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Initiatives and Prospects for Sustainable Agricultural Production in Karangasem Regency, Bali, Indonesia

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Abstract: Improving agricultural productivity to ensure food security while maintaining sustainability is a challenge that needs to be overcome in Bali, Indonesia. Ten farmers in Karangasem Regency, which is among the areas in Bali with a low food security index, were interviewed regarding their agricultural practices and government support for increasing the production of rice and chili—the main crops in the regency—while maintaining sustainability. The interview results revealed that the farmers recognized a lack of sunlight and disease as constraints to cultivation and attempted to improve productivity and control the disease by selecting varieties, cropping systems, and synthetic insecticides based on their previous experiences and the recommendations of agricultural extension workers. The Karangasem Regency Government actively encourages farmers to use biofertilizers and biological control agents to promote sustainable agriculture. Their use to improve rice and chili productivity is important to sustainably increase food security not only in Karangasem Regency but also in Bali Province. Furthermore, since agricultural extension workers are a source of information on agricultural production for farmers, it is important to train them for further extension activities in the future.

Keywords: agricultural extension worker; Bali; chili; plant growth-promoting rhizobacteria; rice; sustainable agricultural production

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1. Introduction

In Bali, agriculture is the second-most important industry after tourism. Bali has a high potential for agricultural development, given its paddy fields, fruit trees, horticulture, and plantations. Unlike the tourism sector, which is vulnerable to economic, social, and natural disruptions (for example, the number of tourists visiting Bali Province decreased from 6.2 million in 2019 to 1.06 million in 2020 and 51 in 2021 [1]), the agricultural sector is resilient to these disruptions. For this reason, the Bali Provincial Government has focused on agricultural development [2].

Agriculture in Bali is closely related to the beliefs and culture of Balinese people. For example, the Balinese calendar is based on Balinese Hinduism and rooted in the cycle of rice cultivation that has continued for approximately 1000 years. This calendar includes rice-related festivals, which are closely related to various aspects of the lives of Balinese people, and the work schedule for rice cultivation, such as rice planting and harvesting [3]. The irrigation system for rice cultivation in Bali has been developed for a long time and is supported by Subak, a traditional water-use organization. Subak equally distributes water to its members, manages land and water facilities and resources, resolves disputes between members, and enforces agricultural rituals [4]. The unique traits of Subak, which practices environment-based agriculture in natural and cultural landscapes, has attracted worldwide attention [5]; in 2012, the Subak in Jatiluwih was designated as a UNESCO World Heritage

Site under the title "Cultural Landscape of Bali Province: Subak System as a Manifestation of the Tri Hita Karana Philosophy" [6].

In the 1980s, agriculture in Bali was dependent on chemical fertilizers [7], which cause various environmental problems, including biodiversity loss, soil and water contamination, and eutrophication [8]. Recently, social problems, including the conversion of paddy fields into residential areas, increased waste generation, and water pollution, have occurred in Bali. Therefore, awareness of these issues has gradually increased in recent decades, and the Indonesian Government has emphasized its mandate to achieve "sustainable agriculture" in its new agricultural development plan for 2020–2024 [9,10]. In the context of promoting sustainable agriculture, organic farming [7], systems of rice intensification farming [11], and the plant growth-promoting rhizobacteria (PGPR) [12] have been applied in rice farming in Bali.

In 2022, Bali Province had the highest food security index (IKP = 85.19), which is calculated from three aspects of food security: the availability (ratio of normative consumption to net production of rice, corn, sweet potato, cassava, and sago and local government rice stocks), affordability (percentage of the population below the poverty line; percentage of households with a proportion of expenditure on food of more than 65% of total expenditure; percentage of households without access to electricity), and utilization (average years of schooling for women over 15 years old; percentage of households without access to clean water; ratio of population per health worker to population density level; percentage of stunted toddlers; life expectancy at birth) of food in Indonesia [13], followed by Central Java (82.95), South Sulawesi (81.38), and Papua (37.80). However, there were regional differences within Bali Province [13]; the IKP values for each regency of Bali Province were as follows: Tabanan (92.20), Denpasar (91.82), Badung (91.29), Gianyar (91.07), Jembrana (83.29), Klungkung (83.29), Brereng (79.91), Karangasem (78.79), and Bangli (75.10). The regencies with higher IKP values have more developed irrigation networks than other regions in Indonesia; therefore, rice and other staple crops grow more intensively in such regencies [14].

As the population in Bali is projected to grow from 4.31 million in 2020 to 4.67 million by 2035 [15] and the current population of 4.47 million in 2023 exceeds that projection, agricultural production in the regencies with low IKP values should be improved to ensure a stable food supply for the growing population in Bali Province.

The aim of this study was to determine the current plans and strategies of farmers and the provincial government to balance agricultural productivity and sustainability in Karangasem Regency, which has a lower-than-average (85.19) food security index for Bali Province, and discuss future prospects. The findings of this study contribute to the set of agricultural practices and strategies for increasing agricultural production while maintaining sustainability.

2. Materials and Methods

2.1. Survey Area Overview

The survey was conducted in Karangasem Regency, Bali. Karangasem Regency is located east of Bali, in a region with varying elevations, including Mount Agung (3142 m). Table 1 shows the meteorological data for Karangasem Regency in 2022. The average annual temperature was about 28 °C, and the average humidity was about 76%. The annual number of rainy days was 155, with precipitation exceeding 2400 mm. Precipitation during the dry season (May to October) was 756 mm, and during the wet season (November to April) it was 1654 mm. The average annual sunshine duration was 6.0 h, ranging between 7.2 h in the dry season and 4.8 h in the wet season [16]. In 2022, paddy production in Karangasem Regency was 52,091 t, the harvested area was 8536 ha, and rice production was 29,377 t [17]. Moreover, Karangasem Regency is a major chili production area; in 2022, the harvested area of chili was 964 ha and the production was 9027 t, accounting for 31.88% of the total production in Bali Province [18].

