Technology Adoption Report 2023

Food Security and Agriculture Productivity Project (FSAPP)

Project Management Unit

Department of Agriculture

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Executive Summary

This study examines the adoption of various agricultural technologies promoted by three Agriculture Research and Development Centers (ARDCs) through Food Security and Agriculture Productivity Project (FSAPP) in south-west districts of Bhutan. The study analyses the socio-demographic characteristics of the surveyed population, technology adoption rates, perceived benefits, and challenges faced by farmers in adopting the technologies promoted. The technologies promoted through FSAPP project interventions were broadly categorized as follows:

1. Promotion of Improved kitchen or nutrition garden
2. Promotion of newly introduced crops (quinoa and black pepper)
3. Promotion and demonstration of protected cultivation technologies
4. Promotion of improved crop varieties (Yusi maap & DQ 11)
5. Training and demonstration on improved soil fertility and plant protection technologies
6. Promotion of climate smart agricultural technologies (low-cost water harvesting technology, plastic mulch, drip irrigation, protected agriculture structures)
7. Promotion of improved crop production practices (citrus canopy management)
8. Promotion of direct seeding technology in paddy

The study revealed that the overall (weighted) technology adoption rate across all ARDCs was 73.18%. The weighted adoption rate of technology for ARDC Bajo, Samtenling, and NCOA Yusipang was 81.90%, 75.64%, and 62.00% respectively.

1. Introduction

Increasing agricultural productivity is essential to meet the rising global demand for food and alleviate poverty, particularly in developing countries. The Green Revolution in India, which began in the 1960s, significantly enhanced agricultural productivity through the introduction of high-yielding varieties, improved irrigation techniques, and increased use of fertilizers and pesticides. This transformation was crucial in ensuring food security for India's growing population.

Bhutan's journey toward agricultural modernization began with its first five-year plan in 1961–1966. Since then, the country has made strides in various areas, including farm machinery, improved crop production technologies, and the use of high-yielding varieties. Despite these advancements, agricultural development has been uneven, with more progress seen in the west-central parts of the country. Smallholder farmers, particularly those in remote areas, often lack access to modern technologies. Bhutan has an estimated 164,331 households, with 67% in rural areas and 33% in urban areas. The country's population stands at approximately 650,118, with 61% residing in rural areas. Most of the rural population relies on subsistence farming as their primary livelihood.

The Food Security & Agriculture Productivity Project (FSAPP), funded by the Global Agriculture and Food Security Program (GAFSP), aims to improve the productivity of smallholder farmers in southwestern Bhutan (Chhukha, Dagana, Haa, Samtse, and Sarpang), where poverty rates are higher. Agricultural research plays a significant role in boosting productivity, yielding high benefit-cost ratios, and enhancing social welfare. A 10% increase in public investment in agricultural research and development is projected to trigger a 2.4% growth in agriculture at constant prices. The Agriculture Research & Development Centers (ARDCs), with support from the FSAPP, have actively promoted various agricultural technologies to enhance practices and productivity among smallholder farmers, focusing on poverty reduction in project districts
Despite these efforts, no comprehensive study has been conducted to document and analyze the adoption and diffusion of technologies promoted by the ARDCs. The World Bank has requested an analysis to evaluate the success of the ARDCs' promotional activities in encouraging farmers to adopt new technologies and production practices. This analysis aims to generate evidence on how these promotional activities lead to effective adoption of improved technologies and practices, driving sustainable productivity growth and resilience.

2. Theoretical Framework

2.1. What is technology?

The definition of "technology" can vary slightly depending on the organization or context. However, in general, technology refers to the application of scientific knowledge and tools to solve problems and achieve practical goals. It involves using tools, techniques, systems, and

processes to create, manipulate, transmit, store, and exchange information or to produce goods and services.

UNESCO defines technology as "the set of specific processes, skills, and methods used to accomplish particular tasks in various sectors." The European Commission defines technology as "the application of science, especially to industrial or commercial objectives." However, the World Bank often uses technology-related terms in the context of development and innovation. They refer to technology as tools, techniques, systems, and methods that contribute to economic and social progress. Therefore, in this study, the definition for the technology is in line with the world bank's definition where tools, techniques, systems, and methods are included in this adoption study.

Technology Adoption: Loevinsohn et al., 2013 defines adoption as the integration of a new technology into existing practice and is usually proceeded by a period of 'trying' and some degree of adaptation.

2.2. Technology adoption model

The study used straightforward criteria, such as technology persistence, benefits, challenges, and enumerator observations, to assess the adoption rate of technologies among farmers. These parameters were derived from Rogers' diffusion of innovations theory, which outlines characteristics that influence the adoption and diffusion of new innovations or technologies among individuals and groups.

3. Materials and methodology

3.1. Selection of technologies

The data from Project Management System (PMS) and annual progress reports were used to extract the list of technologies promoted through FSAPP by ARDCs. Broadly, the technologies (Table 1) promoted were categorized as follows:

i. Promotion of improved Kitchen Garden Technology & Nutrition gardens

To enhance vegetable production through the adoption of appropriate modern agricultural technologies, various climate-smart and improved agricultural technologies (such as plastic mulch, drip irrigation, and protected agriculture structures) were promoted as a comprehensive package. Farmers were supported with basic input and provided with training and demonstrations on the improved package of practices.

ii. Promotion of introduced crops (Quinoa & Black pepper)

Quinoa, a nutrient-dense pseudo-cereal, and black pepper, a high-value crop that can be intercropped with existing areca nut trees, were promoted for crop diversification, improved nutrition, and enhanced income.

iii. Demonstration and promotion of protected cultivation technologies

The ARDCs promoted the use of protected cultivation techniques in the form of prefabricated and low-cost poly houses. These technologies help extend the growing season, protect crops from adverse weather, and enhance overall productivity.

iv. Promotion of improved potato and rice varieties (Yusi Maap & DQ-11)

The ARDC Samtenling evaluated two high yielding varieties of rice, DQ 11 and Mashuri, and promoted through on-farm demonstrations and field day. The former one was released as Samtenling Ray Kaap-3. Similarly, National Centre for Organic Agriculture (NCOA) Yusipang promoted the improved potato variety – Yusi Maap in west central region.

v. Training and demonstrations on improved soil fertility and plant protection technologies

NCOA conducted demonstrations related to soil fertility and plant protection techniques. This involved showcasing sustainable and organic practices to enhance soil health and protect crops from pests and diseases.

vi. Promotion of climate smart agricultural technologies

Under these interventions, climate smart technologies such as low-cost water harvesting technology, plastic mulch and drip irrigation were promoted.

vii. Promotion of improved crop production practices

This involved the promotion of improved production practices such as citrus canopy management and training on enhanced mushroom production techniques. Additionally, farmers were supported with necessary input and guidance to implement these practices effectively, aiming to boost overall productivity and sustainability.

viii. Promotion of direct seeding technology in paddy

In collaboration with the Agriculture Machinery Centre (AMC), ARDC Samtenling promoted paddy drum seeding technology in Sarpang and Samtse. This labor-saving technology is feasible in water-scarce areas and serves as an alternative to the conventional practice, which requires substantially more labor.

Table 1 List of agricultural technologies promoted by ARDCs and NCOA through FSAPP.

#	Technology promoted	Activity Demonstrated	Input supports provided	Promoting Agency
1	Improved kitchen Garden Technology	Establishment of model kitchen garden	Mulching plastic, drip irrigation, fencing net, polyhouse, seeds	ARDC Samtenling
2	High value crops (Black pepper)	Black pepper cultivation	Black pepper seedlings	
3	Demonstration and Promotion of Protected Cultivation Technologies		Top and side ventilated poly house	
4	Promotion of improved crop varieties (DQ 11 & Mashuri paddy varieties)	Participatory varietal selection through field-day	Paddy Seeds	
5	Promotion of Direct seeding technology in paddy	Paddy drum seeding technology	Paddy seeds	
6	Improved potato (Yusi Maap) variety		Input support (Seed Tuber)	NCOA Yusipang
7	High value crop (Quinoa)	Cultivation of Quinoa	Input support (Seeds)	
8	Soil fertility and Plant Protection Technologies	Rangzhin bubmen, Rangzhin Lue Chu, plastic mulch, Bio digesters		
9	Demonstration of Nutritional Garden		Inputs support (Sintex, seeds and seedlings)	
10	Demonstration and promotion of Protected cultivation		Fabricated Polyhouse, Rain shelters, low-cost poly houses	
11	Climate smart technologies	Hands-on training provided to participants	Input support provided as package	ARDC Bajo
12	Low-cost water harvesting technology	Training, demonstration on construction of low-cost water harvesting technology	Input support	
13	Electric fencing using High Density Polyethylene (H DPE) poles	Demonstration on Electric fencing using HDPE pipes poles	Electric fencing equipment	
14	Citrus Canopy Management	Training & Demonstration, inputs support		
15	Mushroom Cultivation	Training & Demonstration, inputs support		

4. Study sample

4.1. ARDC Samtenling

The gewogs were sampled through purposive sampling, followed by random sampling of farmers from the beneficiary data extracted from PMS. The study involved at least two gewogs where the technology was promoted under Sarpang and Samtse. Semi-structured questionnaires, developed using Google Forms, were utilized for the survey. The data was analyzed using MS Excel. The adoption rate for technologies such as black pepper, direct seeding technology, and improved paddy varieties was calculated from the beneficiary data by determining the number of farmers who, at the time of the survey, were still utilizing these technologies after the demonstration or promotion programs were carried out in previous years.

