



ANNUAL REPORT 2024-2025



June, 2025

Agriculture Research and Development Center
Bajo, Wangduephodrang
Department of Agriculture
Ministry of Agriculture and Livestock

ROYAL GOVERNMENT OF BHUTAN

Copyright © ARDC Bajo, 2025

Published by:

Agriculture Research & Development Centre-Bajo, Wangduephodrang,
Department of Agriculture,
Ministry of Agriculture & Livestock,
Royal Government of Bhutan.

Write-up contributors: All sectors

Editors, Layout & design: Tanka Maya Pulami

Suggested Citation:

ARDC Bajo 2024. Annual Report 2024-2025

Agriculture Research and Development Centre, Bajo, Wangduephodrang,
Department of Agriculture
Ministry of Agriculture & Livestock

Reproduction:

This publication may be reproduced in part or whole in any form for educational and research purpose provided acknowledgement is made. ARDC-Bajo, DoA, would appreciate receiving a copy of publication using any information from this document.

For a copy of the report, contact:

Program Director

ARDC Bajo

Wangdue Phodrang

Bhutan

Tel: +975-2-481361

Email: ardcbajo@moal.gov.bt

Website: www.rcbajo.gov.bt

ANNUAL REPORT 2024-25

Agriculture Research and Development Centre
Bajo, Wangduephodrang
Department of Agriculture
Ministry of Agriculture and Livestock
ROYAL GOVERNMENT OF BHUTAN

FOREWORD

It is an immense pleasure to publish the 39th Annual Technical Report of Agriculture Research and Development Centre (ARDC) Bajo, coinciding with for the financial year (FY) 2024-25. This report synthesizes the research and development activities conducted in the areas of field crops, horticulture, technical support services, and project-supported initiatives by the Centre and its Sub-Centre at Menchhuna, Tsirang in the last financial year (FY) 2024-25.

ARDC-Bajo implements activities focused on its national mandate for coordinating field crops research and development, a regional mandate for horticulture research and development, and specific commodity mandates for rice, wheat, and citrus. These activities are carried out in close collaboration and consultation with the Ministry of Agriculture and Livestock, the Department of Agriculture and its central agencies, projects, local government agencies, and, most importantly, the farmers and other beneficiaries.

The Centre initiated and implemented numerous activities, including Rice Varietal Evaluations, Evolutionary Plant Breeding, Rice Mechanization, Characterization of Premium Paddy Varieties Legume Crop Evaluations, Nationally Coordinated Trials on fruits and nuts as well as vegetables. It also established an Irwin mango evaluation trial and conducted various vegetable evaluation trials. During this FY, the Centre tested and promoted durum wheat through the Seed Without Borders Program. The Centre successfully implemented the Million-Fruit Tree Program (MFTP). As of June 30, 2024, the National Citrus Repository (NCR) collected 120 citrus germplasm cultivars through budwood and seed. Additionally, the Centre supported farmers by developing the capacity of farmers and extension workers in new innovations and climate-resilient technologies.

ARDC-Bajo successfully completed all planned activities for the financial year 2024-25, as outlined in the Annual Work Plan and the Individual Work Plan (IWP). These achievements were made possible through tremendous support from central agencies, projects, and the unwavering dedication of the staff at ARDC-Bajo and ARDSC-Menchhuna. Their significant efforts contributed to reaching the targets set for planned activities as well as ad-hoc initiatives. We remain steadfast in our commitment to making a positive difference in farming communities and express our gratitude to all those who contributed to the Centre's achievements in 2024-25. I would like to request all seniors, colleagues, supporters, and stakeholders to continue providing their full cooperation, support, and best wishes for our future endeavours.

This report is intended not only to serve as an account of activities implemented over the past year but also as a technical reference and guideline for all stakeholders involved in agricultural research and rural development. It aims to contribute to achieving national food and nutrition self-sufficiency, economic self-reliance, and ultimately, the overarching national goal of Gross National Happiness in Bhutan.

Tashi Delek!