Table 1. Meteorological data for Karangasem Regency in 2022.

	2022	Jan.	Feb.	Mar.	Apr.	May	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Avg. temperature (°C)	28.2	27.1	27.5	28.2	29.0	28.9	28.5	27.6	27.8	28.3	28.1	28.7	28.2
Avg. humidity (%)	76.5	83.0	81.9	80.1	74.2	77.1	74.9	74.0	70.6	72.1	76.4	76.7	77.2
Total precipitation (mm)	2410	456.8	295.3	233.2	151.7	100.1	93.7	20.4	145.3	31.1	365.8	239.4	277.1
Total no. of rainy days (days)	155	23	15	15	11	14	15	10	9	6	14	12	11
Avg. sunshine duration (h)	6.0	2.4	3.9	5.5	7.3	6.3	6.7	7.6	8.3	8.7	5.5	4.4	5.4

Source: the BPS; our own calculations.

2.2. Details of the Survey

Ten farmers who own agricultural land in three Subaks (A–C) were interviewed on September 16–17, 2023. The farmers were randomly selected. Of the 10 farmers, No. 5 and No. 7 are the leaders of two Subaks, which consist of 116 and 208 members, respectively. Planting and irrigation are decided by the Subak assembly (Sangkepan), and information related to agricultural production is also shared within the Subak [19]. Therefore, many of the surrounding farmers may face similar problems. The opinions of the leaders can be taken as a general opinion of the direction of Subak and reflect the direction of most of the areas interviewed in this study.

Therefore, each farmer was interviewed regarding their annual cultivation schedule, cropping system (reasons for choosing a crop and variety, yield, seeds used, fertilizers, pesticide availability, and cultivation issues), and sources of information on items related to agricultural production (climate, irrigation water, seeds, fertilizers, cultivation techniques, agricultural inputs, machinery, policies, and cash conversion) in 2022. The respondents were provided up to three options for the selection of cultivars and varieties, cultivation issues, and sources of information. An official from the Department of Agriculture (Dinas Pertanian) of Karangasem Regency was present during the interviews.

3. Results

3.1. Information on Farmer Category, Farmland, and Main Crops

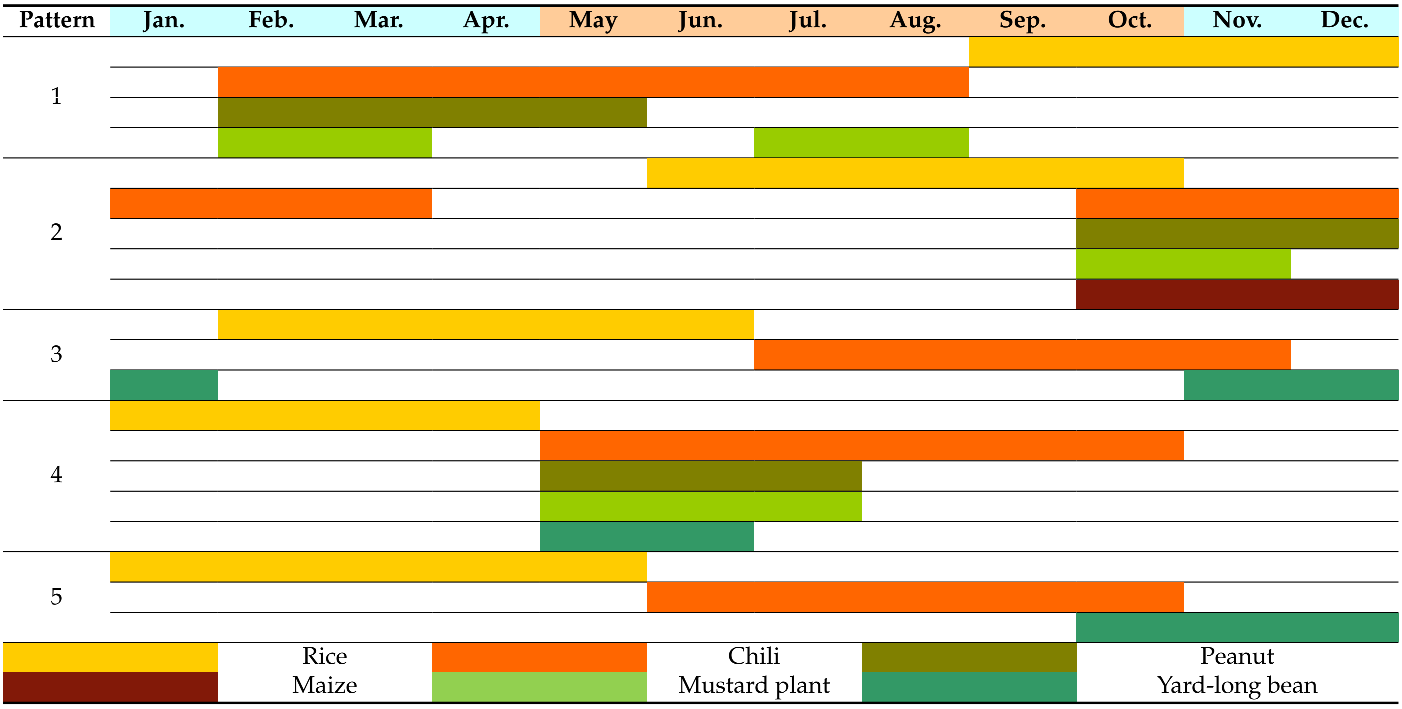
Table 2 shows information on farmer categories, farmland, and main crops. The ten farmers have had 11–40 years (average = 26 years) of farming experience. The area of their farmlands ranged from 11 to 100 ha (average = 40 ha). Nine out of ten farmers stated that their main crops are rice and chili (Table 2).