Table 2 Total number of beneficiaries reached & number of beneficiaries surveyed for each technology promoted by ARDC Samtenling

Activity	Technology	No of Beneficiaries	No of Beneficiaries surveyed (*n*)
Promotion of improved kitchen Garden Technology	Plastic mulch	892	48
	Drip irrigation	684	48
	Fencing net	109	48
	Protected agriculture structures	516	48
	GI stalking	25	48
Promotion of black pepper	Seedlings	48	NA[1]
Promotion of DQ 11 & Mashuri	Seeds	224	NA[1]
Demonstration and promotion of Direct seeding technology	Drum seeder	184	NA[1]

4.2. NCOA Yusipang

The study employed a stratified random sampling method. Initially, samples were stratified based on the types of technology promoted by the Project Implementing Units (PIUs). Subsequently, random sampling was applied to select beneficiaries, ensuring a consistent sampling intensity. A total of 60 respondents for each selected technology were randomly surveyed from two sample villages in each sampled gewog in Haa and Chhukha. Semi-structured questionnaires, developed

[1] The exact adoption rate was calculated from number of beneficiaries who attended field demonstration during promotional program and number of farmers who have adopted the technology promoted.

using Kobo Toolbox, facilitated the survey of the selected respondents. The data was then analyzed using frequency distribution and crosstabulation analysis to gain insights into technology adoption and challenges within the selected regions.

Table 3 Total number of beneficiaries reached & number of beneficiaries surveyed for each technology promoted by NCOA Yusipang

Technology Promoted	No of Beneficiaries	No of Beneficiaries surveyed (n)
Promotion of improved potato (Yusi Maap) variety	287	60
Promotion of newly introduced high value crop (Quinoa)	123	60
Promotion of soil fertility and Plant Protection Technologies	319	60
Demonstration of Nutritional Gardening	99	60
Demonstration and Promotion of Protected cultivation	636	60

4.3. ARDC Bajo

The technology adoption survey was conducted using a purposive random sampling method to randomly select beneficiaries of each promoted technology. A semi-structured questionnaire was designed for this survey, and data were collected through interviews and Google Forms from a random sample of beneficiary farmers in Dagana Dzongkhag. The collected data were then analyzed using the Statistical Package for the Social Sciences (SPSS).

Table 4 Total number of beneficiaries reached & number of beneficiaries surveyed for each technology promoted by ARDC Bajo

Technology Promoted	No of Beneficiaries	No of Beneficiaries surveyed (n)
Promotion of Climate smart technologies	47	41
Promotion of Low-cost water harvesting technology	250	30
Promotion of Electric fencing using HDPE poles	12	11
Promotion of Citrus Canopy Management	306	41
Promotion of Mushroom Cultivation	46	46

5. Result and Discussion

5.1. Technology adoption rate under ARDC Samtenling

The overall adoption rate of technologies promoted under ARDC Samtenling in Sarpang and Samtse was 71.95%. However, the weighted adoption rate was slightly higher at 75.64%, as shown in Table 5. The highest adoption rate was observed in the promotion of black pepper, followed by protected agriculture structures. Technologies promoted under improved kitchen gardens (plastic mulch, drip irrigation, fencing net, protected agriculture structures, and GI staking) had an average adoption rate of 82.5%. Improved rice varieties were adopted by 56% of the farmers, while the lowest adoption rate was observed for the paddy drum seeding technology, at just 7%.

Table 5 Summary table for technology adoption rate of different technologies promoted under ARDC Samtenling.

Sl. No.	Technology promoted	Adoption rate from survey %	Total HHs beneficiary as per PMS	Share % of beneficiary
1	Plastic mulch	91.70%	892	33%
2	Drip irrigation	56.30%	684	26%
3	Fencing net	97.90%	109	4%
4	Protected agriculture structures	100%	516	19%
5	GI stalking	66.70%	28	1%
6	Improved paddy varieties (DQ 11 & Mashuri)	56%	224	8%
7	Newly introduced crops (Black pepper)	100%	48	2%
8	Paddy drum seeding Technology	7%	171	7%
Technology adoption rate (%)			**71.95%**	
Weighted Adoption rate (%)			**75.64%**	

5.1.1. Promotion of improved kitchen garden technology

Social and demographic information

Table 6 presents a summary of the distribution of the sampled population across two dzongkhags. Approximately 48.8% of the sampled population were from Dekiling (25%) and Gakidling (20.8%) Gewogs in Sarpang dzongkhag, while 54.4% were from Tendu (20.8%), Sangngacholing (18.8%), and Yoseltse Gewogs (14.6%) in Samtse dzongkhag. Notably, 75% of the respondents were farmers with over 10 years of farming experience, 18.8% had 5-10 years of experience, and 6.3% had less than 5 years of experience. Additionally, more than half of the respondents were female (54.2%) compared to male (45.8%).

Table 6 Survey respondents under promotion of kitchen garden

Dzongkhag	Gewog	No. of respondents	N count (%)
Sarpang	Dekiling	12	25.0
	Gakidling	10	20.8
Samtse	Sang-ngacholing	9	18.8
	Tendu	10	20.8
	Yoeseltse	7	14.6
Total		**48**	

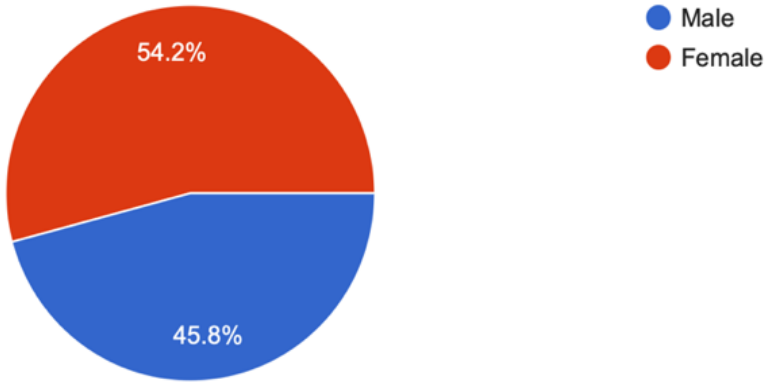

Figure 1 Respondents gender in percentage.

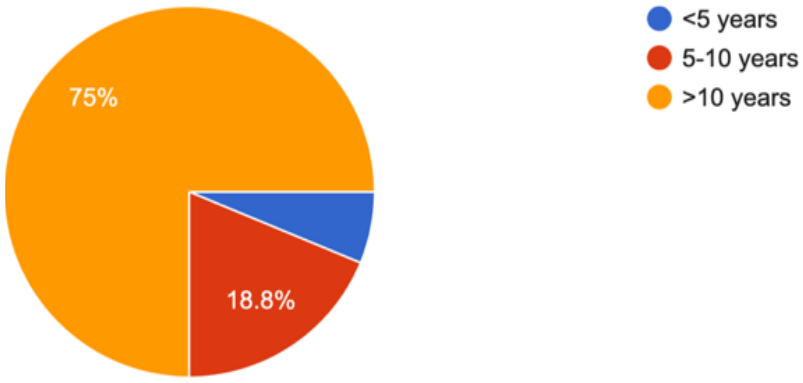

Figure 2 Farming experience of respondents in years

5.1.2. Inputs supported as package

As part of climate-smart agriculture technologies, various inputs such as mulching plastic, improved seed varieties, seedlings, irrigation equipment, drip irrigation, fencing nets, poly houses, and GI staking wire were promoted. This input support was complimented by training and demonstration programs to promote improved agricultural practices in the field. Respondents rated poly houses, fencing nets, seeds, seedlings, and training and demonstration on improved kitchen garden as extremely useful.

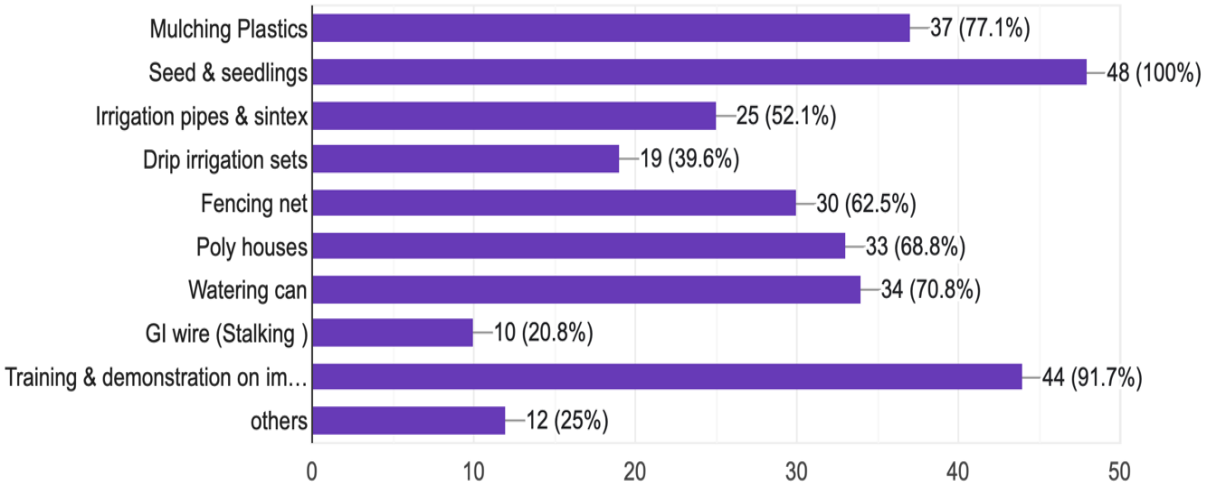

Figure 3 Types of inputs received as part of improved kitchen garden promotion

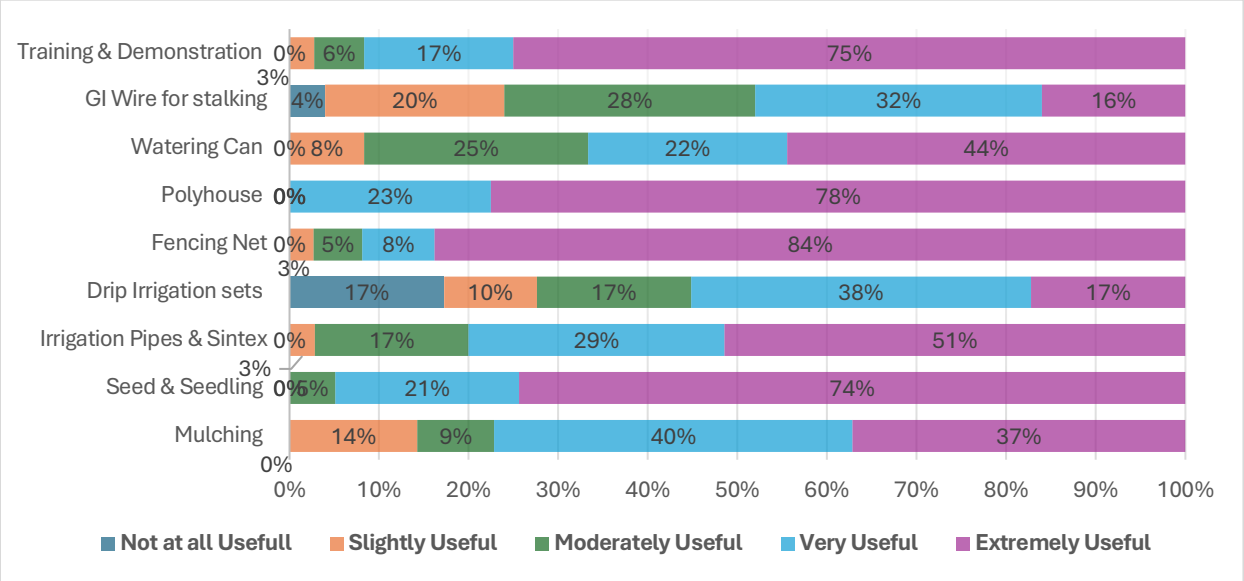

Figure 4 Farmers preference for different inputs supplied based on the usefulness in field