Passang Tshering

Program Director

GLOSSARY OF ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
AET	Advance Evaluation Trial
AFACI	Asian Food and Agriculture Cooperation Initiative
ARCM	Agriculture Research Coordination Meeting
ARDC	Agriculture Research and Development Centre
ARDSC	Agriculture Research and Development Sub-Centre
AVRDC	Asian Vegetables Research and Development Centre
AWD	Alternative Wetting and Drying
BAMS	Bhutan Agri-microbial Solution
BFDA	Bhutan Agricultural and Food Regulatory Authority
BJA	Bhutan Journal of Agriculture
CIMMYT	International Center for Wheat and Maize
CRP	Chimipang Royal Project
CV	Coefficient of variation
DAO	Dzongkhag Agriculture Officer
DBT	Days before transplantation
DoA	Department of Agriculture
DTF	Date to Flowering
DTM	Date to Maturity
EPB	Evolutionary Plant Breeding
ESP	Elementary Service Personnel
EM	Effective Microorganism
FAW	Fall Armyworm
FMCL	Farm Machinery Corporation Limited
FSAPP	Food Security and Agriculture Productivity Project
FY	Financial Year
FYM	Farm Yard Manure
GAFSF	Global Agriculture and Food Security Program
GCF	Green Climate Fund
GEF	Global Environment Facility
GSP	General Service Personnel
HDPE	High-Density Polyethylene
HLB	Huanglongbing
HPYT	Harvest Plus Yield Trial
HYV	High Yielding Varieties
IET	Initial Evaluation Trial
IFAD	International Fund for Agricultural Development
IHPP	Integrated Horticulture Promotion Project
ICT	Information and Communication Technology
IPM	Integrated Pest Management
IPNM	Integrated Plant Nutrients Management
IRRI	International Rice Research Institute
IoT	Internet of Things
IWP	Individual Work Plan
JICA	Japan International Cooperation Agency
LBR	Late Blight Resistant

LCR	Large Cardamom Repository
LSD	Least Significant Difference
MAP	Medicinal and Aromatic Plants
MET	Multi Environmental Trial
MFTP	Million Fruit Tree Plantation Project
MoAL	Ministry of Agriculture and Livestock
NBC	National Biodiversity Centre
NCR	National Citrus Repository
NCT	National Coordinated Trial
NCOA	National Centre for Organic Agriculture
NPK	Nitrogen Phosphorus Potassium
NPPC	National Plant Protection Centre
NSC	National Seed Centre
NSSC	National Soil Services Centre
ORP	Outreach Programme
PET	Participatory Evaluation Trials
PST	Project Support Team
RCBD	Randomized Complete Block Design
RDTC	Rural Development Training Centre
RNR	Renewable Natural Resources
SLM	Sustainable Land Management
TSS	Total Soluble Sugar
VET	Varietal Evaluation Trial

Table of Contents

FOREWORD	IV
List of Figures	IX
List of Tables	IX
1. FIELD CROP RESEARCH AND DEVELOPMENT PROGRAM	1
1.1 . Rice Research and Development Program	1
1.1.2. Advance evaluation trial of Nepal rice varieties	1
1.2 Performance Evaluation of Black Rice as NCT	2
1.3 Black rice evaluation in the farmer’s field	3
1.4 Characterization of premium traditional rice varieties	4
1.5 Demonstration of Released Rice Varieties	6
1.6 Evaluation of Upland Rice Varieties under Rainfed Conditions in Sergithang, Tsirang	6
1.7 Comparative Study of Manual and Machine Transplanting Methods in Rice Cultivation	7
1.8 Upscaling of Bajo Kaap-3 (BK III)	8
1.9 Demonstration of Promising Rice Varieties to Enhance Self-Sufficiency	8
1.10 Maintenance of Released Rice Varieties On-Station Trial at ARDSC Menchhuna	9
1.11 Seed production and maintenance of rice varieties	9
1.12 Evolutionary Plant Breeding (EPB) Trial at ARDC Bajo	10
1.13 Evolutionary Plant Breeding Trial at ARDSC Menchhuna	11
2. Wheat Research and Development Program	12
2.1. Initial Evaluation of Promising Wheat Lines (2024–2025)	12
2.2. Second Year Evaluation of Indian Durum Wheat Semolina	13
2.3. Participatory Evaluation Trial (PET) of Three Selected Lines from the 11th Harvest Plus Yield Trial (HPYT) – CIMMYT Lines	14
2.4. Establishment of Sentinel Plots for Rust Surveillance	14
2.5. Seed production and maintenance of released wheat varieties	15
3. Quinoa	15
3.1 Evaluation of On-Station Tri-Colour Quinoa Varieties	15
3.2 Enhancing Quinoa Production through Capacity Building and Seed Support	16
3.3 Quinoa Promotion through Field Days in Dagana and Tsirang	16
4. Oil Seeds	17
4. 1. Evaluation of Peanut Varieties	17
4.2 On-station Evaluation of Soya Varieties	18
4. Seed Production and Maintenance of Finger Millet	19
HORTICULTURE RESEARCH AND DEVELOPMENT PROGRAM	20