Table 3 shows a typical cultivation schedule in Karangasem Regency based on the information gathered through the interviews. Rice planting occurs during the dry season (May to October) or rainy season (November to April). Crop items and growing seasons differ by Subak (Table 3). The cultivation schedule also slightly varies within a Subak because hand tractors are rented out in turn within a Subak. The common practice among different Subaks is the cultivation of chili and other cash crops as soon as the rice harvest has ended. Peanut and mustard plants, which have short growing seasons, are intercropped with chili until chili is harvested and sold. Moreover, yard-long bean is grown between rice and chili (Table 3). The farmers refer to the Balinese calendar and the Awig-Awig (Subak regulations) established for each Subak [5] for the cultivation schedule (data omitted). The Balinese calendar is based on Balinese Hinduism and rooted in the cycle of rice cultivation that has continued for approximately 1000 years. It is the most important Balinese tradition because it is believed to harmonize the Balinese Sang Kala (time) with the lives of people; for example, the weather and timing of rice planting are harmonized to reduce or eliminate harvest failures [3]. The Awig-Awig determines when to plant rice during the rainy season and when to draw irrigation water; farmers who do not keep their promises are severely punished [4]. Therefore, farmers strictly follow the cultivation schedule in conjunction with the Balinese calendar.

Table 2. Information on categories of surveyed farmers, farmland, and main crops.

No.	Subak	Hearing Site Latitude Longitude	Gender	Age	Academic Background	Farming Experience (year)	Farmland Area (a)	Main Crop
1	A	−8.471363 115.436641	Male	45	Elementary school	30	30	Rice, Chili
2	A	−8.475013 115.435203	Male	52	High school	40	15	Chili
3	A	−8.477463 115.435828	Male	41	High school	11	30	Rice, Chili
4	A	−8.476963 115.435234	Male	53	Elementary school	30	18	Rice, Chili
5	A	−8.452187 115.440234	Male	43	Junior high school	20	34	Rice, Chili
6	A	−8.469263 115.436766	Male	58	High school	30	32	Rice, Chili
7	B	−8.482438 115.444734	Male	57	Junior high school	10	36	Chili
8	B	−8.482438 115.444734	Male	60	Junior high school	30	50	No Answer
9	C	−8.452187 115.462766	Male	46	Elementary school	30	100	Chili, Yard-Long Bean
10	C	−8.452187 115.462766	Male	58	Elementary school	30	50	Rice, Chili

Table 3. Cultivation schedule used by rice farmers in Karangasem Regency.



Dry season from May to October (filled in red); wet season from November to April (filled in blue); rice growing season (filled in yellow); chili growing season (filled in orange); peanut growing season (filled in khaki); maize growing season (filled in dark red); mustard plant growing season (filled in yellow green); yard-long bean growing season (filled in green).

3.2. Planting System of Main Crops

3.2.1. Rice

Table 4 shows the rice planting system. The cropping pattern practiced by all the farmers interviewed is a monoculture in the lowlands. The main rice varieties are Ciherang, Inpari (high-yielding and pest-resistant variety), and mapan05 (hybrid rice, good-taste variety). The average rice yield of the ten farmers was approximately 8 t/ha. All farmers responded that they have selected rice as the crop to cultivate because they follow the Awig-Awig (Figure 1). However, most of them select high-yielding, good-tasting, and pest-resistant rice varieties, as these varieties are grown for subsistence purposes (Figure 2). The farmers consciously select varieties based on the recommendations of other farmers or extension workers. The farmers obtain fertilizers, seeds, and pesticides used for rice cultivation depending on the Subak to which they belong. Fertilizers, seeds, and pesticides are sold at a lower price or freely provided by the government to Subaks. However, the Subak farmers who received the provision compensated for the shortfall by purchasing other products in addition to the provision (Table 4). The main constraints for rice cultivation are a lack of sunlight due to rainfall, diseases, and pest infestation, as well as inadequate irrigation facilities and adherence to the cropping season (Awig-Awig). Although pesticides have been used to control pests and diseases, there have been no innovations or measures to address the lack of sunlight.

Table 4. Planting system of rice.

No.	Subak	Farmland	Cropping Pattern	Variety	Yield (t/ha)	Seed	Fertilizer	Pesticide
1	A	Lowland	Monoculture	Mapan05	9.3	Purchased	Purchased	Purchased
2	A	Lowland	Monoculture	Unclear	7.8	Purchased	Purchased	Purchased
3	A	Lowland	Monoculture	Ciherang	7.8	Purchased	Purchased	Purchased
4	A	Lowland	Monoculture	Ciherang	7.8	Purchased	Purchased	Purchased
5	A	Lowland	Monoculture	Inpari43	7.3	Self-collection Purchased	Purchased Provided	Purchased Provided *
6	A	Lowland	Monoculture	Ciherang Mapan05	7.8	Purchased Provided	Provided	Purchased
7	B	Lowland	Monoculture	Inpari32	8.3	Provided	Provided	Provided
8	B	Lowland	Monoculture	Inpari32	8.3	Provided	Purchased Provided	Provided
9	C	Lowland	Monoculture	Inpari43	7.0	Purchased	Purchased	—
10	C	Lowland	Monoculture	Inpari32	8.2	Purchased Provided	Purchased Provided	—

Provided fertilizer (fertilizer sold by the government at subsidized prices). Provided seed and pesticide (items provided free of charge by the government). * Not provided due to financial difficulties in 2022.