5.1.3. Adoption rate for improved kitchen garden

Adoption of improved kitchen garden refers to any individual household that has maintained their kitchen garden following the recommended packages of practices and technologies on at least two decimals of land after participating in the promotional program. Following the demonstration program, all beneficiaries (100%) adopted the improved kitchen garden technology practices. The size of kitchen garden maintained by the individual households varied from 16-40 decimals, with an average size of 24 decimals. Farmers cultivated a variety of vegetables, such as chili, beans, cauliflower, broccoli, bitter gourd, tomato, lady finger(okra), leafy greens, cucumber, and pumpkins.

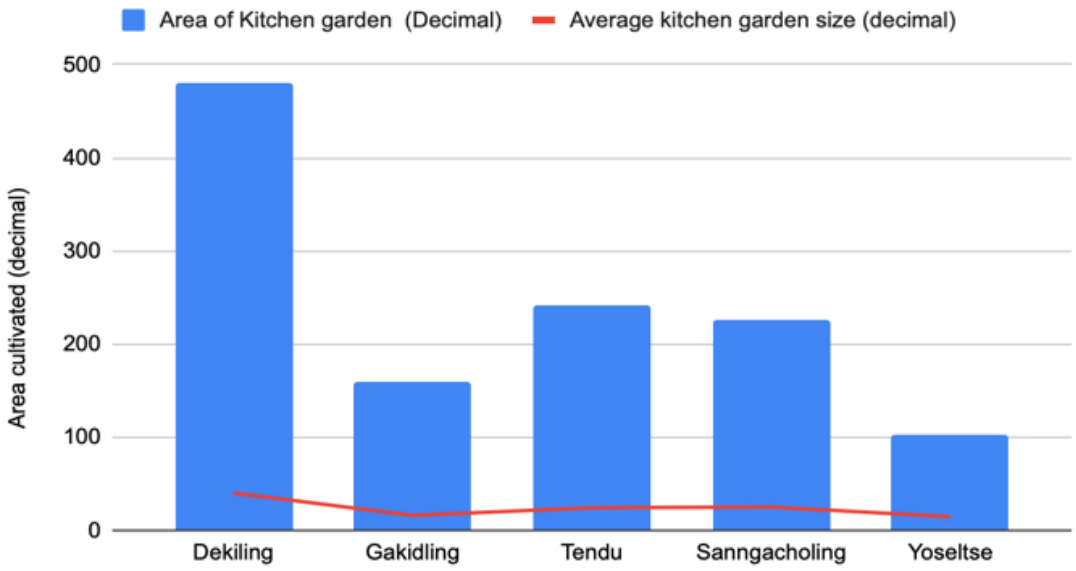

Figure 5 Kitchen Garden cultivated area and average size of kitchen garden maintained in previous cropping season

5.1.4. Adoption rate for different technologies promoted under kitchen garden.

i. Plastic mulch technology

The survey revealed that approximately 91.7% of the farmers adopted the plastic mulch technology following its promotion. A previous study conducted in 2019 indicated that at the farmers' level, vegetable cultivation with plastic mulch reduced the labor required for weeding by 55.65% and the number of weeding instances by 50.58%, as shown in Table 7. The use of plastic mulch was found to have a relative advantage in reducing the labor required for weeding and watering, in addition to enhancing soil moisture conservation and easing other intercultural operations. About 90% of the surveyed farmers agreed that the use of plastic mulch contributed to increased vegetable yield, as shown in Figure 6.

Table 7 Labor saving by use of plastic mulching at farmer's level

Operations	Mean	SD
No. of labour involved in plastic mulching (man-days)	10.23	8.30
No. of labour involved in weeding with mulch (man-days)	4.39	3.65
No. of labour involved in weeding without mulch (man-days)	9.90	9.28
No. of weeding with plastic mulch	3.39	1.12
No. of weeding without plastic mulch	6.86	3.88

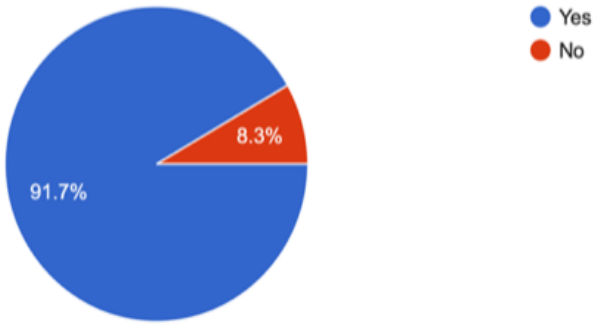

Figure 7 Adoption rate of plastic mulch technology

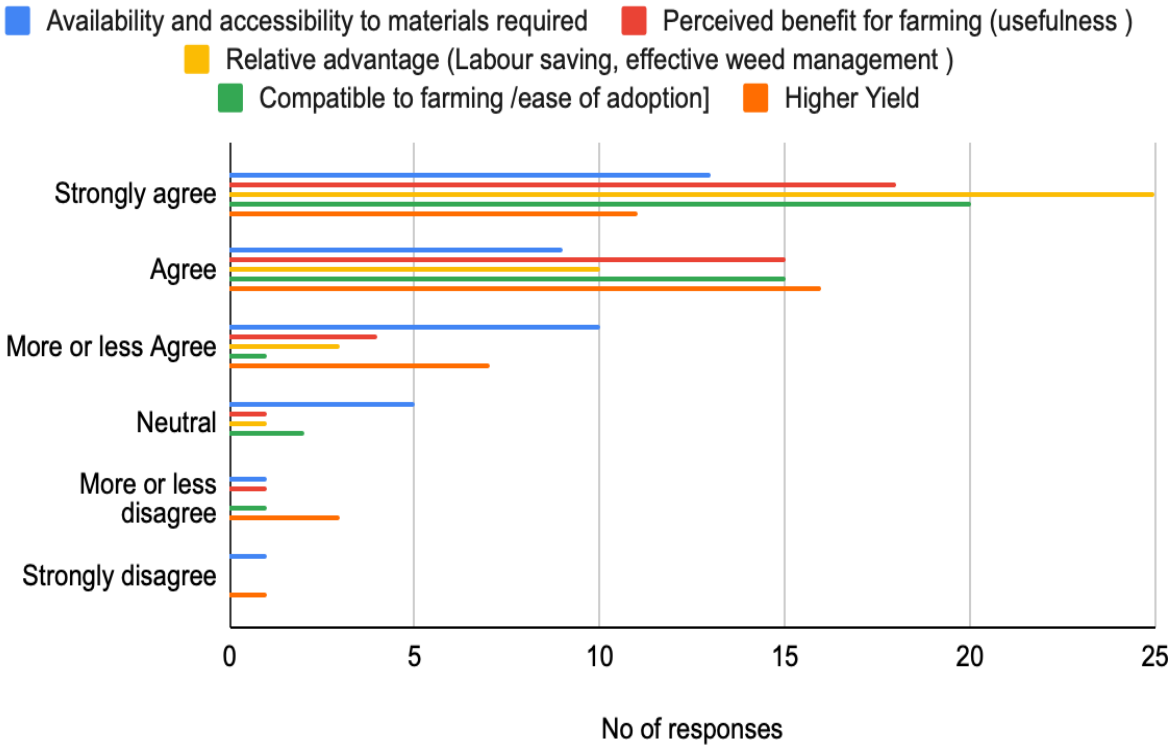

Figure 6 Factors influencing decision for adoption of plastic mulch technology

ii. Drip irrigation technology

The survey results show that the adoption rate of drip irrigation technology was 56.3%. More than 50% of the respondents adopted drip irrigation technology due to its relative advantages of better water use efficiency, labor-saving, and increased crop productivity. However, the requirement for skilled labor for installation and the high initial setup cost were some of the reasons for not adopting the drip irrigation technology.

