



Management of Biological-Agent Utilization in Swampland Rice Farming: A Case Study in South Sumatra, Indonesia

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ARTICLE INFO

Keywords: Management, Biological Agents, Agricultural Products.

Received : 27, December

Revised : 29, January

Accepted: 28, February

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ABSTRACT

This study aims to assess the application of biological agents to enhance rice productivity in the lowland swamp areas of Pemulutan District, Ogan Ilir Regency, South Sumatra. Employing a qualitative research methodology with a field research approach, data were gathered through direct observation and informant interviews. The findings indicate a significant increase in the utilization of biological agents for boosting rice yields in the specified region. Specifically, harvested yields from a demonstration plot averaged 8.1 tons per hectare, totaling 24.3 tons across 3 hectares. This represents a 15.1 percent per hectare increase compared to 2022 production figures, which recorded 5.4 tons per hectare (16.2 tons for 3 hectares) using the same rice varieties, Ciherang and IR 42. The improvement in rice production is attributed not only to the application of biological agents but also to the systematic implementation of planning, organization, mobilization, and monitoring by observers, plant pest controllers, extension workers, and farmers

INTRODUCTION

Indonesia possesses approximately 34.12 million hectares of swamp land distributed across Sumatra, Kalimantan, Sulawesi, and Papua, of which around 14.18 million hectares are suitable for agriculture, although only 6.77 million hectares are currently cultivated. Swamp lands are classified into tidal swamps and lowland swamps, with the latter further categorized into shallow, central, deep, and very deep swamps based on water depth and inundation period. Despite their considerable agricultural potential, rice cultivation in these areas is constrained by seasonal flooding, drought, low soil fertility, and plant pest organisms (PPOs). In Pemulutan District, swamp lands are considered sub-optimal, producing 3–5 tons/ha under conventional management but capable of yielding 6–8.3 tons/ha with improved cultivation practices. Excessive reliance on synthetic pesticides for PPO control has led to environmental contamination, farmer health risks, pesticide residues, and pest resistance, highlighting the need for environmentally friendly alternatives. Biological control, as a key component of Integrated Pest Management (IPM), utilizes natural enemies such as predators, parasitoids, pathogens, and antagonistic microorganisms, including *Trichoderma* and *Pseudomonas fluorescens*, to suppress pest populations while maintaining ecosystem balance. The application of biological agents provides a sustainable approach to improving rice productivity, reducing dependence on chemical pesticides, and promoting environmentally responsible swamp-land management.

LITERATURE REVIEW

Management Theory

Management is a systematic process of planning, organizing, directing, and controlling resources to achieve organizational objectives effectively and efficiently. According to George R. Terry, management consists of four core functions: planning, organizing, actuating, and controlling (POAC). Planning involves setting objectives and determining strategies, organizing focuses on structuring resources and assigning responsibilities, actuating emphasizes leadership, communication, and stakeholder participation to implement activities, while controlling monitors performance, evaluates outcomes, and applies corrective actions when necessary. In agricultural development, the POAC framework supports the systematic implementation of innovations through effective planning, institutional coordination, farmer participation, and continuous evaluation to improve program effectiveness.

METHODOLOGY

This study employed a qualitative case study approach to examine the management of biological-agent utilization in swampland rice farming in South Sumatra, Indonesia, focusing on *Beauveria bassiana*, Plant Growth-Promoting Rhizobacteria (PGPR), and *Paenibacillus* as biological agents for pest control, plant growth promotion, and sustainable agriculture. Field data were collected through participant observation, semi-structured interviews with farmers, agricultural extension officers, and relevant stakeholders, as well as documentation analysis, while data validity was ensured through source triangulation, method triangulation, and member checking. Data were analyzed descriptively using George R. Terry's management function theory—planning, organizing, actuating, and controlling—to evaluate the planning, implementation, coordination, and supervision of biological-agent utilization, enabling the identification of effective management practices, challenges, and opportunities for improving the adoption of biological agents in sustainable swampland rice cultivation.

RESEARCH RESULT

The research result on the Use of Biological Agents to Increase Rice Yields in Pemulutan District, Ogan Ilir Regency will be described based on the management aspects used in rice cultivation on lowland swamp land. This dimension provides guidance on procedures for suboptimal land management to be productive by referring to the planning, organizing, mobilizing and monitoring processes. This study examines the application of biological agents for enhancing rice yields in the Pemulutan District of Ogan Ilir Regency, focusing on the management strategies employed in cultivating rice on suboptimal lowland swamp terrain. This perspective offers a framework for transforming such lands into productive agricultural areas through systematic approaches encompassing planning, organization, resource mobilization, and ongoing monitoring.