6. Fruits and Nuts	20
6.1 Evaluation of temperate and sub -tropical fruits and nuts germplasm	20
6.2 Performance Evaluation Trial of Passion Fruit	20
6.3 Evaluation of Pure Germplasm of Langra and Himsagar Mango Varieties.....	21
6.4 Evaluation of Irwin Mango under Protected Cultivation	22
6.5 Evaluation of Germination Enhancement Techniques for Persimmon (Diospyros spp.)	23
6.6 Pomelo Varietal Evaluation Trial	23
7. Citrus	24
7.1 National Citrus Repository	24
7.2 On-farm performance evaluation of different citrus varieties	24
7.5 Development of Virus-Free Citrus Plants through Shoot Tip Tissue Culture	26
7.6 Citrus Phenology Study at NCR.....	26
7.7 Citrus Phenology Study at ARDC Bajo	27
7.8 Performance Evaluation of different Citrus Variety in Patshaling Gewog, Tsirang	27
8. Million Fruit Tree Plantation (MFTP)	28
8.1 Key Achievements under MFTP Phase IV	28
8.2 MFTP Subtropical Seedling Distribution (Phase IV).....	30
9. Vegetable Research and Development	30
9.1 Adaptability and performance of new watermelon variety (Summer sweet)	30
9.2 Aadaptability performance of new muskmelon varieties	31
9.3 Evaluation of varieties of Chinese cabbage (Japanese varieties).....	31
9.4 Performance evaluation of Japanese pumpkins	32
9.5 Effect of Rice Husk Biochar and Bokashi on Chilli Yield and Productivity	32
9.4 Fast Track Evaluation of Green Pia (Hybrid Broccoli).....	33
9.5 Fast Track Evaluation of Hybrid Cabbage	34
9.6 Fast Track Evaluation of Hybrid Cauliflower	34
9.7 Evaluation of World Vegetable Chili Lines	35
9.8 Varietal Performance Evaluation Trial of Sweet Potato	35
9.9 Performance Evaluation of White Dwarf Beans	36
10. Medical and Aromatic Plants	36
11. Floriculture	37
SUPPORT SERVICES RESEARCH AND DEVELOPMENT PROGRAM	38
12. Mushroom Development Program	38
13. Seed Samples Tested for Quality Parameters	39

14. Plant Protection.....	40
14.1 Effectiveness of Wood Vinegar to Control Weeds of Potato	40
14.2 Evaluation of wood vinegar as a fungicide against early blight in tomato cultivation	41
14.3 Efficacy of wood vinegar as herbicide on broad leaves of tomato	42
14.4 Citrus Fruit Fly Management Training and Awareness Campaign	42
14.5 Evaluation of Maize-Legume Intercropping for Fall Armyworm Management	43
15. Soil and Land Management Services.....	43
15.1 Climate Smart Agriculture (CSA) Technologies	43
15.2 Agriculture Land Development (ALD)	44
15.3 Soil Test Results	44
15.4 Soil Fertility Assessment of Citrus Orchards in Dagana	45
15.5 Soil Nutrient Status of Yarjugang OAP Farm	45
15.6 Demonstration of biochar charging	46
16. Visitors' information.....	47
CENTRE AT A GLANCE.....	49
Contact Address:	49

List of Figures

Figure 1 : Black Rice Growth Stages Captured (2024)	3
Figure 2 : Black Rice Performance 2024 at different locations	4
Figure 3 : premium traditional rice varieties	5
Figure 4 : External and internal views of the 'Summer Queen' passion fruit variety	21
Figure 5 : Map showing location of trial sites	25
Figure 6 : MFTP activities during the FY 2024-25	29
Figure 7 : Capacity building and cultivation practices in mushroom production	38
Figure 8 : Awareness campaign on fruit fly management and dumping of fruit drops	43
Figure 9 : Figure 9: Distribution of nutrient status across all samples	45
Figure 10 : Visitor Engagement Summary at ARDC-Bajo	48