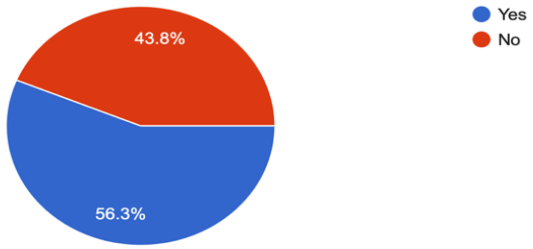

Figure 8 Adoption rate for Drip irrigation technology

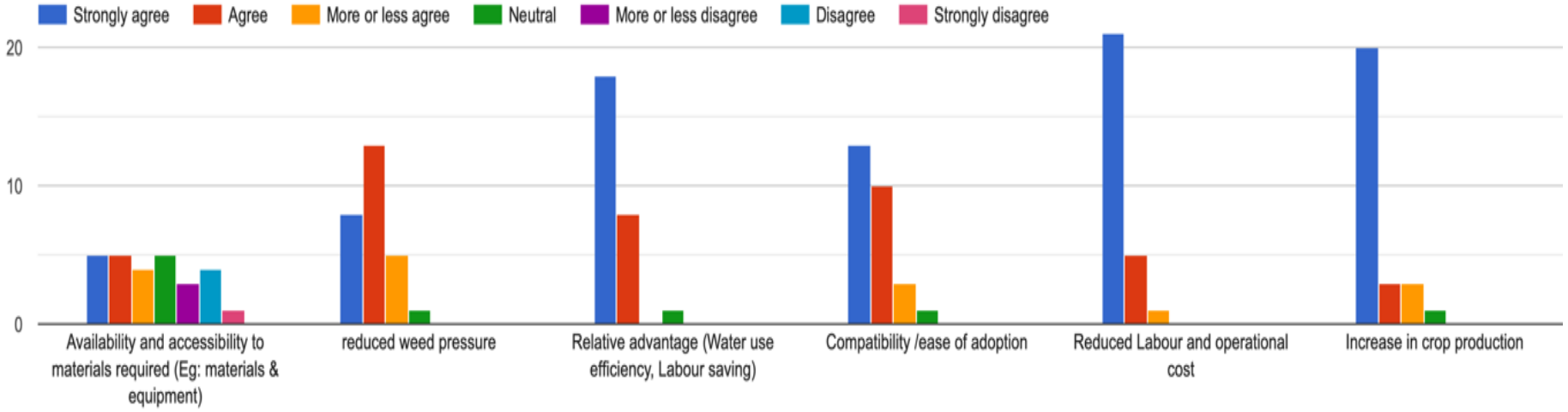

Figure 9 Factors influencing decision to adopt drip irrigation technology

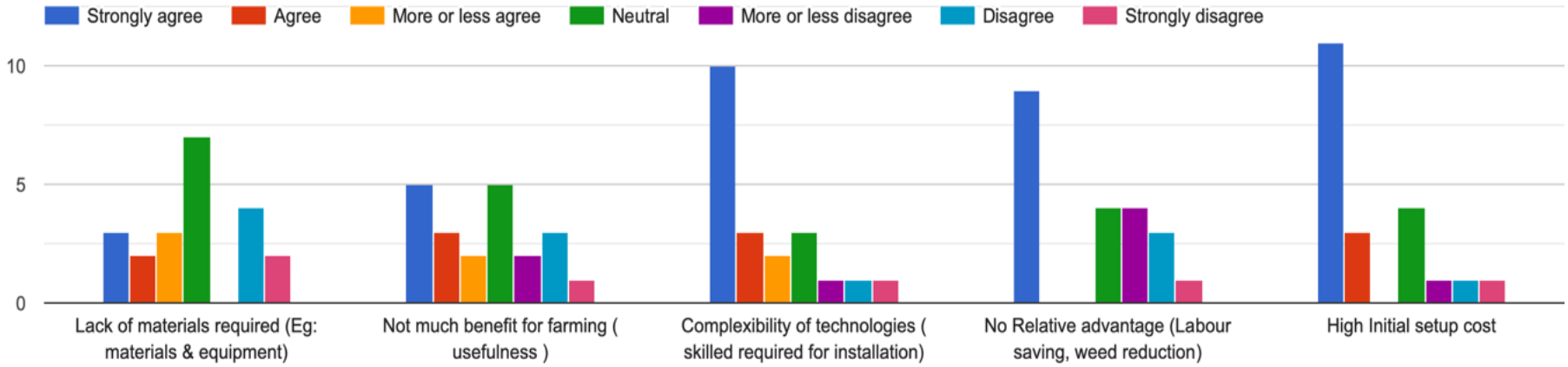

Figure 10 Factor influencing decision for not adopting drip irrigation technology

iii. Protected Agriculture Structures

Protected agriculture structures (polyhouses) were promoted to enhance vegetable production. Heavy rainfall during the summer is a significant challenge for vegetable production in the foothills. To address this, side- and top-ventilated polyhouses were promoted for off-season vegetable production to enhance vegetable self-sufficiency at the household level. Polyhouses were supplied with other inputs, such as drip irrigation systems and fencing sets, as part of a package. The study revealed that the adoption rate of polyhouses was 100% in Samtse and Sarpang Dzongkhags.

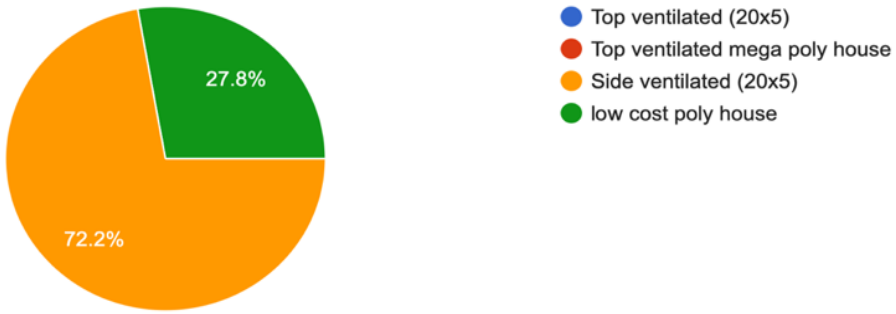

Figure 11 Type of polyhouses promoted

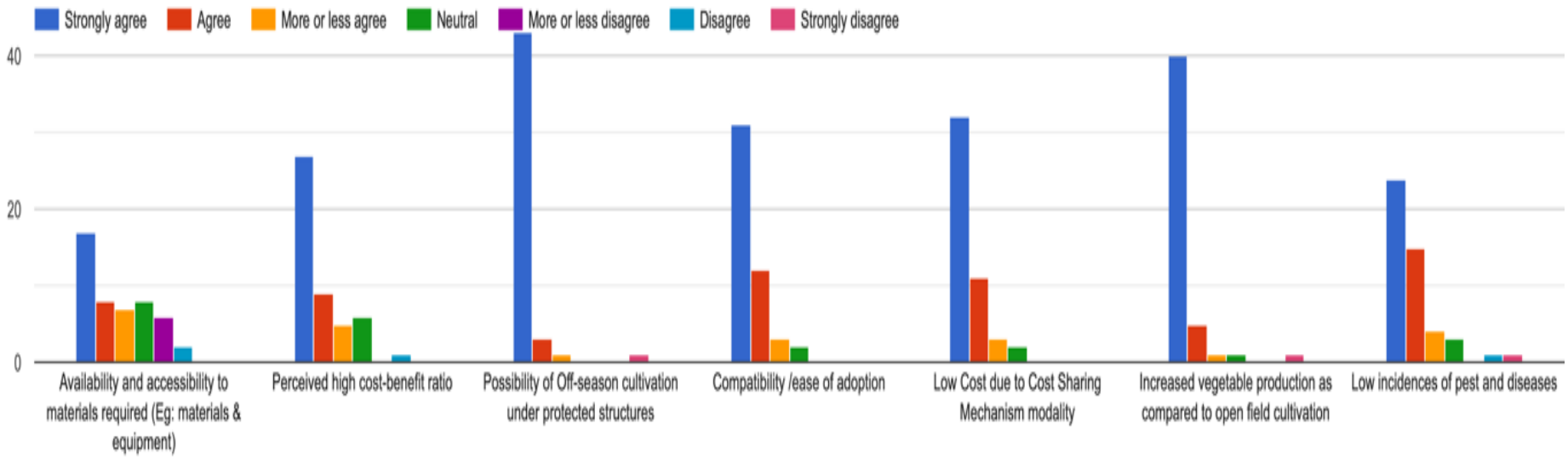

Figure 12 Factors influencing adoption of polyhouse

iv. GI Wire staking technology

As an improved package of technologies, the staking method using GI wire and split bamboo of recommended length was promoted for crops like beans, cucumber, and bitter gourd. The adoption rate of GI staking was found to be 66.7%, with 33.3% being non-adopters.

v. Fencing net

Fencing net was one of the most adopted inputs from the package of improved kitchen garden technology, with an adoption rate of 97.9%. A primary reason for this high adoption rate is their effectiveness in reducing crop damage caused by both wild and domestic animals. The reason for adoption and factors influencing its adoption are given in Figure 13 and Figure 14, respectively.