3.2.2. Chili

Table 5 shows the chili planting system. The production of chili is vigorously increasing because it is considered a national strategic horticultural crop; for instance, it is grown in almost all regencies and cities in Bali because of the high demand from hotels and restaurants, in addition to local consumption [20]. All 10 farmers cultivated chili for cash after rice cultivation had been completed. The cropping pattern they apply is either a monoculture or mixed-cropping with peanut and mustard plants. In particular, the farmers that grow local chili varieties tend to mix chili with vegetables and peanut, which have a shorter growing season, to ensure cash flow until the chili harvest begins. Moreover, several farmers responded that chili is the main crop that can equal or replace rice (Table 5). This finding indicates the importance of chili cropping in Karangasem Regency. The reasons for selecting chili as a crop for cultivation differed according to the Subaks to which they belong. For example, in the Subaks to which farmers 1–6 belong, cropping is determined based on the Awig-Awig (Figure 1) because the land owned by farmers 1 and 4 has been converted into a tourist attraction: the Sidemen Rice Terrace. However, the farmers who do not abide by the Awig-Awig select their crops based on the difficulty of cultivation and cash value of the crops (Figure 1). The main chili varieties are Pilar F1 and local varieties (Table 5).

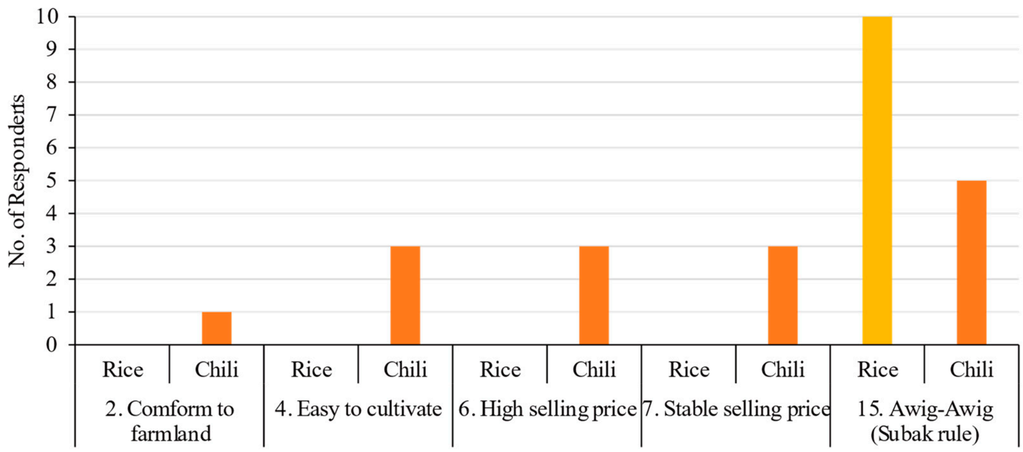


Figure 1. Reasons for crop selection. Multiple selections can be made for up to three items from a total of 16 items; of the items selected, only those for which a response was obtained are shown. Omitted items (1. Conform to weather condition. 3. Low capital input. 5. Agricultural policy intentions. 8. Tradition. 9. Short growing season. 10. To exchange for other crops. 11. Request from family. 12. Request from broker. 13. Short working hours. 14. Curiosity. 16. Other).

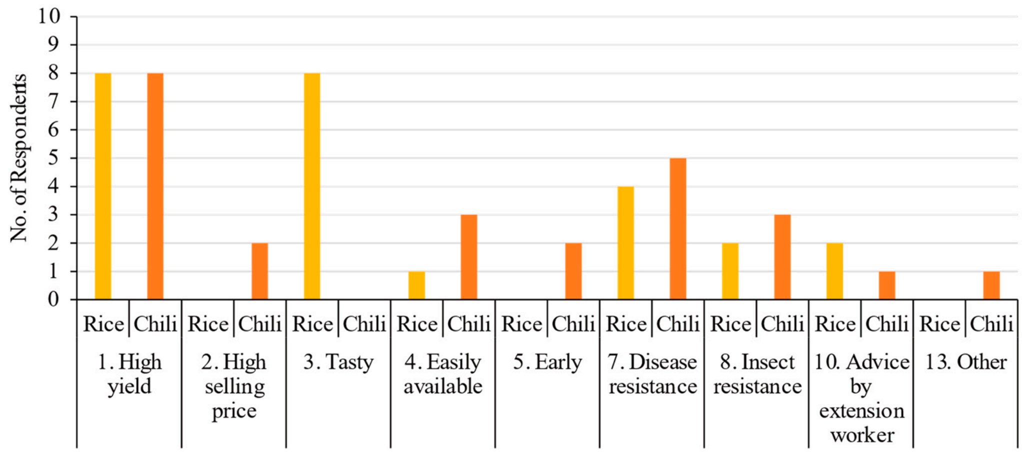


Figure 2. Reasons for variety selection. Multiple selections can be made for up to three items from a total of 13 items; of the items selected, only those for which a response was obtained are shown. Omitted items (6. Drought resistance. 9. Tradition. 11. Request from broker. 12. Request from family). Other (Market demand).