A. Planning

The development of the operational plan commences with the establishment of a dedicated team, the creation of comprehensive Terms of Reference for specific activities, the meticulous preparation of cost estimates within the Expenditure Budget Plan, and the execution of relevant surveys for investigation and design, supplemented by diligent monitoring and reporting. The finalized work plan serves as the foundational document for all parties involved in the implementation of the rice yield enhancement program utilizing biological agents in the Pemulutan District. Farmers adhere to the directives provided by the implementing agency, in this instance, the Department of Agriculture, Food Crops and Horticulture, which are all aligned with the established work plan. This structured planning process ensures both farmers and implementers are guided effectively, facilitating the directed execution of the biological agent utilization program and the optimal achievement of its intended outcomes. The subsequent data presents a graphical representation of the distribution of lowland swamp land and other land types within the Pemulutan District.

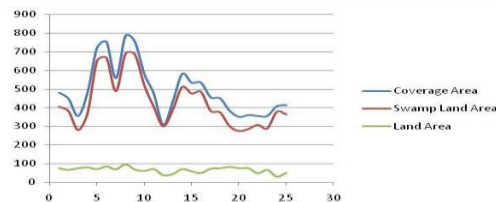


Figure 1. The area of lowland and terrestrial swamps in Pemulutan District

The agricultural swamplands in Pemulutan District encompass an area of approximately 6,289 hectares of shallow swamps, 3,303 hectares of medium swamps, and 1,058 hectares of deep swamps. The substantial extent of these agricultural lands, coupled with budgetary constraints, presents challenges for farmers in acquiring biological agents for their rice fields. Furthermore, the supporting infrastructure for the Biological Agent Utilization program is not yet fully developed. Available funding is allocated to a select few areas for the implementation of this program as per the established plans. The program's funding is derived from both the State Revenue and Expenditure Budget and the Regional Revenue and Expenditure Budget.

Human resources for the program are also not optimally available. Several impediments hinder the implementation of the Biological Agent Utilization program, notably the limited number of Plant Pest Organism Control Officers and their supporting staff within Pemulutan District, Ogan Ilir Regency. The designated Plant Pest Organism Control Officers are tasked with providing assistance across 25 villages

regarding the use of biological agents. Considering the 5,632 members across farmer groups in Pemulutan District, an estimated three to five accompanying officers are required per group.

The availability of facilities and infrastructure is also suboptimal. This limitation stems from the scarcity of essential equipment, including a small number of excavators, water pumps, and drilled wells. The quantity of these tools often proves insufficient for the vast areas of swamp or wetland cultivated by the farmer groups. It is important to note that managing swamp land differs significantly from managing conventional rice fields.

B. Organization

Task allocation for the Biological Agent Utilization Program follows established organizational duties and functions, with the Regional Technical Implementation Unit of the Department of Agriculture, Food Crops, and Horticulture serving as the main implementing agency. Responsibilities are distributed among program coordinators, Plant Pest Organism officers, Extension Officers, and farmer groups, covering program coordination, technical guidance, supervision, monitoring, activity planning, and identification of participating farmers and locations. Program implementation is supported through coordination among provincial and regency agricultural offices, the Pemulutan District Extension Coordinator, village officials, and farmer groups, with collaboration facilitated through coordination meetings, briefings, and implementation reporting to ensure effective biological agent utilization for improving rice yields.

C. Mobilization

Socialization of the Biological Agent Utilization Program has involved provincial and regency agricultural agencies, sub-district and village officials, as well as farmers through training and direct outreach to promote environmentally friendly pest management and improve rice productivity while preserving swamp ecosystems. However, program implementation in Pemulutan District remains suboptimal due to limited farmer awareness of the benefits of biological agents and organic pest control, compounded by a short-term profit-oriented mindset and limited participation in collective activities. Despite these challenges, the program has successfully encouraged stakeholder collaboration and community participation, providing farmers with free biological agents, transportation support, agricultural knowledge, and practical experience that contribute to improving rice production.



Figure 2. **A.** The process of planting rice plants on lowland swamp land, **B.** Spraying using biological agents, **C.** Rice plants that have been treated/application of biological agents, **D.** Harvesting process using machines, to see an increase in agricultural yields carried out by tiling.

