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Empowering Seaweed Farmers through the Anakonda Rote Method with Tissue Culture Seeds

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Abstract

Holulai Village in Rote Ndao Regency is a coastal village with significant potential for seaweed cultivation. In 2024, the village produced 2,050 tons of dry seaweed, which serves as the economic backbone for many households. However, farmers face three major challenges: limited access to superior seedlings due to long-term reliance on aged cuttings, continued use of conventional off-bottom cultivation methods, and insufficient hygienic processing of seaweed-based products. To address these constraints, the *Pemberdayaan Desa Binaan* (PDB) program was implemented in collaboration with two farmer groups involving 40 active members. The program introduced the Anakonda Rote Net Method, combined with tissue–culture–derived seedlings, to enhance production performance and resilience. The results showed a substantial increase in seaweed biomass, with harvest weights rising from approximately 150–350 g per cultivation unit under conventional methods to 150–710 g using the Anakonda Rote Method, representing an increase of up to 100%. In addition, the program enabled farmers to diversify seaweed-based products into four hygienically processed variants (sticks, brownies, biscuits, and syrup), which increased product value and household income opportunities. Preliminary economic observations indicated reduced production losses due to pest attacks and improved post-harvest quality, which contributed to more stable incomes for participating households. Continuous mentoring and periodic monitoring are maintained to ensure the sustainability of seaweed cultivation and value-added processing in Holulai Village.

Keywords Empowerment; Holulai; Rote Anaconda; Seaweed; Tissue Culture

1. INTRODUCTION

Holulai Village is one of the coastal villages in Rote Ndao Regency, East Nusa Tenggara Province (NTT) (Badan Pusat Statistik Provinsi Nusa Tenggara Timur, 2022). Indonesia with considerable potential for seaweed cultivation. Most coastal communities in this village rely on seaweed farming as their primary source of livelihood. Since seaweed cultivation was introduced in Rote Ndao in 1999, there has been a shift in the main source of income from palm sap tapping and capture fisheries to seaweed farming as the primary occupation, while fishing activities have become a secondary source of income (Kumalasari, 2022).

At the regional level, seaweed is a strategic commodity that makes a significant contribution to the local economy. According to data from the Central Statistics Agency (BPS) in 2024, seaweed production in Rote Ndao Regency reached 88,028 tons of dried seaweed, ranking second among 22 regencies/cities in East Nusa Tenggara Province. In the same year, seaweed production in Holulai Village amounted to 2,050 tons of dried seaweed. This high level of production indicates that seaweed plays a crucial role in sustaining the economic resilience of farming households. A survey conducted by the research team in 2025 recorded 310 seaweed farmers organized into 14 farming groups established by the village government in collaboration with the Rote Ndao Fisheries Office. However, four of these groups were inactive. The strong commitment of the Holulai Village Government is reflected in the Village Medium-Term Development Plan (RPJMDes) for 2021–2027, which prioritizes seaweed development as a key village development program (Pemerintah Desa Holulai, 2021).

Despite its high production potential, seaweed cultivation in Holulai Village faces several fundamental challenges. The primary issue is the limited availability of high-quality and sustainable seedlings (Rahayu & Trisnawati, 2022). For many years, farmers have relied on vegetative cuttings from previous cultivation cycles without clear information regarding the physiological age of the seedlings. Although the seedlings may appear young visually, biologically, their cells have aged, resulting in decreased productivity and increased vulnerability to disease. This condition is a major trigger for the occurrence of *ice-ice* disease, which is influenced by the repeated use of aged cuttings, pathogenic bacterial infections, extreme seasonal changes—particularly during the second transitional season (west monsoon), primary infections by herbivorous biota, and epiphytic algae attachment

In addition to seed quality issues, the cultivation methods applied by seaweed farmers in Holulai Village remain highly conventional. The dominant practice is the off-bottom method, which is implemented without technological innovation, particularly in relation to the sustainable provision of high-quality seedlings. Furthermore, efforts to diversify seaweed-based products and improve post-harvest processing remain limited, both in terms of product variety and compliance with food sanitation and hygiene standards, thereby restricting the added value of seaweed products.