The farmers select chili varieties based on yield, pest resistance, and cash (Figure 2); most farmers cited high yields as the reason for selecting a certain chili variety. However, chili yields typically range from 2.4 to 25.2 t/ha, suggesting that yield varies depending on the variety and cultivation management (Table 5). The farmers cited weather, such as the lack of sunlight during the rainy season and dryness during the dry season, as the most common limiting factor for chili cultivation; they also regarded disease and insect infestation as limiting factors (Figure 3). As is the case with rice, pesticides have been used to control pests and diseases; however, no innovations or countermeasures have been developed to combat the lack of sunlight or drought.

Table 5. Planting system of chili.

No.	Subak	Farmland	Cropping Pattern	Variety	Yield (t/ha)	Seed	Fertilizer	Pesticide
1	A	Lowland	Monoculture	PILAR F1	25.2	Purchased	Purchased	Purchased
2	A	Lowland	Mixed-cropping	Local	7.0	Purchased	Purchased	Purchased
3	A	Lowland	Monoculture	PILAR F1	2.4	Purchased	Purchased	Purchased
4	A	Lowland	Monoculture	PILAR F1	16.0	Purchased	Purchased	Purchased
5	A	Lowland	Mixed-cropping	Local	6.5	Self-collection Purchased	Purchased Provided	Purchased Provided *
6	A	Lowland	Monoculture	PILAR F1	10.5	Purchase Provided	Provided	Purchased
7	B	Lowland	Mixed-cropping	Local	6.2	Provided	Provided	Purchased
8	B	Lowland	Mixed-cropping	Local	6.5	Self-collection Purchased	Purchased Provided	Provided
9	C	Lowland	Monoculture	PILAR F1	7.5	Purchased	Provided	Purchased
10	C	Lowland	Monoculture	PILAR F1	7.5	Purchased	Purchased Provided	Purchased

Provided fertilizer (fertilizer sold by the government at subsidized prices). Provided seed and pesticide (items provided free of charge by the government). * Not provided due to financial difficulties in 2022.

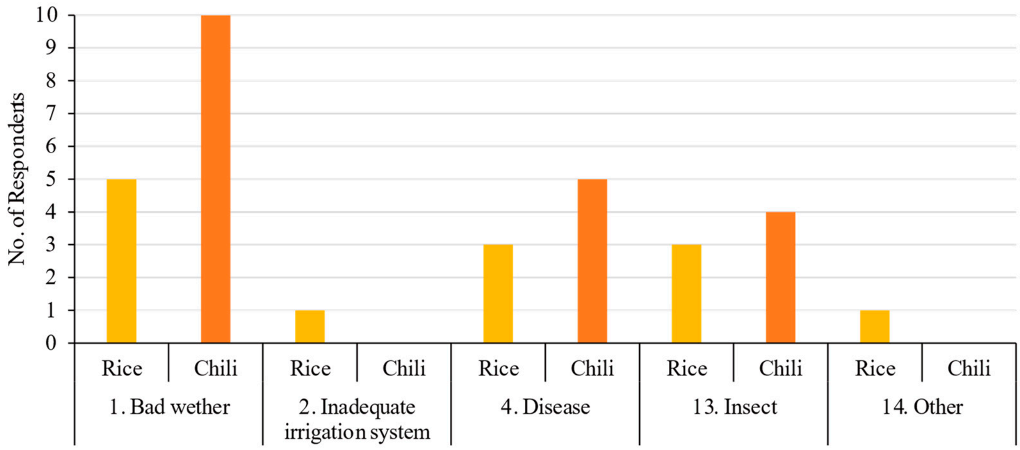


Figure 3. Cultivation limiting factors. Multiple selections can be made for up to three items from a total of 14 items; of the items selected, only those for which a response was obtained are shown. Omitted items (3. Variety. 5. Soil fertility. 6. Weed. 7. Lack of pesticides. 8. Lack of fertilizer. 9. Labor shortage. 10. Lack of arable land area. 11. Technical deficiency. 12. Animal). Other (Must be on time).

3.3. Government Response to Limiting Factors in Cultivation

Indonesian governments have implemented various agricultural policies to support farmers in increasing their production. For example, in the fertilizer subsidy system, the Indonesian Government provides subsidies to state-owned fertilizer manufacturing companies, which, in turn, sell low-priced fertilizers (urea: urea fertilizer; SP-36: phosphate fertilizer; ZA: ammonium nitrate; NPK: fertilizer, etc.) to smallholders with less than 2 ha of farmland [10]. The survey revealed that the government's share is 80%, and each farmer purchases fertilizers at 20% of the original price. In addition, the type of fertilizers desired by the farmers are sold thrice a year on an ongoing basis.

On the other hand, the Karangasem Regency Government freely provides seeds and pesticides once a year; however, there was no provision in some years owing to financial constraints. In addition to the low-priced NPK fertilizers sold, biofertilizers and biological control agents were provided by the government (Figure 4a,b). The biofertilizers include plant growth-promoting microorganisms of the genera *Azotobacter*, *Bacillus*, and *Rhizobium* (Figure 4a), while the biological control agents are obtained from *Trichoderma* (Figure 4b). PGPR, such as *Azotobacter* and *Rhizobium*, are beneficial bacteria that actively occupy the rhizosphere and improve soil fertility and plant resistance to pests [21]. Additionally, the government provided equipment and a refrigerator free of charge for a room in the Subak meeting hall, which belongs to 208 farmers, including farmers 7 and 8. Furthermore, PGPF were produced through a simple experimental method using rice and distributed to farmers (Figure 4c,d).