D. Oversight and Monitoring

Oversight by pertinent authorities has been diligently exercised throughout the program. Within the framework of the Biological Agent Utilization initiative,

supervision is conducted by both internal organizational units and external entities. Internal oversight is systematically implemented according to established positions and levels of authority. The internal supervision for this program aligns with the existing organizational hierarchy within the Department of Agriculture, Food Crops, and Horticulture. Key personnel involved in this oversight include the Head of Service, the Head of the Regional Technical Implementation Unit, departmental employees, plant pest control officers, and agricultural extension workers. Supervision methods encompass direct observation and formal meetings. In addition to internal oversight, external organizations such as Non-Governmental Organizations, media outlets, the general public, and farmers themselves contribute to monitoring the services rendered, offering critical feedback and suggestions.

Effective management is predicated on meticulous planning and robust organization to mitigate potential implementation challenges. Subsequently, the mobilization of human resources pertinent to the program or activity is crucial during the execution phase. This is followed by an assessment phase where ongoing implementation is monitored for any deviations from the plan, enabling the evaluation of overall program success. Implementation itself constitutes a set of diverse activities, categorized into cohesive operational units within an administrative structure.

The program for Utilizing Biological Agents to Increase Rice Yields in Pemulutan District, Ogan Ilir Regency, focuses on the management of lowland swamp ecosystems through the strategic application of biological agents. This initiative aims to enhance the active role of farmers and their groups, fostering the development of farmer collectives into thriving agricultural enterprises.

The distribution of farmer groups and their respective memberships across the 25 villages within Pemulutan District, Ogan Ilir Regency, is detailed in Table 2:

Table 2. Number of farmer groups and members in Pemulutan District

Num ber	Village Name	Number of Farmer Groups	Number of Members
01.	Pemulutan Ulu	21	500
02.	Pemulutan Ilir	16	370
03.	Pegayut	8	207
04.	Sungai Rasan	8	206
05.	Pelabuhan Dalam	13	425
06.	Teluk Kecapi	16	398
07.	Muara Dua	9	253
08.	Aurstanding	14	312
09.	Pahu	15	387
10.	Sukarami	10	227
11.	Ibul Besar I	12	213
12.	Ibul Besar II	5	150
13.	Ibul Besar III	6	145
14.	Mekar Jaya	6	173
15.	Lebung Jangkar	4	119
16.	Kedukan Bujang	9	248
17.	Rawa Jaya	4	120
18.	Babatan Saudagar	5	145
19.	Tanjung Pasir	4	115
20.	Harapan	5	134
21.	Pipa Putih	5	147
22.	Sungai Buaya	5	149
23.	Muara Baru	8	122
24.	Simpang Pelabuhan Dalam	7	208
25.	Sembadak	6	159
	Jumlah Total	221	5.632

Source: Pemulutan District Agricultural Extension Center (BPP), 2023

This program's objective is to enhance rice yields in the Pemulutan District, Ogan Ilir Regency, through the strategic application of biological agents. This initiative focuses on optimizing lowland swamp land and is integrated with strategies to augment farmers' living standards by employing pest control substances. The consistent utilization of biological agents not only contributes to increased agricultural output but also plays a crucial role in preserving natural equilibrium and fostering ecosystem harmony, particularly within the agricultural landscapes of lowland swamps.

Consequently, elevated production levels are anticipated to directly correlate with improved farmer prosperity and the promotion of environmental sustainability in these specific agricultural regions.

The optimization of agricultural outcomes via the employment of biological agents represents a concerted effort to maximize the potential of agricultural land resources, transforming them into productive areas for food crops, horticulture, and plantations. This is achieved through dedicated efforts focused on enhancing and increasing the land's carrying capacity, thereby rendering it more conducive to productive farming practices.

Research findings unequivocally demonstrate that the implementation of biological agents for augmenting rice production in the Pemulutan District, Ogan Ilir Regency, has provided substantial benefits to farmers. In 2023, a specialized application of biological agents was conducted on demonstration plots in Sembadak Village, Pemulutan District, Ogan Ilir Regency. At harvest, the demonstration plots yielded an average of 8.1 tons per hectare, totaling 24.3 tons across 3 hectares. This represents a notable increase of 15.1 percent per hectare compared to the production figures from 2022, when the same rice varieties, Ciherang and IR 42, yielded 5.4 tons per hectare, or 16.2 tons across 3 hectares.

The adoption of biological agents for managing plant pest organisms constitutes a judicious approach to boosting agricultural yields. Specifically, the utilization of the biological agent *Beauveria Bassiana*, a Plant Growth Promoting Rhizobacteria (PGPR), offers an environmentally sound method for controlling plant pests, presenting a preferable alternative to conventional pesticides and chemical treatments. It is imperative for farmers to embrace the use of naturally derived materials to cultivate a balanced relationship with their environment. Furthermore, relying on natural resources helps mitigate environmental degradation, thereby ensuring the continuity of natural resources for subsequent generations.