Previous studies have recommended the use of tissue–culture–derived seedlings to enhance seaweed quality, productivity, and disease resistance. Likewise, innovative cultivation techniques such as the Anakonda Rote Method have been shown to suppress pest and disease attacks while enhancing seaweed growth. However, the integration of the Anakonda Rote Method with tissue culture seedlings has been rarely implemented at the local farming community level, particularly in Holulai Village. This limited adoption highlights a critical research and implementation gap between scientific findings and their practical application in community-based seaweed farming systems in coastal areas of Rote Ndao.

Therefore, this Community Service Program under the Empowerment of Assisted Villages (*Pemberdayaan Desa Binaan*/PDB) scheme aims to apply the research outcomes of the implementation team by introducing the Anakonda Rote Method combined with tissue culture seedlings for pest and disease management in seaweed cultivation, as well as to enhance community capacity in processing seaweed-based food products that meet sanitation and hygiene standards.

2. METHODS

This community service program was conducted as part of the *Empowerment of Assisted Villages* (*Pemberdayaan Desa Binaan*, PDB) scheme and implemented as a multi-year program over three years in Holulai Village, Rote Ndao Regency. The present study reports activities carried out during the second year of implementation (2025). The target partners were seaweed farmers organized into two officially recognized groups, each consisting of 20 members. These groups were legalized through the Decree of the Head of Holulai Village in 2023, namely Decree No. 140/050/DH/III/2023 for the Litianak Group and Decree No. 140/051/DH/III/2023 for the Holotula Group (Pemerintah Desa Holulai, 2023). The participants were predominantly women (35 members), with five male members involved in supporting activities.

The program was implemented using a participatory approach, emphasizing active community involvement throughout all stages of the activities. In this approach, the implementation team acted primarily as facilitators, guiding and assisting the community in applying research-based innovations rather than acting as sole executors. The overall program consisted of several sequential stages, conducted over an approximately eight-month period.

The initial stage involved team preparation and coordination, which lasted for one month and included internal planning, field reconnaissance, and coordination with village authorities and farmer groups. This was followed by a socialization phase conducted over two weeks, during which program objectives, activity plans, and expected outcomes were introduced to all participants. Institutional strengthening of farmer groups was conducted over one month through focused group discussions and mentoring sessions aimed at enhancing group management, role distribution, and collective decision-making.

Capacity-building activities were implemented through counseling and technical training sessions conducted over two weeks. These sessions focused on innovations in seaweed cultivation, disease and pest management, and post-harvest handling. Subsequently, a demonstration plot (*demplot*) was established for seaweed cultivation using the Anakonda Rote Method, combined with tissue–culture–derived seedlings. The demplot phase was conducted for one full cultivation cycle of 45 days, representing the standard harvesting period for *Kappaphycus* spp. in the study area.

Seed preparation involved the use of new, disease-resistant cultivars produced through tissue culture techniques. Before planting, site preparation was conducted over a two-week period, which included water quality analysis to assess parameters such as temperature, salinity, water clarity, and current velocity, ensuring the suitability of the site for seaweed growth. Planting activities were followed by routine maintenance and care conducted every three to four days throughout the cultivation cycle. Maintenance activities included cleaning epiphytic organisms, checking rope tension and structure stability, and replacing damaged or detached thalli.

Monitoring and evaluation of seaweed growth were conducted systematically throughout the demplot period. Growth performance was assessed using indicators such as daily growth rate (DGR), thallus length increase, biomass weight gain, and visual health conditions of the seaweed. Measurements were taken at the beginning of cultivation and subsequently at 15-day intervals until harvest. Observations of pest and disease incidence, particularly *ice-ice* symptoms and herbivore damage, were also recorded descriptively. The effectiveness of the Anakonda Rote Method with tissue culture seedlings was evaluated by comparing growth performance and survival rates with those of conventional off-bottom cultivation practices previously applied by farmers.