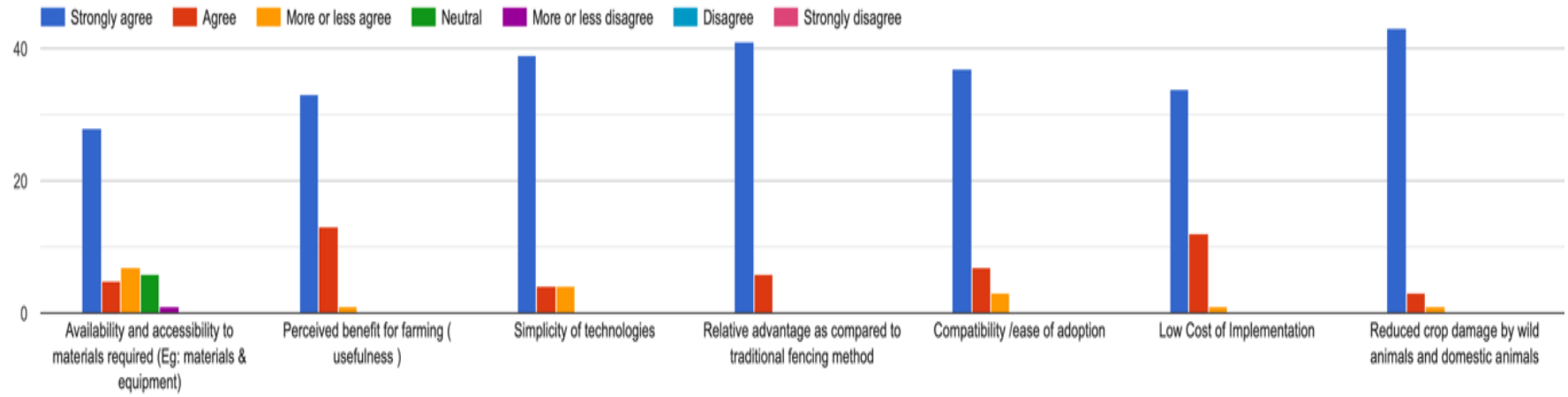

Figure 13 Reason for adoption of fencing net

5.1.5. Paddy drum seeder

Direct seeding in paddy is a widely adopted technology in western rice-growing areas and various parts of Asia. This technology is known for its labor-saving benefits and feasibility in water-scarce areas, making it an efficient alternative to labor-intensive paddy transplanting systems. The practice of direct seeding in puddled fields has been refined and tested by the Agriculture Machinery Centre and ARDC Samtenling, which have experienced both successes and failures, leading to the refinement of drum seeding in the local context. In 2017, 53% of our farming communities identified labor shortages as one of the most significant constraints for agricultural production in Bhutan, highlighting the need for labor-saving technologies. Direct seeding is particularly promising in the southern part of Bhutan. Research by ARDC Samtenling revealed that drum seeding requires 42% less labor than traditional transplantation methods, with no significant difference in yield between the two methods. To promote this technology, a field day and demonstration on paddy direct seeding under FSAPP were conducted by Regional Agriculture Machinery Centre (RAMC) and ARDC, Samtenling, at Shompangkha, Samtenling, and Dekiling in Sarpang, benefiting a total of 28 farmers. During the field day, 184 farmers participated in the program. The reasons for the non-adoption of paddy drum seeding technology included several drawbacks: the labor cost for field leveling, higher weed pressure, bird attacks on crops due to early maturity, and plant lodging due to poor rooting.

Table 8 Total area and number of beneficiaries of drum seeding technology promotion.

Dzongkhag	Gewog	No of beneficiaries	Area demonstrated (acre)
Samtse	Sanngacholing	11	16.45
	Norbugang	1	1.12
	Dophuchen	1	0.60
	Tendu	1	0.20
Sarpang	Gakidling	3	3.00
	Tareythang	4	2.20
	Dekiling	7	4.81
Total		**28**	**28.38**

Table 9 No of participants who attend the paddy drum seeding demonstration (by gewog and gender)

Financial Year	Gewog	Technology demonstration Participants		
		Male	Female	Total
2018-2019	Dekiling	6	18	24
2018-2019	Gakidling	41	33	74
2018-2019	Samtenling	36	25	61
2018-2019	Shompangkha	14	11	25
Total		**97**	**87**	**184**

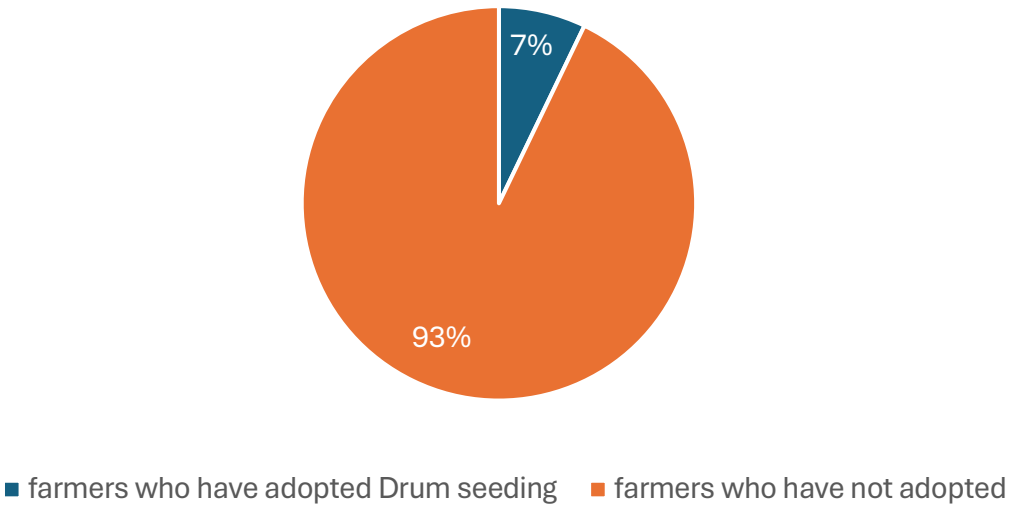

Figure 14 Adoption rate of paddy drum seeding technology under Sarpang and Samtse

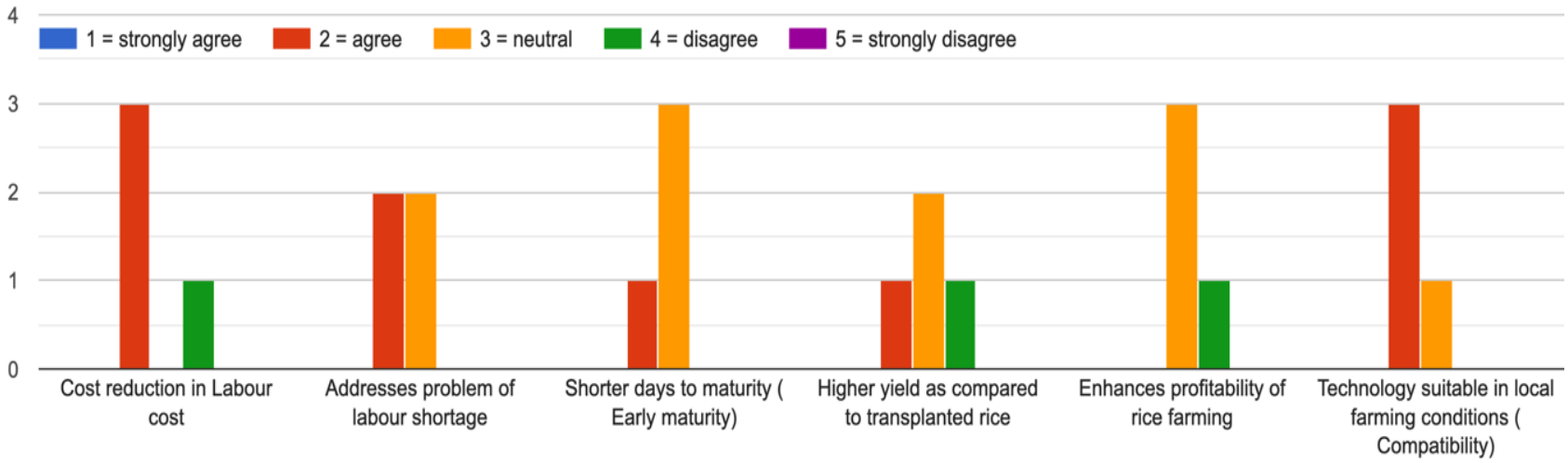

Figure 15 Reasons for adoption of paddy drum seeding technology

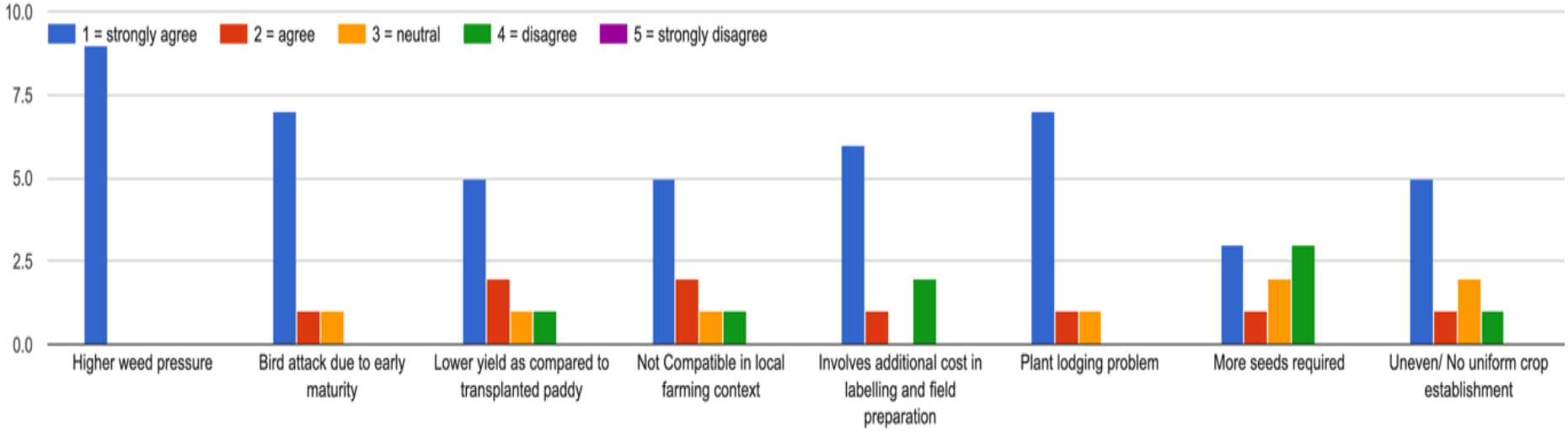

Figure 16 Reasons for non-adoption of paddy drum seeding technology

5.1.6. Promotion of introduced crops.

i. Black pepper

Black pepper has been identified as a potential cash crop, leading the Agriculture Research and Development Centre (ARDC) to initiate its promotion as an intercrop in areca nut plantations. This initiative is also a key focus of the Department of Agriculture. As part of the promotional activities, interested beneficiaries were provided with black pepper seedlings, as detailed in Table 10. Additionally, demonstrations on the cultivation and management of black pepper were conducted. In Sarpang, a total of 1,696 seedlings were supplied to five gewogs, resulting in a total cultivated area of approximately 12.25 acres. Similarly, in Samtse, about 2,336 seedlings were distributed across two gewogs, with an expected plantation area of 16.05 acres. The adoption rate for black pepper has been 100%, as all beneficiaries have successfully planted the seedlings, making this newly introduced crop a promising addition for crop intensification for enhance income. The promotion of black pepper carried out in Sarpang and Samtse since 2018-19 FY is given in Table 11.