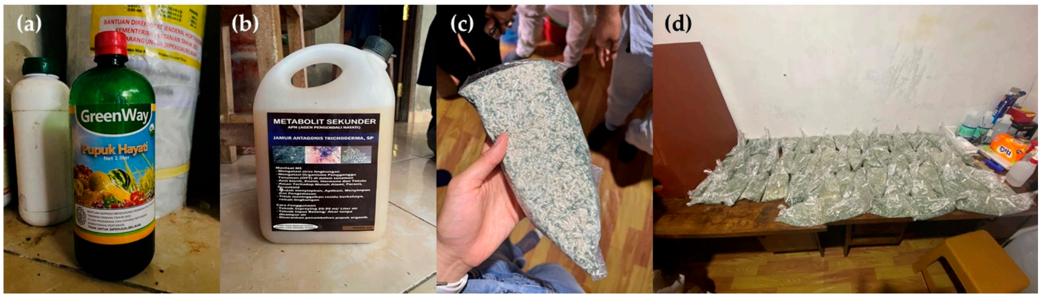


Figure 4. (**a**) Biofertilizer; (**b**) biological control agent; (**c**) producing fungus from rice as PGPF; (**d**) experiment in the meeting hall of the Subak.

3.4. How Do Farmers Obtain Useful Agricultural Information?

Figure 5 shows the sources of information on the soft and hard items related to agricultural production. The soft aspects of this study were climate, cultivation techniques, agricultural policies, and cash conversion, while the hard aspects were irrigation, seeds, fertilizers, agricultural materials, and agricultural machinery.

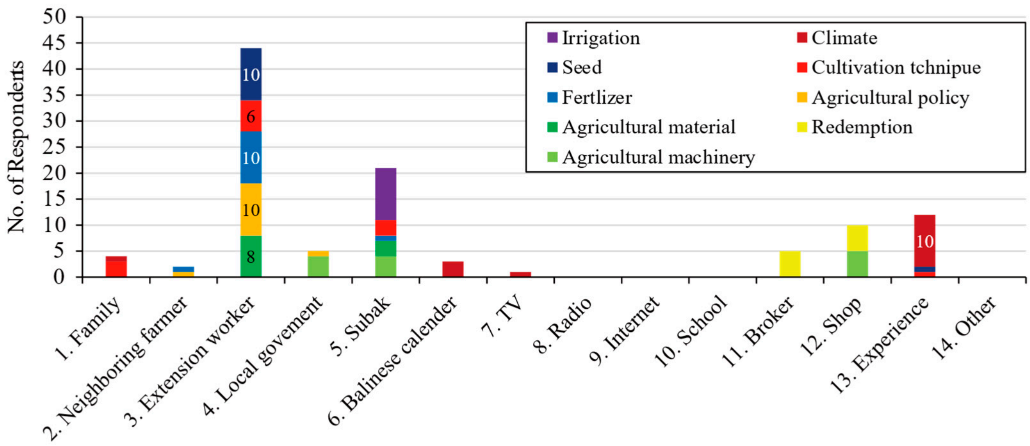


Figure 5. Sources of information on agricultural production.

3.4.1. Soft

All respondents recognize the prevailing (weather, rainfall, temperature, and disaster information) climate based on their own experiences and observations. Five out of ten farmers refer to the Balinese calendar, their family members, and television broadcasts for information regarding climate. The farmers obtain information on cultivation techniques (planting time, irrigation, and fertilizer management) from their family members, agricultural extension workers, and the Subak. One farmer also indicated that his experience was a source of information on cultivation techniques. All of them obtain information about agricultural policies (availability of subsidies for fertilizers, seeds, pesticides, etc.) from agricultural extension workers, neighboring farmers, and local governments. Lastly, the farmers obtain information on redemption (sales price, timing of redemption, quantity demanded, etc.) from brokers and stores (Figure 5).

3.4.2. Hard

All respondents have been informed about irrigation by the Subak. All receive information about seeds (purchase costs, introduction of new varieties, subsidies, etc.) from agricultural extension workers, neighboring farmers, and their experiences. All participants receive information about fertilizers (purchase costs, subsidies, etc.) from their extension workers. Other information is obtained from neighboring farmers and the Subak. Regarding agricultural materials (purchase cost and use), eight out of ten farmers obtain information from agricultural extension workers, and the Subak was mentioned as a source of information. Lastly, they obtain information on agricultural machinery (price of use, method of borrowing, etc.) from Subaks and stores, their family members and the local government (Figure 5).

Although the sources of information on agricultural production differ, all farmers rely on agricultural extension workers as sources of information on seeds, fertilizers, agricultural materials, cultivation techniques, and agricultural policies.

3.5. Role of Agricultural Extension Workers as Sources of Agricultural Information

The results of the interviews suggest that the role of agricultural extension workers as sources of information is important. The role of agricultural extension workers was summarized based on interviews with staff members who participated in the field survey.

The extension workers in charge of the study area visit each farmer every 2 weeks to provide information on seeds, fertilizers, agricultural materials, cultivation techniques, and agricultural policies. The extension workers also observe cultivated plots and advise them on problems and countermeasures. Although the penetration rate of smartphones is increasing, information is primarily transmitted by people because the Internet was rarely mentioned as a source of information (Figure 5). In addition, most of the farmers are elderly and have low literacy rates; therefore, it is essential to share information through conversations with agricultural extension workers. However, some farmers said that the widespread use of smartphones has made it easier to interact with agricultural extension workers through messaging applications. However, information on climate was not provided. Because weather information is important for agricultural production, this is an issue to be addressed in the future.

