounding hybrid rice cultivation while strengthening farmers' technical knowledge and confidence in making future adoption decisions.

This participatory approach differs from conventional technology transfer models that often position farmers as passive recipients of innovation [24]. Instead, farmers were engaged as co-evaluators who contributed local knowledge while simultaneously learning from researchers and technology providers [25], [14]. Such an approach aligns with participatory development theory, which argues that sustainable community development is achieved when beneficiaries actively participate in problem identification, decision-making, and evaluation [11]. Likewise, Diffusion of Innovations Theory suggests that opportunities for reliability and observability are essential for reducing uncertainty and encouraging technology adoption [26].

Community empowerment in agriculture extends beyond increasing technical knowledge. Effective empowerment also enhances farmers' confidence, encourages informed adoption of technology, strengthens collaboration among universities, private-sector partners, and local communities, and ultimately improves farmers' economic opportunities [27], [28]. Previous studies have shown that participatory agricultural extension methods, including demonstration plots and farmer field schools, improve farmers' knowledge, decision-making capacity, and willingness to adopt improved technologies by reducing perceived risks through experiential learning [27], [14].

Based on these perspectives, this community service program evaluates farmer capacity development using five interrelated dimensions: knowledge, confidence, adoption, collaboration, and empowerment. These dimensions represent the cognitive, behavioral, institutional, and socioeconomic outcomes expected from participatory agricultural interventions [29], [30]. By assessing these dimensions simultaneously, the study demonstrates how university-led community engagement can strengthen local agricultural capacity while supporting the adoption of sustainable technologies among smallholder rice farmers [28].

This article therefore aims to describe and evaluate the implementation of a participatory hybrid rice demonstration program as a community empowerment initiative in Sidemen, Karangasem, Bali. Beyond reporting the technical performance of hybrid rice varieties, the study highlights how collaborative partnerships among universities, private technology providers, and local farming communities can address practical agricultural problems and strengthen farmers' capacity to adopt sustainable innovations. Furthermore, the program integrates human literacy, life skills, social competence, progressive values, transcendent values, local cultural wisdom, and sustainability to strengthen farmers’ adaptive capacity, participatory decision-making, and long-term resilience in community-based agricultural development.

Method

The community service program was implemented during the 2025 rice cultivation season in Sidemen Village, Karangasem Regency, Bali, Indonesia. The area is characterized by irrigated smallholder rice farming managed under the traditional *Subak* irrigation system and was selected because it represents a typical Balinese rice-growing community with active farmer organizations and strong local institutional support [31], [6].

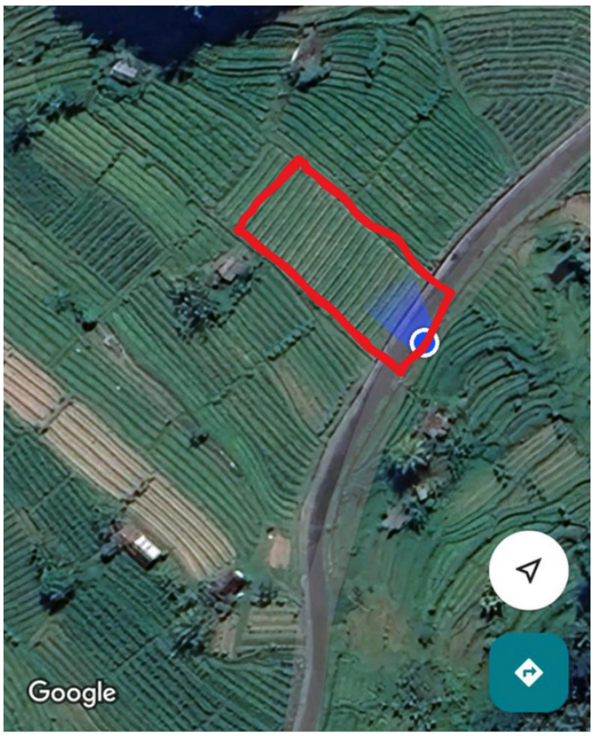

Figure 1. Satellite view of the hybrid rice demonstration plot location in Sidemen, Karangasem, Bali (highlighted in red).

The program adopted a participatory community empowerment approach involving multiple stakeholders [12]. The primary beneficiaries consisted of 10 smallholder rice farmers who voluntarily participated throughout the entire cultivation cycle. Community leadership was represented by one village agricultural leader and two *Pekaseh* (Subak leaders) who coordinated farmer participation, facilitated communication within the farming community, and ensured that the demonstration activities aligned with local agricultural practices and the Subak planting system [10], [21].