Table 10 Black pepper adoption rate in Sarpang & Samtse

Gewog	No of households reached	No of HHs adopted	Adoption %
Samtenling	11	11	100%
Sompangkha	24	24	100%
Tading	7	7	100%
Average			**100%**

Table 11 Promotion of black pepper since 2018-19 FY in Sarpang & Samtse

Dzongkhag	Gewog	Financial Year						Total seedling (No)	Total area (acre)
		2018-2019		2019-2020		2023-2024			
		Seedling (No)	Area (acre)	Seedling (No)	Area (acre)	Seedling (No)	Area (acre)		
Sarpang	Samtenling	300	2.10	210	1.75	0	0.00	510	3.85
	Dekiling	300	1.80	40	0.50	0	0.00	340	2.30
	Sompangkha	0	0.00	40	0.50	736	4.60	776	5.10
	Tareythang	0	0.00	35	0.50	0	0.00	35	0.50
	Gakidling	0	0.00	35	0.50	0	0.00	35	0.50
Samtse	Tading	600	3.30			0	0.00	600	3.30
	Norbugang	0	0.00	40	0.50	0	0.00	40	0.50
Total		**1200**	**7.20**	**400**	**4.25**	**736**	**4.60**	**2336**	**16.05**

ii. Improved paddy varieties

The ARDC Samtenling has released five improved paddy varieties for sub-tropical regions, but their adoption rates have been moderate due to the medium to shorter plant height and modest taste. To address this, the evaluation of two promising varieties, DG-11 & Mahsuri, was initiated based on yield and agronomic parameters, including organoleptic preference. Through FSAPP, these two paddy varieties were promoted via on-farm demonstration or field day. In Sarpang and Samtse, a total of 57.3 acres were cultivated with Mahsuri from 1,032 kg of seed, benefitting 66 farmers. In addition, 1270 kg of DQ-11 seed was supplied, covering 55.9 acres, as shown in Table 12. The average adoption rate for these two improved varieties was 56%, calculated by dividing the number of farmers who attended the field day or demonstration program by the number of farmers who cultivated the improved varieties in the following seasons.

Table 12 Adoption rate for improved rice varieties (DQ-11 & Mashuri)

Gewog	No of participants for demonstration/field day	HHs growing the improved varieties	Adoption %
Gakidling	27	9	33%
Samtenling	19	11	58%
Dekiling	60	46	77%
Tading	12	10	83%
Yoseltse	31	9	29%
Average Adoption %			**56%**

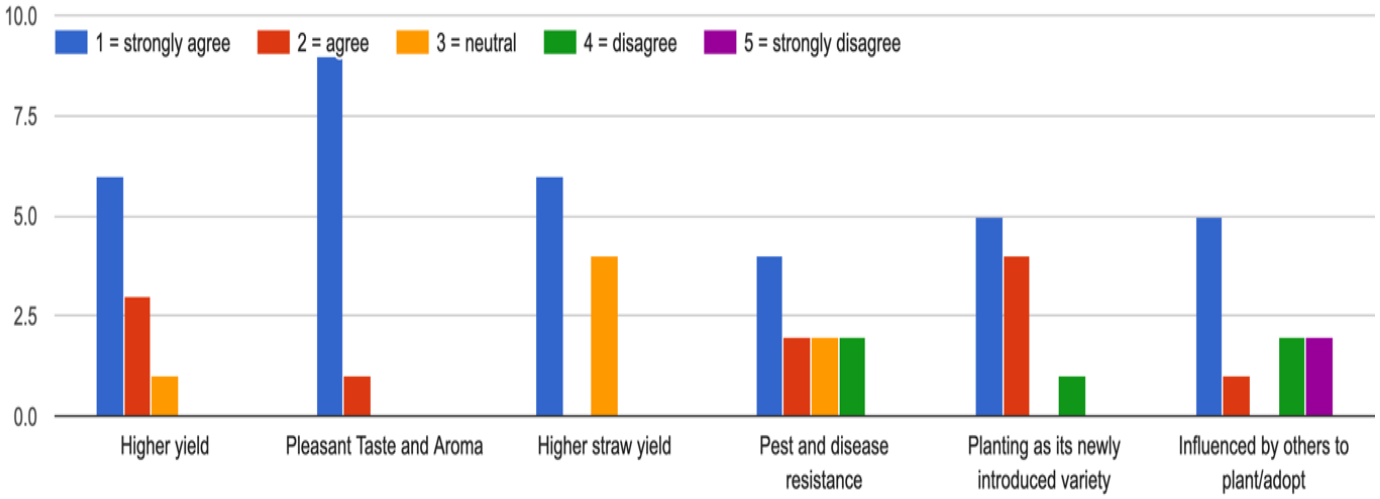

Figure 17 Reason for adoption of improved rice varieties (DQ-11 & Mashuri)

5.2. Technology adoption rate under NCOA Yusipang

The study revealed that the overall adoption rate for technologies promoted by NCOA Yusipang in the Chhukha and Haa regions was 61.79%, closely aligning with the weighted adoption rate of 62.00%. The highest adoption rate was observed for Yusi Maap, with an impressive 83.30%, while quinoa had the lowest adoption rate at 25.00%. For other technologies, more than half of the beneficiaries (>50%) have adopted the promoted technologies, as detailed in Table 13.

Table 13 Summary table of technology adoption rate under NCOA Yusipang

#	Technology Promoted	Adoption rate from survey (%)	Total HHs beneficiary	% Share of beneficiary
1	Promotion of improved potato (Yusi Maap) variety	83.30	287	20%
2	Promotion of newly introduced high value crop (Quinoa)	25.00	123	8%
3	Promotion of soil fertility and Plant Protection Technologies	67.50	319	22%
4	Demonstration of Nutritional Gardening	79.00	99	7%
5	Demonstration and Promotion of Protected cultivation	54.15	636	43%
Overall Technology adoption percent (%)			**61.79%**	
Weighted Adoption rate (%)			**62.00%**	

5.2.1. Socio demographic information

Table 16 summarizes the socio-demographic characteristics of the surveyed population. Majority of respondents are from Chhukha (55.6%) and are female (70.4%). The average age of respondents was 47.11 years (range of 45.00 to 58.39 years). For education, a significant portion has no formal qualifications (37.0%), while others have completed non-formal primary level education (33.3%) or high school to higher secondary education (29.6%).

5.2.2. Distribution of technologies across Chhukha

Table 17 provides a comparative overview of the adoption of various agricultural technologies in the Chhukha and Haa Dzongkhags. In Chhukha, there is no adoption of improved potato and quinoa cultivation technologies. The highest adoption rate is observed for plant protection and soil fertility management technologies at 50.0%. The newly introduced potato variety "Yusimaap" is not grown by Chhukha farmers due to marketing and storage issues. Nutritional gardening technologies are well-adopted at 68.2%, while protected cultivation technologies have a 35.7% adoption rate. Conversely, in Haa, improved potato and quinoa cultivation technologies have full adoption (100.0%). Plant protection and soil fertility management technologies are adopted by 50.0% of respondents. Nutritional gardening technologies have a 31.8% adoption rate, and protected cultivation technologies are adopted by 64.3% of respondents.

Table 14 Socio demographic variable of survey respondents

		Column %	N count	Mean	Range	Std. Deviation
Dzongkhag	Chhukha	38%	19			
	Haa	62%	31			
villages	Kana	62%	31			
	Sonamthang	38%	19			
Gender	Male	29.6%	15			
	Female	70.4%	35			
Age				47.11	45.00	13.39
Qualification	None	37.0%	18			
	Nonformal-primary level	33.3%	17			
	Highschool-Higer secondary	29.6%	15			
	University	0.0%	0			

Table 15 Distribution of technologies across Haa & Chhukha

Technology	Dzongkhag	
	Chhukha % Distribution	Haa % Distribution
Promotion of improved potato cultivation	0.00%	100.00%
Promotion of Quinoa cultivation	0.00%	100.00%
Promotion of plant protection & soil fertility management	50.00%	50.00%
Promotion of nutritional gardening	68.20%	31.80%
Promotion of protected cultivation	35.70%	64.30%

5.2.3. Adoption of improved crop varieties

i. Yusi Maap variety

Table 16 indicates the proportion of respondents who cultivated the Yusi Maap variety in Kana village, Haa. A large majority of respondents (83.3%) cultivated the Yusi Maap potato variety, while 16.7% did not. Among the perceived benefits, 100% of respondents agreed that Yusi Maap provides a good yield and is resistant to pests and diseases. However, the lowest agreement was observed for the benefits of increased income and ease of maintenance. Additionally, 17.1% of respondents noted that cultivating Yusi Maap encouraged other farmers to grow the same variety as shown in Table 17.

Table 16 The continuity of Yusi Maap variety promoted

		Percent	Valid Percent	Cumulative Percent
	No	16.7	16.7	16.7
Valid	**Yes**	83.3	83.3	100.0
	Total	100.0	100.0	

Table 17 Perceived Benefits of Yusi Maap

		Responses Percent
Benefits of Yusi Maap[a]	Increased in Income	22.2%
	Gives Good Yield	100.0%
	Less Crop Loss	33.3%
	Easy to Maintain	11.1%
	Other farmers are also encouraged	55.6%
	Less Pest and Diseases incidences	100.0%
Total		322.2%

a. Dichotomy group tabulated at value 1.

ii. Quinoa

The overall quinoa adoption rate in Chhukha and Haa stood at 75%, with 25% of farmers choosing not to grow the crop. As indicated in Table 18, key challenges contributing to non-adoption include a lack of knowledge on its utilization and limited market demand, each accounting for 49.2%. Additionally, 14.3% of farmers cited farm labor shortages as a reason for not adopting quinoa cultivation.

Table 18 Perceived challenges for adopting quinoa cultivation.

		Responses Percent
Challenges in adopting quinoa technology	Limited knowledge on utilization.	42.9%
	labour shortage	14.3%
	Lack of market demand	42.9%
Total		100.0%

a. Dichotomy group tabulated at value 1.

5.2.4. Plant protection and soil fertility management technologies.

Organic fertilizers such as jeevamrut (Rangzhi Luechu), heap composting, biodigester, jholmol 1 and jholmol 2 for soil fertility management. Jholmol 3 (Rangzhin Bupmen), neem oil, ginger-garlic extract, were promoted as plant protection technologies for organic pest management. 61% of total respondents were found to be practicing soil fertility management and plant protection technologies as shown in Figure 19. The perceived benefits of these technologies are shown in Table 19.