Post-harvest handling training was conducted over a period of one week, focusing on proper drying, storage, and hygiene practices to maintain product quality.

Further activities included assistance in obtaining household food production permits (PIRT), food safety feasibility testing at the National Agency of Drug and Food Control (BPOM), and halal certification from the Indonesian Ulema Council (MUI) of East Nusa Tenggara Province. These activities aimed to strengthen the legality of products and enhance the market value of seaweed-based processed products produced by the community.

The application of the Anakonda Rote Method combined with tissue culture seedlings offered several advantages, including protection of seaweed seedlings from herbivorous pests such as rabbitfish (*Siganus guttatus*), sea turtles, and epiphytic organisms. In addition, the method utilized minimal plastic materials for construction and reduced biomass loss caused by strong currents and wave movement, thereby supporting more sustainable and resilient seaweed cultivation practices.

3. FINDINGS AND DISCUSSION

3.1. Assisted Village Empowerment Activities to be Carried Out in 2025

The *Pemberdayaan Desa Binaan* (PDB) activities implemented in 2025 comprised a total of twelve core activities involving two seaweed farmer groups, each consisting of 20 members. The program focused on seaweed pest and disease management, the establishment and management of superior seed nurseries, the development of seaweed cultivation through the application of the Anakonda Rote Method, and the strengthening of post-harvest handling and value-added processing of seaweed products (Bessie et al., 2025). The activities began with training sessions and the establishment of demonstration plots for seaweed cultivation using the Anakonda Rote Method, accompanied by the development of technical modules on seaweed farming and the management of superior seed nurseries as practical guidelines for farmers. In addition, training and mentoring were provided for post-harvest processing and product diversification with strong market potential, resulting in several seaweed-based food products, including sticks, syrup, biscuits, and brownies. To ensure food safety and product quality, the partners also received training and a practical module on Hazard Analysis Critical Control Point (HACCP) as a framework for proper handling and processing of fishery products. The processed products were subsequently analyzed for composition and safety at the National Agency of Drug and Food Control (BPOM) as part of the process to obtain distribution permits, followed by assistance in securing Home Industry Food Production (PIRT) licenses from the Rote Ndao District Health Office and halal certification from the Indonesian Ulema Council (MUI) of East Nusa Tenggara Province. Continuous mentoring in seaweed cultivation, utilizing the Anakonda Rote Method, was conducted throughout the program to ensure the effective and sustainable implementation of the project.

In addition to technical cultivation and processing activities, the program included planned and direct guidance and extension services for partner groups on seaweed farming using the Anakonda Rote Method, routine maintenance and pest and disease control, post-harvest handling, business management, and product marketing. These mentoring activities were conducted in collaboration with fisheries extension officers from the Marine and Fisheries Office of Rote Ndao Regency, specifically those assigned to Loaholu District. They were further supported by the involvement of university students through the *Merdeka Belajar Kampus Merdeka* (MBKM) internship program and undergraduate thesis research. To improve post-harvest quality, the program also facilitated the construction of drying racks or raised drying tables, replacing the previous practice of drying seaweed directly on sand or soil.

The 2025 PDB program also aimed to enhance partners' capacity to select suitable farming sites based on local environmental conditions, apply appropriate cultivation methods, and select high-quality seaweed seedlings to support increased production in terms of both quantity and quality. Accordingly, water quality analyses were conducted across the coastal waters of Holulai Village to map areas that were highly suitable for seaweed cultivation and seed nursery development. Furthermore, training was provided on seed selection in nurseries at 25–30 days after planting to ensure that newly planted seedlings originated from selected superior varieties. This selection process was conducted in a structured and sustainable manner, involving at least three stages of proper screening.

To support increased production capacity, the program also strengthened partners' facilities and infrastructure by providing adequate production equipment. The equipment supplied included vacuum packaging machines, sealing machines, blenders, stick-forming machines, mixers, cooking stoves, and other processing tools, as well as the rehabilitation of production houses. Additional support included the provision of drying racks, the development of more attractive product packaging designs, and other supporting equipment. The improvement of facilities and infrastructure is expected to enhance both the quantity and quality of production while increasing the competitiveness of seaweed-based processed products produced by the partner groups.