In addition to providing information, extension workers suggest palawija (crops secondary to rice, which include corn, peanut, and soy bean [7]) to rice farmers. The extension workers suggest three crops suitable for the growing area; however, the farmers still decide which crops to grow. For instance, the extension workers proposed the cultivation of a subspecies of chili and cosmos in the Sidemen district of Karangasem Regency. In addition to determining the needs of farmers for subsidized fertilizers, extension workers ensure that fertilizers sold at low prices by the government and free seeds and pesticides are properly distributed to and used by each farmer.

4. Discussion

Global climate change affects food security and sustainability by causing changes in cropping patterns, intensifying plant diseases and pest infestations, decreasing agricultural production, and disrupting the livelihoods of farmers [9]. Indonesia is among the most vulnerable countries to climate change [22]. In Bali, rice cultivation is supported by a traditional water-use organization (Subak) that aims to distribute water equitably [23]. Farmers still embrace the Balinese Hindu philosophy of Tri Hita Karana to maintain traditional rice cultivation systems [24]. The results of the interview revealed that the rice cultivation schedule is also determined by the Balinese calendar and Awig-Awig (Subak regulation). As the demand for agricultural water decreases due to increasing tourism and industrial water use, as well as changing rainfall patterns, equitable water distribution by Subaks is important for maintaining the sustainability of rice cultivation and agricultural production. However, one farmer cited that the timing for rice planting determined by Subaks is a limiting factor for rice cultivation (Figure 3). This also affects the planting of cash crops such as chili, which is planted after the harvest season of rice and is presumably at an increased risk of poor growth due to bad weather. Therefore, using mixed-cropping cash crops or short legumes to bridge the growing season is among the strategies applied to prepare for bad weather and continue generating income while adhering to the growing schedule set by the Subak.

Most of the farmers interviewed cited the lack of sunlight and pest- and disease-induced damage as the major factors (Figure 3) limiting the cultivation of rice and chili—the main crops they grow—because during cloudy or rainy weather, a lack of sunlight delays growth and reduces the vigor of the grass; moreover, disease outbreaks and pest infestations become more prevalent under hot and humid conditions such as those in Bali. Information and communication technology (ICT)-based tools such as WeRise [25] could be used to improve rice crop yields. However, farmers place the highest priority on planting according to the Balinese calendar, and agricultural extension workers cannot provide information on weather. Therefore, it is difficult to avoid the lack of sunlight by using ICT tools and changing the planting time. Additionally, agricultural materials such as LED bulbs and reflective materials could be used [26]; however, these materials are costly and are not a field measure in Bali, as they are greenhouse measures. Therefore, countermeasures against pest outbreaks induced by a lack of sunlight are considered important in Karangasem, Bali.

Although the Awig-Awig determines the planting schedule and crop items, the farmers can freely select the crop varieties they grow (Figures 1 and 2). The most widely planted rice variety in 2012 was the indica rice Ciherang. However, the production of this variety has recently declined, owing to its susceptibility to rice blast. Meanwhile, the percentage of Inpari lines (high-yielding and pest-resistant variety) has increased since 2008 [7]. Recently, widespread efforts have been made to introduce hybrid rice [27]. On the other hand, chili is prone to productivity fluctuations due to weather and climate changes [20]; chili production in Bali repeatedly increased and decreased from 2015 to 2022 [17,28]. The Pilar variety, which is grown by the farmers interviewed, is susceptible to Pepper yellow leaf curl Indonesian virus. Damage caused by this virus has spread throughout Indonesia [29] and was previously confirmed in Bali in 2012 [30]. Setiawari et al. [31] reported that losses due to this virus ranged from 20 to 100%. Interviews revealed considerable differences in Pilar production, which may be due to differences in pest management. Thus, several farmers use high-frequency synthetic insecticides to control the disease; however, there are concerns regarding the negative effects of insecticides on agricultural workers, consumers, and the environment [32]. The freedom of farmers in selecting which crop varieties to grow enables them to select pest-resistant varieties. However, because yield loss due to pests and diseases cannot be prevented by variety selection alone, the use of pesticides has become indispensable for both rice and chili cultivation. Recently, there has been increasing demand for pesticides that are environmentally safe.

4.1. Productivity and Sustainability

The fertilizer subsidy budget of the Indonesian Government for the agricultural development plan for 2015–2019 decreased from Rupiah (Rp) 31.3 trillion (2015) to Rp 26.6 trillion (2019). While the fertilizer subsidy budget in the plan for 2020–2024 remains at Rp 26.7 trillion (2024) due to the impact of COVID-19, the government encourages the use of organic fertilizers [9]. Rice farmers in Indonesia tend to use large amounts of fertilizer purchased at subsidized prices [10]. Therefore, shifting to non-chemical fertilizers is a challenge for rice farmers, who need to maintain productivity. Recently, organic farming has been promoted in Bali [7]. Additionally, liquid biofertilizer is provided by the Bali Provincial Government in Tabanan Regency [33], and this survey revealed that biofertilizers and PGPR are being promoted by the Karangasem Regency Government (Figure 4). Rice faces various plant diseases from germination to maturity. Among them, blast is a typical disease that causes yield loss and is considered one of the most damaging diseases to rice worldwide [34]. In response, Suriani et al. [12] found that simultaneous application of piper leaf extracts and PGPR inhibited blast disease and improved the growth of red rice in Bali. Several studies of PGPR have been conducted for chili [35–37]. For example, Thilagar et al. [36] reported that in pot trials, PGPR application increased soil phosphorus levels and produced indoleacetic acid and siderophores, which promoted plant height and stem girth growth in chili. In a field trial on dry land, Ichwan et al. [37] reported that PGPR application increased root biomass and enhanced nutrient water uptake, leading to increased fruit number and fruit weight in chili.