The implementation team consisted of four undergraduate students from the Food Technology Department at Universitas Bali Internasional Muhammadiyah (BIM University) and four local farmer youths who served as field facilitators. These facilitators assisted with daily plot maintenance, field observations, farmer coordination, and documentation of program activities, while simultaneously strengthening youth participation in agricultural development [32]. Technical supervision and scientific guidance were provided by an expert team from the Faculty of Agriculture, Universitas Brawijaya, together with academic staff from the Food Technology and Entrepreneurship Departments of BIM University. Hybrid rice seed and technical cultivation recommendations were provided by Microgene China, the technology partner.

Figure 2. Research team and local farmers at the Hybrid Rice Research Project demonstration site in Sidemen, Karangasem, Bali.

The community empowerment program was implemented through five sequential stages: 1) Participatory Needs Assessment and Planning; 2) Establishment of the Demonstration Plot; 3) Farmer Mentoring and Capacity Building; 4) Participatory Monitoring and Evaluation; and 5) Reflection and Knowledge Dissemination. The community empowerment strategy focused on strengthening five dimensions of farmer capacity: (1) technical knowledge of hybrid rice cultivation, (2) confidence in evaluating agricultural innovations, (3) willingness to adopt improved rice varieties, (4) collaboration among farmers and supporting institutions, and (5) overall empowerment reflected in improved decision-making capacity and economic opportunities.

Program evaluation combined technical and community empowerment assessments. Agronomic observations included flowering time, harvest maturity (days after planting), plant height, productive tiller number, fertile grains per panicle, empty grain percentage, grain weight per panicle, shattering percentage, pest and disease incidence, and grain yield. Economic potential was estimated using prevailing local rice prices (IDR 11,000–17,000 kg).

Participatory evaluation was conducted through guided field observations, group discussions, and reflective evaluation meetings that covered five empowerment dimensions: knowledge, confidence, intention to adopt, collaboration, and empowerment [30]. Quantitative findings were complemented by participatory group discussions to capture farmers' experiences, perceived benefits, implementation challenges, and recommendations for future community empowerment initiatives [11], [13].

Program success was determined by the integration of three indicators: (1) satisfactory agronomic performance of the hybrid rice varieties, (2) measurable improvements in farmers' knowledge, confidence, collaboration, and adoption intentions, and (3) strengthened institutional partnerships among farmers, the *Subak* organization, local government, universities, and the private-sector technology provider, thereby supporting sustainable agricultural innovation in the community [22], [28].

Result and Discussion

Community Participation Process

The hybrid rice demonstration plot was implemented using a participatory community empowerment approach involving multiple stakeholders throughout the entire cultivation cycle [12]. The program directly involved 10 smallholder farmers from the Sidemen Subak community as the primary beneficiaries. Community participation was further strengthened through the involvement of one village agricultural officer, two *Pekaseh* (Subak leaders), four local farmer youths serving as field facilitators, four undergraduate students from the Food Technology Department of Universitas Bali Internasional Muhammadiyah (BIM University), and an expert team from the Faculty of Agriculture, Universitas Brawijaya. Microgene China provided hybrid rice seed varieties together with technical recommendations for hybrid rice cultivation.

Unlike conventional extension programs in which farmers receive information passively, the demonstration plot positioned farmers as active participants in planning, crop management, field observations, problem identification, and variety evaluation [14]. Farmers contributed local ecological knowledge while simultaneously acquiring new technical competencies regarding hybrid rice cultivation [10]. This collaborative arrangement transformed the demonstration plot into a community learning platform where knowledge was co-created among farmers, researchers, extension facilitators, and technology providers [25], [23].

Figure 3. Early vegetative growth stage of hybrid rice varieties at the Sidemen demonstration plot.

The participation of farmer youths and university students also strengthened intergenerational learning [32]. Farmer youths assisted with daily crop monitoring and communication between researchers and participating farmers, whereas university students supported field observations, documentation, and technical assistance. This interaction created reciprocal learning opportunities that extended the program's benefits beyond the demonstration plot itself.

Knowledge and Technical Capacity

One of the primary outcomes of the community service program was the improvement of farmers' practical knowledge regarding hybrid rice cultivation. Throughout the growing season, participating farmers continuously observed the development of five hybrid rice varieties under identical environmental conditions. This direct comparison enabled farmers to recognize differences in growth characteristics, flowering time, disease resistance, grain filling, and yield performance that would have been difficult to understand through classroom training or printed extension materials alone [19].

The demonstration plot significantly enhanced farmers' understanding of the relationship between planting synchronization and pest pressure. During field observations, farmers found that Variety V3 flowered considerably earlier (58 days after planting) than neighboring rice fields. This asynchronous flowering exposed the crop to concentrated attacks by birds and rice bugs during grain filling, resulting in approximately 90% empty grains despite vigorous vegetative growth and abundant productive tillers. Direct observation of this phenomenon enabled farmers to understand the ecological importance of synchronized planting within the Subak irrigation system and to reinforce local integrated pest management practices [9], [6].