Table 19 Perceived benefits of Soil fertility management & Plant protection technologies

		Responses Percent
Benefits of soil fertility & plant protection technologies	Increase income	3.8%
	Good yield	15.4%
	Inexpensive	19.2%
	Easy maintenance	3.8%
	Less pest and diseases	15.4%
	Improved soil water	19.2%
	Control weeds	23.1%
Total		100.0%
a. Dichotomy group tabulated at value 1.		

The key limiting factors for the adoption of these technologies, as shown in Table 20, were a strong reluctance to change traditional or conventional practices (40%) and a shortage of labor (40%). Additionally, 10% of respondents had recently received training and had not yet implemented the technologies, while another 10% cited the unavailability of necessary inputs.

Table 20 Challenges in practicing the soil fertility management and plant protection technologies

		Responses Percent
Challenges in practicing the plant protection and soil fertility management technologies	Received the trainings recently	10.0%
	Reluctant to change traditional practice	40.0%
	Labor shortage	40.0%
	Inputs not available	10.0%
Total		100.0%
a. Dichotomy group tabulated at value 1.		

5.2.5. Nutritional Gardening technology

As part of the nutritional gardening initiative, inputs such as seeds, irrigation equipment (sprinklers and flexible pipes), and green shed nets were provided. In Kana village, Eusu gewog, Haa, 58.3% of respondents adopted the technology, whereas in Sonamthang village, Sampheling gewog, Chhukha, adoption was at 100%. The perceived benefits of nutritional gardening, as shown in Table 21, included increased income (10%), food diversity (40%), good market demand (40%), and improved taste (10%). These findings indicate that respondents view nutritional gardening as a significant intervention pertaining to nutrition and food diversity.

Table 21 Perceived benefits of Nutritional Gardening Technology

		Responses Percent
Benefits of Nutritional Gardening Technology	Increased in Income	10.0%
	Food Diversity	40.0%
	Good Market demand	40.0%
	Better test	10.0%
Total		100.0%

a. Dichotomy group tabulated at value 1.

5.2.6. Protected cultivation technologies

The study observed that the protected cultivation technologies were adopted by 75% of respondents in Kana Village, Eusu Gewog, in Haa, and by 33.3% in Sonamthang Village, Sampheling Gewog, in Chhukha. Table 22 outlines the perceived benefits of these technologies among respondents, which include increased income (9.7%), good yield (19.4%), easy maintenance (6.5%), encouragement for other farmers (16.1%), reduced pest and disease incidences (12.9%), the ability to grow in the off-season (22.6%), and fewer weed issues (12.9%).

Table 22 Perceived benefits of protected agriculture technology

		Responses %
Benefits of protected cultivation technologies	Increased in Income	9.7%
	Good yield	19.4%
	Easy maintenance	6.5%
	Other farmers are also encouraged	16.1%
	Less Pest and Diseases incidences	12.9%
	Can grow in off season	22.6%
	Less weed issues	12.9%
Total		100.0%

a. Dichotomy group tabulated at value 1.

5.3. Technology adoption rate under ARDC Bajo

The study revealed an overall adoption rate of 82.60% for technologies promoted by ARDC Bajo in the Dagana region, with a weighted adoption rate of 81.90%. All beneficiaries of electric fencing using HDPE poles and climate-smart technologies adopted the technologies (100%). However, 46% of beneficiaries trained in oyster spawn and mushroom production adopted or continued mushroom production. The adoption rates for low-cost water harvesting technology and citrus canopy management were 89% and 78%, respectively, as shown in Table 23.

Table 23 Summary table of technology adoption rate under ARDC Bajo

SL	Technology Promoted	Adoption rate from survey (%)	Total HHs beneficiary	% Share of beneficiary
1	Climate smart technologies (package)	100	47	7
2	Low-cost water harvesting technology	89	250	38
3	Electric fencing using HDPE poles	100	12	2
4	Citrus Canopy Management	78	306	46
5	Mushroom Cultivation	46	46	7
Overall Technology adoption percent (%)			**82.60%**	
Weighted adoption rate			**81.90%**	

5.3.1. Promotion of climate smart technologies

ARDC Bajo, in collaboration with Dagana Dzongkhag, initiated a Youth Skilling Program on Climate Smart and Improved Agriculture Technologies at ARDC Bajo. The training was conducted in batches over a period of 10 days. This intensive program covered the following technologies.

i. Demonstration and hands-on training in preparation of following organic inputs:
   - Risk husk biochar
   - Fermented rice bran Bokashi
   - Bhutan Agri-microbial solution
   - Fermentation of cattle urine using BAMS
   - Open air biochar preparation
   - Vermicomposting
   - Azolla production

ii. Integrated Pest and Disease Management technologies

iii. Protected agriculture including hydroponics

iv. Improved crop production technologies
   - Mushroom cultivation and spawn production
   - Use of improved potting media and commercial vegetable production
   - Fruit crops cultivation covering orchard designing or layout, planting methods, and grafting techniques.

The skilling program achieved a 100% adoption rate for one or more of the imparted technologies. Among the climate-smart technologies studied, the highest adoption was seen for rice husk biochar, with 56.1% of participants using it. This was followed by open-air biochar and improved potting methods, each adopted by 46.3% of participants. Commercial vegetable production, utilizing fermented rice bran bokashi, was adopted by 41.5% of respondents. The lowest adoption rate was observed for vermicomposting, with only 4.8% of participants adopting this method. This data is illustrated in Figure 18.

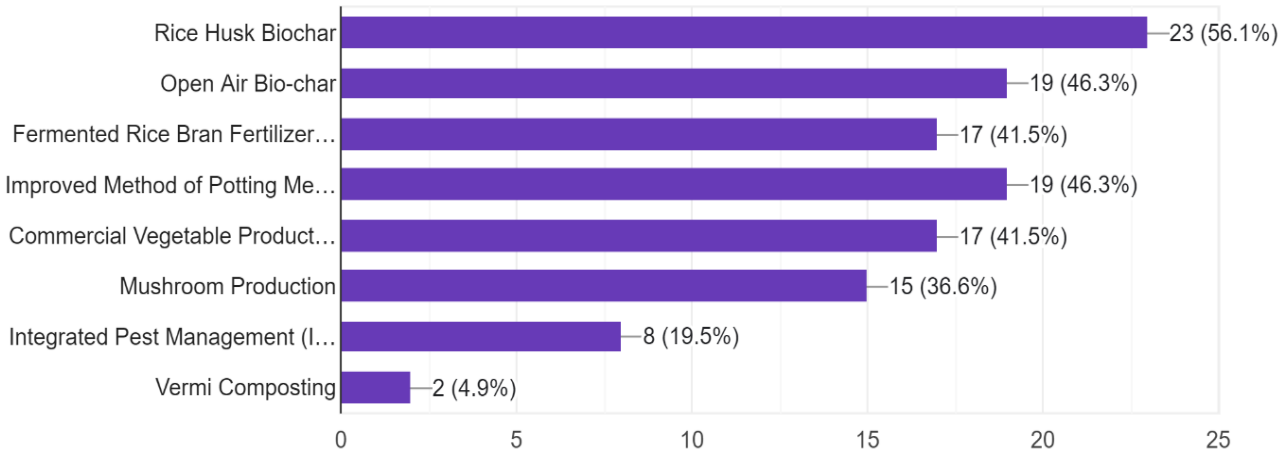

Figure 18 Adoption rate for climate smart technologies

The low cost of implementation (51.2%) emerged as a primary factor influencing the adoption of climate-smart technologies, as depicted in Figure 19. Unlike other regions, the availability of materials had minimal impact on the adoption of technologies by participants in the skilling program.

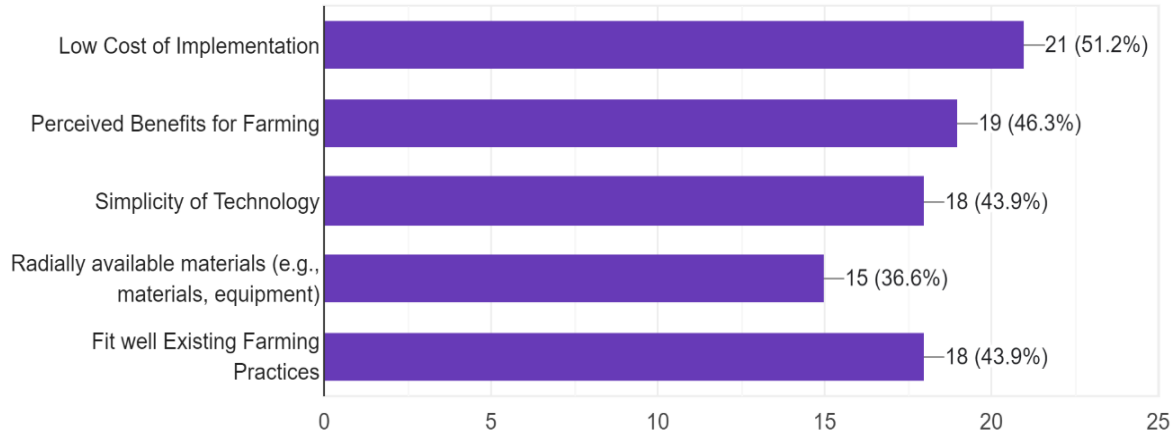

Figure 19 Factors influencing the adoption of climate smart technologies

5.3.2. Promotion of low-cost water harvesting technology

Crop production in Bhutan faces significant challenges due to the scarcity of irrigation water. Despite ample summer rainfall, the lack of suitable water harvesting technology leads to underutilization of rainwater and runoff. To combat this, ARDC Bajo promoted and supported the adoption of low-cost plastic-lined water harvesting ponds, using 300 GSM plastic sheets, to store water for agricultural and household use during the dry season. Farmers in the project gewogs have eagerly adopted it, marking a success story. ARDC Bajo provided hands-on training and demonstrations on installing these ponds, contributing to their widespread adoption and effectiveness. To evaluate the adaptability and impact of this technology, ARDC Bajo conducted a quick social study, confirming its successful integration into farming practices.