DISCUSSION

The utilization of biological agents has emerged as an increasingly important strategy for promoting sustainable rice production, particularly in environmentally sensitive ecosystems such as swamplands. As concerns over excessive dependence on chemical fertilizers and pesticides continue to grow, biological agents offer a promising alternative by enhancing soil fertility, improving plant health, and supporting ecological balance. In Indonesia, swampland rice farming plays a strategic role in national food security, especially in regions such as South Sumatra, where extensive swamp ecosystems provide significant agricultural potential.

However, the successful implementation of biological-agent technology depends not only on its technical effectiveness but also on the management processes that govern its planning, distribution, adoption, monitoring, and evaluation. Effective management is essential to ensure that biological agents are utilized appropriately, efficiently, and sustainably by farmers operating under diverse environmental and socio-economic conditions. Furthermore, the unique characteristics of swampland agriculture—including fluctuating water levels, soil acidity, and limited infrastructure—require adaptive management approaches tailored to local contexts.

This discussion examines the management of biological-agent utilization in swampland rice farming through a case study conducted in South Sumatra, Indonesia. It explores how management functions such as planning, organizing, implementation, and supervision influence the adoption and effectiveness of biological agents in rice cultivation. The analysis also highlights the roles of stakeholders, including government

agencies, agricultural extension workers, researchers, and farmer groups, in facilitating technology dissemination and ensuring sustainable agricultural development. Through this examination, the study seeks to provide insights into best management practices that can enhance rice productivity while preserving the eco-logical integrity of swamp-land ecosystems.

Planning of Biological-Agent Utilization Management

The findings indicate that the management of biological-agent utilization in swamp-land rice farming in Pemulutan District has been initiated through a structured planning process. This process includes the establishment of implementation teams, preparation of Terms of Reference (TOR), budgeting through the Expenditure Budget Plan, field surveys, monitoring activities, and reporting mechanisms. These planning activities demonstrate the application of the management principle proposed by George R. Terry, whereby planning serves as the foundation for determining objectives and outlining the procedures required to achieve them.

The operational work plan functions as a strategic guideline for all stakeholders involved in the program. Farmers, extension workers, and implementing agencies perform their respective roles based on predetermined plans. This finding supports Terry's assertion that effective planning reduces uncertainty and provides a clear direction for organizational activities.

However, the planning process faces several constraints. Pemulutan District possesses extensive agricultural swamp-lands consisting of 6,289 hectares of shallow swamps, 3,303 hectares of medium swamps, and 1,058 hectares of deep swamps. The vast agricultural area requires substantial financial resources to support the procurement and distribution of biological agents. Limited funding from both the State Revenue and Expenditure Budget (APBN) and the Regional Revenue and Expenditure Budget (APBD) restricts the program's coverage, resulting in selective implementation across designated locations. Consequently, the planning objectives have not yet fully accommodated the actual needs of farmers throughout the district.

These findings are consistent with previous studies on agricultural innovation management, which emphasize that resource availability significantly influences the effectiveness of agricultural development planning. In the context of biological-agent utilization, comprehensive planning must be accompanied by adequate financial support to ensure broader adoption among farmers.

Organizing of Biological-Agent Utilization Management

The organizing function has been implemented through a clear division of labor and responsibilities among stakeholders. The Department of Agriculture, Food Crops and Horticulture, through its Regional Technical Implementation Unit, serves as the lead institution responsible for coordinating activities, preparing technical guidelines, assigning personnel, conducting supervision, and preparing reports. Plant Pest Organism Control Officers (POCOs) oversee the technical aspects of biological-agent utilization, while farmer groups act as direct implementers at the field level.

The organizational structure reflects an attempt to establish coordination among multiple stakeholders, including provincial and regency agricultural offices, extension coordinators, village governments, extension officers, and farmer groups. Such coordination is essential because the success of biological-agent utilization depends on collaborative efforts among institutional actors.

Despite the existence of a formal organizational structure, the study reveals significant human resource limitations. The number of Plant Pest Organism Control Officers is insufficient to serve the extensive agricultural areas and large farming

population. One officer is often required to assist multiple villages simultaneously, creating challenges in providing intensive guidance and monitoring. Given that Pemulutan District has approximately 5,632 farmer-group members, the current staffing level remains inadequate for effective program implementation.

Furthermore, infrastructural limitations hinder organizational effectiveness. The availability of critical equipment such as excavators, water pumps, and drilled wells remains insufficient compared to the extensive swampland area. Since swamp agriculture requires specific land and water management techniques, inadequate facilities directly affect farmers' capacity to apply biological agents effectively. This finding suggests that organizational success is influenced not only by human resources but also by the availability of supporting infrastructure.