(a) Seaweed seedling binding (b) Seaweed Planting with the Rote Anaconda Method

(c) Seaweed food processing training and demonstration

(d) Training products (sticks, brownies, biscuits, and seaweed blue) (e) Submission of test samples at BPOM as a condition for PIRT management

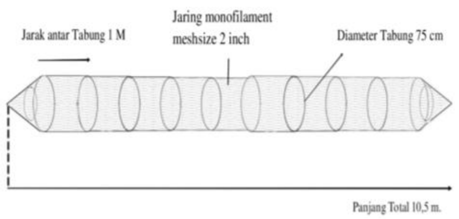
Figure 1. 2025 GDP Scheme Service Activities in Holulai Village

3.2. The Use of the Anaconda Rote Method for Production Enhancement

Anakonda Rote is a cultivation net that has a main tubular construction. This mesh is made of monofilament material with a *mesh size* of 2 inches. Its total length reaches 10.5 meters, which consists of 10 meters for the main body and 0.25 meters for each of the skeletons at both ends. The internal structure is divided into several cylindrical chambers, each 100 cm apart. These spaces are bounded by 10 main rings

(rings) with a diameter of 75 cm made of HDPE (*High Density Polyethylene*) pipes. These rings also have a dual function as buoys (Bessie et al., 2024c). This model is a modification of the previous version, featuring rings on the front and back, which serves as the basis for the naming of the "Anakonda Rote" by the dedicated team and partners.

At both ends of the mesh (front and back mouths), a 5 cm modified ring is installed and fastened using a 2 mm PE (*Polyethylene*) rope. Each room is equipped with a 30 cm-long opening to facilitate the process of entering seedlings and harvesting. The entire frame of the Anakonda Rote is lined with a 2-inch mesh to ensure optimal seawater circulation and aeration, while protecting the seaweed cultivated in it (see Image 1).



(a) Sketsa Anakonda Rote

(b) Anakonda Rote di Lokasi Budidaya

Figure 2. Anaconda Rote Sighting

The Anakonda Rote method excels in seaweed cultivation thanks to two important aspects: maintaining the sustainability of the seedlings and being environmentally friendly. In terms of production, this method is specifically designed to protect seaweed from marine herbivores, such as fish and turtles, that are the main cause of crop failure. This approach has proven effective in overcoming the attack of the beronang fish pest (Siganus guttatus), especially in the waters of Holulai Village (North Rote Waters), which serves as the migration route for the fish during the transition season (January-February and June-August). From an environmental perspective, the construction of the net minimizes the use of plastic and is designed not to pollute the ocean with garbage. This innovation is an effective solution for mitigating plastic waste, considering that the level of plastic pollution from conventional seaweed cultivation is already very concerning.

The development of the Anakonda Rote method is not only limited to innovation, but also involves a mentoring and training process for the local community. This is a real example of the transfer of knowledge and technology from researchers to cultivators. Through training and mentoring activities, the community gains new skills in cultivation that are more efficient and environmentally friendly. This process empowers them to become agents of change in their own communities.

This method has a direct impact on the growth of seaweed compared to conventional methods used by the community (Figure 3). The environmentally friendly aspect of this method plays a crucial role in ensuring the long-term sustainability of the production process. By minimizing plastic waste and reducing marine pollution, aquatic ecosystems remain healthy and resilient. A healthy marine environment is a prerequisite for optimal seaweed growth. Without clean and maintained waters, seaweed production will be difficult to maintain in the long term. Therefore, environmental sustainability is crucial for maintaining stability and enhancing production.