After the Green Revolution, global food production in the 20th century, including Indonesia, has mainly relied on chemical fertilizers and breeding. However, the continuous use of chemical fertilizers and pesticides and the resulting adverse environmental effects are problematic [21]. With the need for sustainability in agriculture in Bali, the use of PGPR can mitigate the negative effects of the over-application of chemical fertilizers and pesticides as a sustainable approach for disease management and nutritional supplementation [38]. In addition, the labels of the biofertilizers and biological control agents that were provided included the organic mark, instructions for use, and benefits, which were thought to facilitate farmers' understanding of the benefits of using the PGPR. Furthermore, the addition of organic fertilizers is recommended for the use of biological pesticides. Farmers who raise livestock tend to use distributed fertilizers and compost livestock manure, which is expected to have a synergistic effect. Therefore, reducing government subsidies for chemical fertilizers and pesticides and shifting to the use of biofertilizers would enable rice farmers in Karangasem Regency to both increase productivity and achieve sustainability. Moreover, the use of PGPR has the potential to increase food security, and improve the production of rice and chili in Karangasem Regency. Increased production of rice, the staple food in Karangasem Regency, supports the food availability aspect in the regency. Additionally, the increased production of chili, a specialty product, will lead to food security not only in Karangasem Regency but also in the entire province of Bali. Moreover, the increase in productivity is expected to lead to higher incomes for farmers.

However, the application of PGPR to food crops is beginning to be widely studied, but implementation in the field is very limited [21]. In addition, agricultural production has been based on chemical fertilizers and pesticides, and PGPR that have performed well in experiments may not work in farmers' fields [39]. Furthermore, the results of the effects of PGPR differ depending on the types of PGPR used and the cultivation conditions. Therefore, practical extension activities with high reproducibility in field experiments are required.

4.2. Sources of Information

To improve and maintain agricultural production in Indonesia, productivity must be increased using limited resources [40]. With the remarkable developments in agriculture in recent years, it is essential to obtain information on new materials, management, and cultivation techniques. However, access to information remains one of the most important issues in agricultural development because most farmers are aging and lack sufficient education [41]. Therefore, in Bali, which is becoming an information society, it is important to identify the information sources that support the improvement and maintenance of agricultural production.

Agricultural extension workers play an important role in promoting agricultural development in rural communities, providing information on climate change and climate impacts and teaching farmers to use new technologies to cope with climate impacts [22]. However, all farmers who were interviewed in this survey cited their previous experiences as their source of information about climate, and they consult their family members or neighboring farmers for information related to agricultural production (Figure 5). The cultivation techniques (machines and methods) used by Balinese farmers are simple and have been passed down from one generation to the next [42]. Farmers do not follow a cultivation manual faithfully, as they have become accustomed to certain agricultural practices [23]. Furthermore, technologies to cope with recent climate changes and environmental protection cannot be established based on one's own experience, and it can sometimes be risky to introduce cultivar selection and cultivation techniques based solely on previous experience [20]. Therefore, the lack of climate information provided by agricultural extension workers is a challenge for supporting agricultural development. Takama et al. [22] also pointed out that a small percentage of agricultural extension workers have a bachelor's degree, suggesting the importance of improving their capacity. The Department of Agriculture in Bali Province and Karangasem Regency regularly conducts technical training sessions for agricultural extension workers. However, the extension workers are responsible for slightly different cultivation environments and challenges in their respective areas, and they have different experiences, so their extension methods and effectiveness are likely to differ slightly. Therefore, it would be effective for further agricultural development to build and utilize a knowledge database that consolidates the failures and successes experienced by each extension worker. Using a knowledge database that consolidates a number of extension cases will improve the capacity of individual extension workers and enhance their ability to respond to farmers. Additionally, the aggregation and utilization of diffusion effects are considered important, especially in promoting adaptation measures to climate change and technologies such as PGPR, which have different effects in different growing environments.

This study was conducted in Karangasem Regency. Bali has a wide diversity of cultivation patterns that differ from region to region. Therefore, further research is needed in other provinces, as limiting factors and sources of information on cultivation may differ.

5. Conclusions

In this study, farmers in Karangasem Regency, Bali, were interviewed regarding their efforts to balance agricultural productivity and sustainability. The loss of yield in both rice and chili, the main crops in the regency, due to pests and diseases cannot be prevented by variety selection alone. Since the use of pesticides is essential to address pest infestation, environmentally safe pesticides have been proposed; moreover, biofertilizers and biological control agents have been actively promoted by the Karangasem Regency Government. Additionally, the increase in the productivity of rice and chili through the spread of PGPR will not only increase food security in Karangasem Regency but also lead to food security in Bali Province.

While all farmers obtain important information on agricultural production, such as fertilizers, pesticides, and cultivation techniques, from agricultural extension workers, the lack of information provided on climate is an important issue. To achieve increased productivity and sustainability in agriculture, it is crucial to develop reliable cultivation techniques and train extension workers to properly communicate them to farmers through the consolidation and utilization of extension cases.

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