Similarly, farmers learned to distinguish differences in varietal resistance to plant diseases. Variety V2 exhibited relatively high susceptibility to bacterial leaf blight and blast disease, whereas V1 maintained more stable growth under the same field conditions. Through guided discussions with agricultural experts, farmers recognized that variety selection should consider not only potential yield but also disease resistance, production stability, and management requirements [7].

These findings demonstrate that experiential learning through demonstration plots substantially strengthened farmers' technical knowledge. Rather than memorizing cultivation recommendations, farmers developed the capacity to independently interpret field conditions and evaluate technological innovations through direct empirical observation. Such experiential learning is consistent with participatory agricultural extension approaches that emphasize learning-by-doing and collaborative problem-solving [14].

Strengthening Technology Adoption

Continuous mentoring throughout the cultivation season also increased farmers' confidence in evaluating and adopting hybrid rice technology. Initially, most participating farmers had limited experience with hybrid rice and expressed uncertainty regarding its productivity, production costs, and management requirements [5]. Through repeated field observations, technical discussions, and direct comparison among varieties, farmers gradually developed greater confidence in assessing the advantages and limitations of hybrid rice under local farming conditions [19], [20].

The demonstration plot encouraged farmers to actively compare varietal performance, discuss production constraints, ask technical questions, and exchange cultivation experiences. This participatory learning environment shifted farmers from passive recipients of information toward active evaluators of agricultural technology [13]. Farmers became increasingly able to balance agronomic performance, production risks, pest resistance, and expected economic returns when making decisions about future adoption [7].

Among the evaluated varieties, V1 received the most positive response from participating farmers. Its stable vegetative growth, relatively low pest incidence, effective grain filling (77 fertile grains per panicle), and consistent yield of 6.79 t/ha generated high confidence among farmers regarding the practical feasibility of hybrid rice cultivation [19]. In contrast, although V4 produced the highest average yield (7.00 t/ha), farmers expressed reservations due to its inconsistent field performance and poor grain filling in individual plants. These observations indicate that farmers considered yield stability and production reliability equally as important as maximum productivity [5].

The participatory evaluation process therefore enhanced farmers' analytical capacity for technology adoption. Rather than accepting recommendations solely from researchers, farmers independently identified V1 as the most suitable variety for future cultivation because it offered the best balance between productivity, stability, pest resistance, and production risk. This evidence suggests that the program successfully strengthened farmers' decision-making capacity, a key objective of community empowerment.

Agronomic Performance

The agronomic evaluation supported farmers' comparative assessment of hybrid rice varieties under local agroecological conditions. Table 1 summarizes the major agronomic characteristics observed during the demonstration.

The five varieties demonstrated distinct agronomic characteristics that became important learning materials during field discussions. V1 combined stable flowering, satisfactory grain filling, relatively low empty grain percentage, and high yield, making it the most balanced variety under Sidemen conditions. V2 produced competitive yield but suffered from higher disease incidence, whereas V3 illustrated the consequences of asynchronous planting through severe pest infestation during grain filling [6]. Although V4 achieved the highest average yield, substantial variability among individual plants reduced farmers' confidence in its consistency. The local control variety produced the lowest yield, providing a clear comparison that illustrated the productivity advantage of hybrid rice [4].

Table 1. Agronomic Performance Summary of Five Rice Varieties, Sidemen, Karangasem, Bali (2025)

Parameter	V1	V2	V3	V4	Control
Flowering (DAP)	69	69	58	62	69
Harvest (DAP)	110	110	95	105	105
Plant height (cm)	106	108	118	112	97–102
Fertile seeds/panicle	77	58	18	17	25
Empty grain (%)	30.4	54.4	90.34	90.60	82.78
Yield (t/ha)	6.79	6.47	5.30	7.00	1.69

Note: DAP = Days After Planting.

The harvested grain samples from each evaluated variety. The visual comparison enabled farmers to assess differences in grain filling, grain size, and seed quality, complementing the quantitative agronomic measurements. These visual observations further strengthened farmers' confidence in their ability to interpret varietal performance based on practical field evidence.

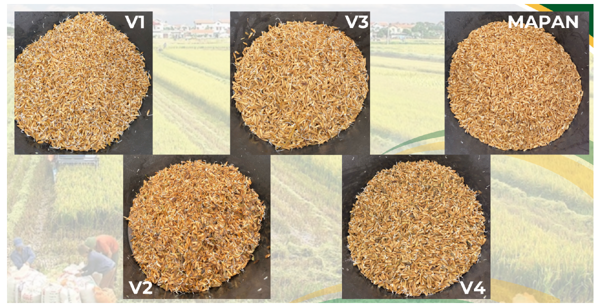

Figure 4. Post-harvest seed samples from all five evaluated varieties (V1, V2, V3, V4, and control)

Rather than serving solely as research data, these agronomic observations functioned as educational tools that enabled farmers to understand the biological and management factors influencing hybrid rice productivity.