Table 24 Participants for installation of low-cost water harvesting ponds

Gewog	Male	Female	Total HHs
Drukjegang	13	37	50
Kana	12	8	20
Nichula	2	14	35
Karmaling	25	15	40
Lhamoizingkha	0	0	0
Total	71	74	145

In Dagana's project gewogs, 250 households established low-cost plastic water harvesting ponds with project support. Of the 286 ponds constructed, 254 (89%) were functional, while 32 became defunct due to rodent damage, water seepage, soil erosion, and complete removal. The damaged ponds were replaced with new silpaulin sheets. These ponds are filled with tap water during night hours, as well as stream water and rainwater, and are used for irrigating vegetable fields and orchards during dry seasons, as well as meeting the needs of livestock. A significant issue with this technology is water seepage, primarily caused by rodents, leading to drainage problems. Additional risks include the ponds becoming potential mosquito breeding sites and the danger of animals getting trapped.

5.3.3. Promotion of Electric fencing using HDPE poles

Human-Wildlife Conflict (HWC) poses a significant challenge to Bhutan’s food security and conservation efforts. In Pungshi, Dagana, substantial crop damage has been reported due to depredation by wild animals. Recognizing the effectiveness of electric fencing in deterring vertebrate pests, ARDC Bajo promoted the use of electric fencing with HDPE poles, an alternative to the conventional wooden poles. A demonstration project benefiting 12 households was established, covering 35 acres with a 2.6 km perimeter in Pungshi village, Kana gewog, Dagana. The demonstration area was selected based on the intensity of recent crop depredation and the economic status of the beneficiary farmers.

The study showed that HWC was effectively addressed, leading to a 63% increase in cultivated area and over 83% of villagers diversifying into new crops. Production of main crops increased by 62-80% due to a significant reduction in crop depredation by wild animals. Respondents reported negligible damage from monkeys after the establishment of the HDPE electric fences. Despite the higher initial cost compared to conventional wooden posts, the durability and low maintenance costs of HDPE poles were highlighted as key benefits.

Promotion of Improved Crop Production Technology – Citrus Canopy Management

Citrus ranks top among Bhutan's agricultural export commodities in terms of both volume and value. However, citrus cultivation practices remain traditional, leading to very low yields and inferior fruit quality. The citrus industry in Bhutan has been gradually declining due to the emerging citrus greening disease. Orchard activities such as canopy management, nutrition, and irrigation have been low priorities for most citrus farmers, resulting in a rapid decline in production. Citrus canopy management is a proven technique for maximizing fresh fruit yield, quality, and profitability. To address this, ARDC Bajo, in collaboration with Dagana Dzongkhag, conducted a canopy management campaign in Drujegang and Kana gewogs. This campaign aimed to provide hands-on training to citrus growers on managing citrus orchards. The canopy management package included pruning, basin making, irrigation trenches, fertilizer application, Bordeaux paste application, and subsequent follow-up activities.

Out of 306 orchards in the two gewogs (Kana and Drujegang), 235 have been managed technically. The adoption rate of this technology was found to be 78%. Farmers reported notable improvements in the growth of their citrus plants following the canopy management program. In addition to increased productivity, there was a noticeable enhancement in the quality and size of the fruits from the managed orchards. The adoption of citrus canopy management technology for different gewogs under Dagana is given in Table 25.

Table 25 Adoption of Citrus Canopy Management in Dagana

Gewog	No. of orchards	No. of managed orchards	Adoption rate %	Remarks
Kana	106	85	80	Information collected
Drukjegang	200	150	70	through Gewog extensions
Total	306	235	78	

Figure 20 shows the benefits of citrus canopy management whereby 70.4% reported that the technology improved tree growth through new growth of shoots followed by increased productivity (69.1%).

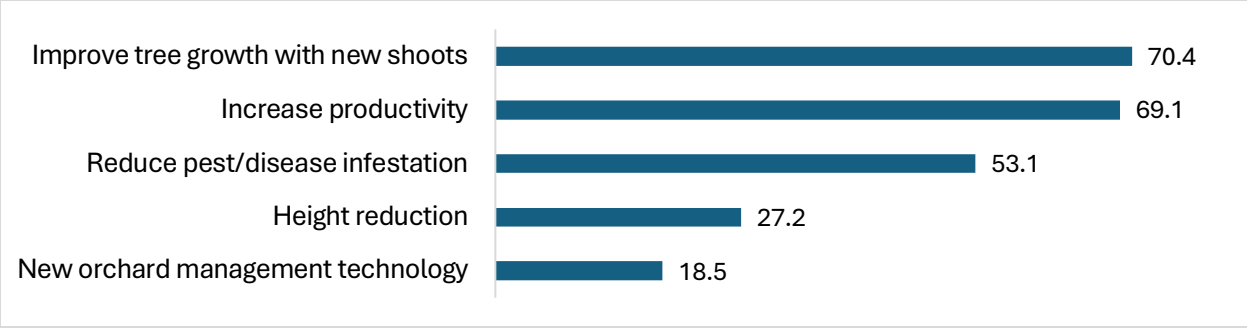

Figure 20 Benefits of citrus canopy management

The promotion program, in addition to canopy management, included trench fertilization, irrigation, basin management, Bordeaux mixture application, and shoot selection. The study revealed that 94.9% of beneficiaries conduct canopy pruning, 72.2% practice trench fertilization, 55.7% irrigate their orchards during dry seasons, 55.7% manage citrus basins, 53.2% apply Bordeaux mixture (paste or spray) in their orchards, and 17.7% practice shoot selection, as shown in Figure 21.

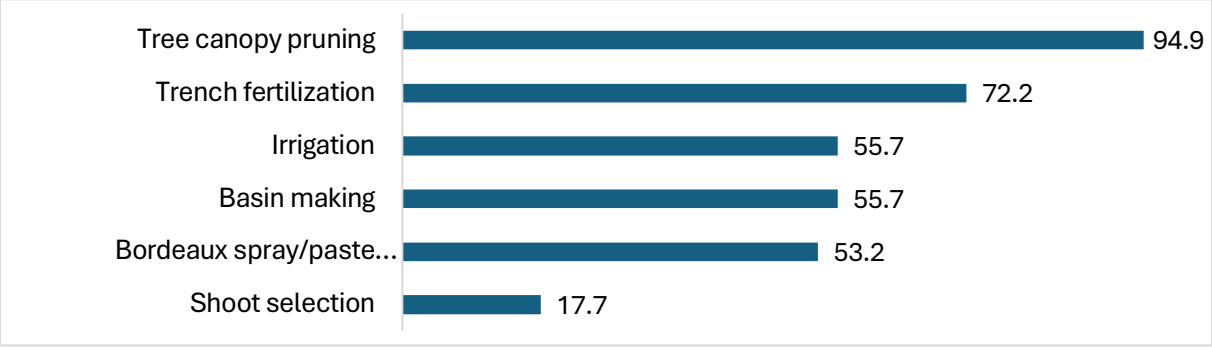

Figure 21 Adoption of practices under Citrus Management

5.3.4. Adoption of Mushroom production

In the fiscal year 2018-19, ARDC Bajo held a week-long training on mushroom cultivation for 46 farmers from the project gewog, focusing on oyster mushroom and spawn production. Post-training, farmers were encouraged to start mushroom cultivation commercially or semi-commercially, with ARDC Bajo and Dzongkhag monitoring their progress. However, many farmers faced challenges due to the COVID-19 pandemic, leading to only 21 remaining actively involved in mushroom production. Of these, five have established semi-commercial enterprises, while the rest engage in backyard cultivation. Challenges reported include difficulties with spawn availability, raw materials, and market access.

6. Policy implications

1. **Promotion of integrated need-based technologies**
   Technologies such as plastic mulch, drip irrigation, and fencing nets have shown a higher rate of adoption when integrated with the promotion of polyhouses and nutrition gardens.

These integrated technologies are highly valued because they reduce farm labor requirements and improve water use efficiency, key factors in their adoption. For instance, the higher adoption rate of citrus canopy management technology is due to the integrated support provided, including water, nutrient, and pest and disease management. Therefore, to enhance the rate of technology adoption, it is essential to promote integrated technology packages.

2. **Sustained advocacy on nutrition or kitchen garden for dietary diversity.**
   The full adoption of nutrition or kitchen gardens can be credited to the effective demonstrations by Agriculture Research and Development Centers (ARDCs) and continuous advocacy on household nutrition through Behavior Change Communication (BCC) and Community Resource Persons (CRPs) of the project. To sustain these initiatives beyond the project period and improve household nutrition and dietary diversity, continuous advocacy is necessary.

3. **Comprehensive research on technology before promotion.**
   Despite the significant labor reduction (42%) achieved with drum seeding technology in paddy, its adoption was hindered due to insufficient research on root development and plant lodging. Similarly, previously promoted rice varieties, which had higher yields than local varieties, were not adopted due to shorter plant height (resulting in reduced straw yield) and preferred taste. Therefore, thorough research on all aspects of a technology is required before promotion to ensure a higher adoption rate.

4. **Market-led production and promotion**
   The low rate of quinoa adoption was attributed equally to lack of market demand along with limited knowledge on its utilization. Therefore, there is need for focused market-led production and promotion to address low adoption rate of crops like quinoa.

5. **Availability of materials**
   The study showed that the limited access to materials like seeds, fertilizers, irrigation equipment, and other essential inputs play a critical role in adoption of technology promoted. Therefore, there is a need to ensure a reliable supply chain for essential materials of technology promoted.

6. **Capacity building and training**
   The successful adoption of new technologies is closely linked to effective demonstration and training programs. Higher adoption rates of technologies such as rice varieties (DQ-11 and Mahsuri) and soil and nutrient management practices can be attributed to the field-day demonstrations and hands-on training sessions conducted by Agriculture Research and Development Centers (ARDCs). These activities provide practical knowledge and build the confidence of farmers to implement new technologies.

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