Based on growth analysis from the first to the seventh week, the Anaconda Rote method showed a significant increase in seaweed weight, with a range of 150–710 grams. This figure far exceeds the conventional method (Basic Release), which yields only 110–350 grams (Figure 3). This result demonstrates that the Anakonda Rote method can significantly increase seaweed production compared to the Basic Release method, thereby directly impacting the income of cultivators. Previously, the average production for one cultivation unit (one 20-meter-long rope with a planting distance of 20 cm) was only around 150-350 grams per harvest period (seven weeks); now it has increased to 710 grams per harvest period. This improvement was supported by the application of the Anakonda Rote method and the introduction of tissue culture seeds.

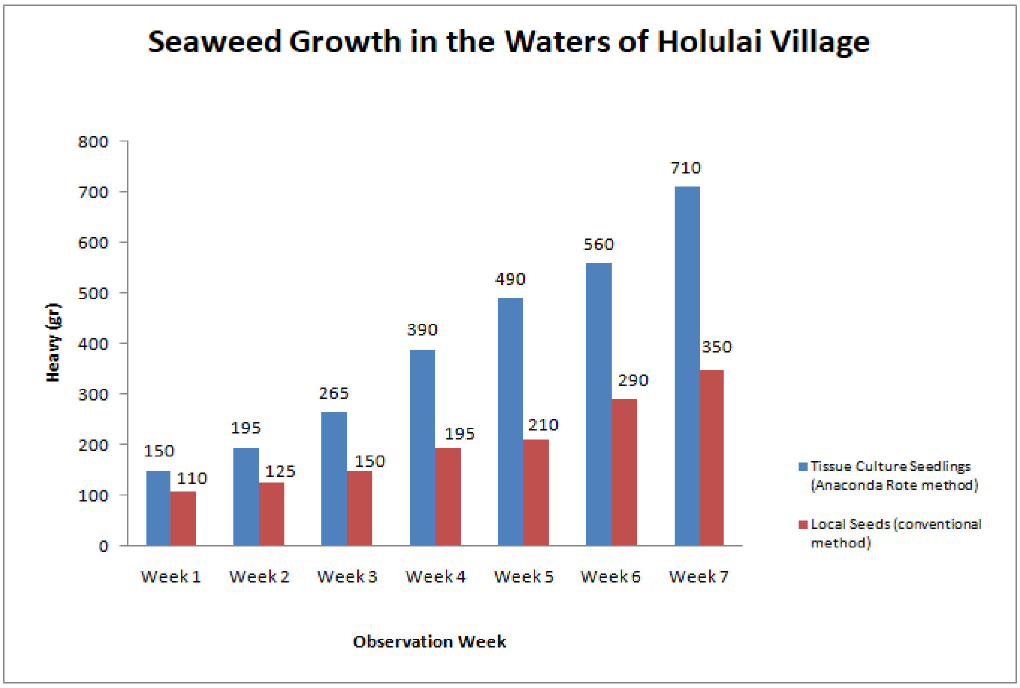


Figure 3. Seaweed Growth in the Waters of Holulai Village

3.3 Active Participation of the Community in the Application of Technology and Innovation

The implementation of the main innovations in the PDB scheme service program, namely: seaweed cultivation using the Anakonda Rote method using tissue culture seeds, the *Hazard Analysis Critical Control Point* (HACCP) Module, and the development of four variants of processed products (sticks, brownies, biscuits, and seaweed syrup), shows the active participation of the community. The community is directly involved as a partner, participating in every stage of the activity, from providing a location for demonstrations and lectures to preparing land for a pilot site. This commitment is evident in the presence of 40 group members (outside of representatives from the Holulai Village PKK and GMIT Women, led by Imanuel Holotula), who are always open to self-development and are ready to be accompanied by a team from Artha Wacana Christian University's service.

The success of this program is inseparable from the active role of the community that voluntarily participates. This participation is a tangible manifestation of community empowerment, where they are not only objects but also subjects that contribute to determining the program's success. Their full involvement accelerates the transfer of knowledge and technology.

This program also involves the village government and fisheries extension workers as the parties closest to the cultivators. This support is crucial to ensure the program's sustainability, as monitoring, motivation, and mentoring can continue to be carried out periodically after the program is completed. Thus, this innovation not only increases production but also fosters long-term community independence and capacity.