Institutional Collaboration

The community service program successfully established collaboration among local farmers, the Subak organization, village government, universities, and the private sector [22], [23]. Each institution contributed complementary expertise that collectively strengthened the demonstration plot's implementation.

Microgene China supplied hybrid rice technology and technical cultivation recommendations. BIM University coordinated community engagement, student participation, field mentoring, and knowledge dissemination. The Faculty of Agriculture, Universitas Brawijaya, provided scientific guidance and technical supervision throughout the cultivation period. Local government representatives and the Pekaseh facilitated community coordination and ensured that demonstration activities remained compatible with local agricultural practices and Subak regulations [6].

This collaborative model created mutual learning among all stakeholders [33], [26]. Farmers gained access to improved technologies and scientific knowledge, while researchers acquired a deeper understanding of local agroecological conditions and farmer decision-making processes [34]. University students developed practical competencies in agricultural extension and community engagement, whereas local farmer youths strengthened their leadership roles as community facilitators [32].

Economic Empowerment Outcomes

Economic empowerment outcomes from the demonstration project are most directly quantified through yield gains and their translation into farm income. The yield advantage of hybrid varieties over the local control (1.69 t/ha) was substantial across all hybrids: V1 achieved 302% higher yield (6.79 t/ha), V2 achieved 283% (6.47 t/ha), V3 achieved 214% (5.30 t/ha), and V4 achieved 314% (7.00 t/ha). At local rice prices of IDR 11,000–17,000/kg, V1's yield advantage translates to additional gross revenue of IDR 22.9–25.5 million per hectare compared to the control, a transformative income gain for smallholder farmers whose average annual household income from rice cultivation is estimated at IDR 15–25 million/ha under traditional variety cultivation. Similar evidence from the Philippines demonstrated that hybrid rice technology substantially improves farm profitability when supported by appropriate agronomic management and farmer training [18].

Social empowerment outcomes, although not formally measured through survey instruments in this study, were observable during the demonstration. Farmers' active engagement in variety evaluation, asking questions, comparing plots, and discussing observations with researchers demonstrated growing agency in agricultural technology decision-making [33], [26]. The participatory format shifted the power dynamic from expert-to-farmer knowledge transfer toward genuine co-evaluation, building the foundation for sustained farmer-led innovation. [11].

The demonstration also strengthened community-level empowerment by providing evidence that locally adapted hybrid technology is feasible under Karangasem's agroecological conditions [13]. This community-level evidence base is critical for collective adoption decisions within the Subak system, where individual farmers' planting decisions are constrained by communal water management schedules and social norms [15], [32].

Conclusion

This community service program demonstrated that a participatory hybrid rice demonstration plot is an effective approach for strengthening the capacity of smallholder farmers while promoting sustainable agricultural innovation. Through experiential learning, continuous mentoring, and active participation in field observations, farmers improved their technical knowledge of hybrid rice cultivation, developed greater confidence in evaluating agricultural technologies, strengthened their decision-making capacity regarding technology adoption, and enhanced collaboration with universities, local government, and private-sector partners. These outcomes indicate that the program achieved its primary objective of empowering farmers rather than merely introducing a new rice variety.

The participatory approach transformed the demonstration plot into a collaborative learning platform where farmers became active contributors to the innovation process. By directly comparing varietal performance under local conditions, discussing field observations with experts, and jointly identifying cultivation challenges, participants developed practical skills applicable to future farming decisions. The involvement of the *Subak* organization, village agricultural authorities, farmer youths, university students, and academic experts further strengthened local institutional capacity and fostered a shared commitment to agricultural innovation within the community.

Although the agronomic evaluation identified V1 as the most promising hybrid rice variety for cultivation in Karangasem due to its stable growth, favorable grain filling, and high yield potential, the program's most significant outcome was enhancing farmers' capacity to make informed, evidence-based decisions about technology adoption. This demonstrates that successful agricultural innovation depends not only on superior technology but also on effective community engagement, knowledge transfer, and institutional collaboration.

The sustainability of this community service program is supported by strong partnerships among Microgene China, Universitas Bali Internasional Muhammadiyah (BIM University), the Faculty of Agriculture at Universitas Brawijaya, the *Subak* organization, village agricultural authorities, and local farmers. These partnerships provide a foundation for continued technical assistance, the expansion of participatory demonstration plots to other farming communities, and the strengthening of local innovation networks that support long-term agricultural development. This model can be replicated in other Subak communities and in similar smallholder rice-farming regions to strengthen sustainable agricultural innovation through university-community partnerships.

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