Actuating of Biological-Agent Utilization Management

The actuating function emphasizes stakeholder participation through socialization and training involving government agencies, village officials, farmer groups, and local communities to promote the use of biological agents such as **Beauveria bassiana**, PGPR, and **Paenibacillus** as environmentally friendly alternatives for sustainable rice production. Although these activities have increased awareness, program implementation remains suboptimal due to limited farmer knowledge, continued reliance on conventional chemical inputs, and a short-term economic perspective that discourages the adoption of long-term innovations without direct incentives. Nevertheless, farmer participation has been relatively positive, supported by free biological-agent materials, transportation assistance, technical training, and practical experience, demonstrating the importance of capacity-building in encouraging agricultural innovation.

Controlling of Biological-Agent Utilization Management

The controlling function has been implemented through internal supervision by agricultural agencies and external monitoring involving local communities, farmers, NGOs, and the media to ensure transparency, accountability, and continuous program evaluation. Although monitoring follows established procedures, its effectiveness is limited by inadequate human resources, logistical constraints, and the extensive coverage of swamp agricultural areas, reducing supervision frequency. From a management perspective, monitoring helps identify implementation gaps and supports corrective actions, highlighting the need for digital monitoring systems, additional personnel, and community-based supervision. Overall, the management of biological-agent utilization in Pemulutan District reflects George R. Terry's POAC framework, but its effectiveness is constrained by limited funding, infrastructure, human resources, and varying farmer awareness. Strengthening institutional coordination, farmer capacity building, budget support, and infrastructure is essential to improve program sustainability while promoting environmentally friendly pest control, reducing reliance on synthetic pesticides, increasing rice productivity, and enhancing the long-term sustainability of South Sumatra's lowland swamp ecosystem.

CONCLUSIONS AND RECOMMENDATIONS

The research findings concerning the application of biological agents to enhance rice yields in Pemulutan District, Ogan Ilir Regency, South Sumatra Province, are presented as follows. At harvest time, the demonstration plot experienced a 15.1 percent increase in yield compared to the preceding year, which did not involve any special interventions. This enhancement resulted in an additional 24.3 tons of produce across three hectares, whereas the previous year's yield for the same land and demonstration plot was only 16.2 tons.

This established plan serves as a guide for program implementers involved in the Utilization of Biological Agents to Increase Rice Yields within Pemulutan District. Farmers have adhered to directives provided by the implementing body, specifically the Department of Agriculture, Food Crops, and Horticulture, in accordance with the operational plan. From an organizational perspective, task allocation has been managed in alignment with defined roles and responsibilities. The distribution of duties among the human resources involved is executed under the guidance of the established organizational framework. The Regional Technical Implementation Unit of the Center for Food Crop Protection and Horticulture holds the primary responsibility for orchestrating this initiative. Its duties include coordinating with pertinent stakeholders, formulating technical guide-lines, deploying teams, providing oversight, compiling progress reports, and conducting supervision and monitoring activities. The designated Plant Destruction Organisms officer on duty serves as the controller for the Biological Agent Utilization program.

The planned socialization activities have been successfully executed, engaging all involved parties. This outreach extended to the South Sumatra Province Food Crops and Horticulture Agriculture Service, the Head of the Ogan Ilir Regency Food Security and Agriculture Service, district officials, village authorities, and the broader community of farmers. Regarding supervision, it has been determined that oversight from relevant authorities has been consistently applied. Supervision for the Biological Agent Utilization program encompasses both internal organizational monitoring and external oversight. Internal supervision is implemented systematically, progressing according to designated positions and established authorities within the Department of Agriculture, Food Crops, and Horticulture of South Sumatra Province. The internal oversight mechanisms for this program operate in a phased manner, consistent with the existing organizational structure.

ADVANCED RESEARCH

This study is limited to a qualitative case study conducted in Pemulutan District, Ogan Ilir Regency, South Sumatra, so the findings cannot be generalized to other swampland agricultural areas with different characteristics. In addition, the study focuses on management aspects of biological-agent utilization without quantitatively measuring the influence of other factors, such as farmers' socio-economic conditions, climate variability, and agronomic practices, on rice productivity. Therefore, future research is recommended to employ mixed-methods or longitudinal approaches across multiple regions to provide more comprehensive and generalizable evidence on the effectiveness of biological-agent management in sustainable rice farming.

ACKNOWLEDGMENT

The author would like to express his gratitude to all those involved throughout the course of this research.

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