The findings of this study align closely with the principles of community empowerment and appropriate technology theory, which emphasize participatory processes, local relevance, and sustainability as key determinants of successful development interventions. The Anakonda Rote Method, combined with tissue culture–derived seedlings, represents an appropriate technology because it is technically effective, environmentally friendly, affordable, and adaptable to the local socio-ecological conditions of Holulai Village. The active involvement of farmers throughout the training, demonstration plots, monitoring, and post-harvest processing stages reflects the empowerment framework proposed by Chambers and other community development scholars, where communities function as active agents rather than passive recipients. Similar outcomes have been reported in community-based seaweed cultivation programs in other coastal regions of Indonesia and

Southeast Asia, where the adoption of participatory technology and improved seed quality have significantly enhanced productivity, resilience to disease, and household income. The integration of production technology with institutional strengthening, food safety certification, and value-added processing further supports the notion that empowerment-oriented interventions are most effective when technological innovation is coupled with capacity building and market access. Therefore, this program demonstrates that locally adapted technological innovation, when embedded within a participatory empowerment framework, can generate sustainable improvements in both production performance and community self-reliance.

Overall, the implementation of the Anakonda Rote Method, integrated with tissue culture–derived seedlings, has demonstrated a significant positive impact on seaweed production, environmental sustainability, and community capacity in Holulai Village. Compared to conventional off-bottom cultivation, this approach effectively increased biomass growth, reduced losses caused by herbivorous pests and environmental stressors, and minimized plastic waste in coastal waters. Beyond technical outcomes, the participatory implementation model strengthened farmers' knowledge, skills, and institutional capacity, fostering greater independence and collective responsibility in managing seaweed farming activities. The integration of cultivation innovation with post-harvest processing, food safety standards, and product certification further enhanced the economic value of seaweed products and expanded market opportunities for local communities. These findings suggest that community-based adoption of locally appropriate technology can serve as a viable and sustainable approach to enhancing coastal livelihoods. Consequently, the Anakonda Rote Method offers strong potential for replication in other seaweed-producing coastal areas facing similar ecological and socio-economic challenges, provided that continued stakeholder support and community engagement are maintained.

4. CONCLUSION

The implementation of the *Pemberdayaan Desa Binaan* (PDB) program was successfully carried out with strong support from multiple stakeholders, particularly the two partner farmer groups (Litianak and Holotula), the Holulai Village Government, and the Community Service Institute of Universitas Kristen Artha Wacana. The partner groups demonstrated high levels of enthusiasm and active participation throughout all stages of the program, including the construction of the Anakonda Rote cultivation system, seaweed farming using tissue culture–derived seedlings, and hands-on training in seaweed-based food processing, which resulted in four diversified product variants. Continuous mentoring was provided to ensure that the program contributes to the long-term sustainability of seaweed farming activities.

At the operational level, cultivation areas and seed nurseries are currently being monitored periodically by the implementation team, students participating in the MBKM internship program, and undergraduate researchers conducting thesis projects. This ongoing monitoring aims to maintain cultivation continuity and ensure the availability of high-quality seedlings for subsequent production cycles.

Despite these positive outcomes, this program has several limitations. The implementation period remains relatively short, making it challenging to fully capture the long-term ecological, economic, and institutional impacts. In addition, variations in seasonal conditions and market dynamics were not comprehensively analyzed within the current program cycle. Therefore, long-term monitoring is crucial for evaluating production stability, disease resistance, and environmental sustainability across multiple cultivation seasons.

Future efforts should prioritize advanced and continuous training for farmer groups, particularly in business management, quality control, and product marketing, to strengthen competitiveness and value-chain integration. Furthermore, stronger support from local and regional governments is recommended, especially in the form of policy alignment, infrastructure development, and facilitation of access to financing and markets. Such policy support will be critical to scaling up the Anakonda Rote Method and ensuring its broader adoption as a sustainable seaweed cultivation model in other coastal areas.

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