List of Tables

Table 1 : ANOVA and descriptive statistics for grain yield among six rice varieties	1
Table 2 : Black rice performance at ARDCs in 2024	2

Table 3 : Economic Assessment of Black Rice vs. Conventional Variety Bajo Kaap	3
Table 4 : Agronomic data of premium traditional rice varieties	5
Table 5 : Released rice varieties demonstrated at ARDC Bajo in 2024	6
Table 6 : Agronomic performance of Nepal Lines on-farm	6
Table 7 : Agronomic and morphological performance under different transplanting methods	7
Table 8 : Average Yield of released rice varieties at demonstration plots, ARDSC Menchhuna ..	9
Table 9 : Paddy seed produced from released and potential varieties in 2024	9
Table 10 : On-station EPB yields assessment result	10
Table 11 : On-Station Yield Assessment	11
Table 12 : On-Farm Yield Assessment	11
Table 13 : Agronomic traits of the selected Durum wheat lines	12
Table 14 : Agronomic traits of the selected 8 Zinc-bio-fortified lines	12
Table 15 : Agronomic traits of the selected 10 Semi-arid lines	13
Table 16 : Evaluation of Durum wheat at ARDC,Bajo	14
Table 17 : Evaluation of Durum wheat at ARDSC,Menchunna	14
Table 18 : Quantity of wheat seed produced in FY 2024-2025	15
Table 19 : Agronomic traits of Tri-Colour Quinoa Varieties	16
Table 20 : Agronomic performance of peanut varieties	17
Table 21 : The summarized results of soya beans across the three replications	18
Table 22 : Fruit crop varieties established in the germplasm block	20
Table 23 : Fruit quality analysis of summer queen passion fruit variety at Bajo	21
Table 24 : Mean Growth Parameters of Mango Varieties	22
Table 25 : Means (SD) of Growth and Environmental Variables in Bajo and Samtenling	22
Table 26 : Citrus Phenology Summary (2024–2025)	26
Table 27 : Fruit quality analysis of different citrus variety at ARDC Bajo	27
Table 28 : Summary of Key Activities under MFTP Phase IV (2025)	28
Table 29 : Agronomic means of Summer Sweet watermelon variety	30
Table 30 : Comparison of Fruit Quality Parameters at ARDC, Bajo	31
Table 31 : Performance of Japanese pumpkin varieties under field conditions	32
Table 32 : Fruit quality parameters among different treatments	33
Table 33 : Agronomic Performance of Green Pia and Centauro Broccoli Varieties	33

Table 34 : Performance of Hybrid Cabbage Varieties	34
Table 35 : Performance of Hybrid Cauliflower Varieties	35
Table 36 : Descriptive Statistics for yield per acre	36
Table 37 : Comparative performance of white dwarf and dwarf borloto beans	36
Table 38 : Number of hhs trained and oyster spawn supplied	38
Table 39 : Summary of results of sampled seed tested in the FY 2024-25	39
Table 40 : Effect of different treatments on weed species	40
Table 41 : Summary of Soil Test Results – Yarju, OAP	46
Table 42 : Beneficiary list on demo of biochar charging	47

1. FIELD CROP RESEARCH AND DEVELOPMENT PROGRAM

1.1. Rice Research and Development Program

1.1.2. Advance evaluation trial of Nepal rice varieties

During the 2024 cropping season, an Advanced Evaluation Trial (AET) was conducted to evaluate the performance of seven rice varieties, including one local check. The varieties included in the trial were selected based on their superior performance in the Initial Evaluation Trial (IET) conducted in 2023. The primary objective of the AET was to assess the yield potential and resistance to pests and diseases of these genotypes, specifically under mid-altitude rice-growing conditions.

The trial was laid out in a Randomized Complete Block Design (RCBD) with three replications to ensure statistical robustness. Seedlings were transplanted into 10 m² plots with a plant spacing of 20 × 20 cm. Fertilizer was applied at the recommended rate of 70:40:40 kg/ha NPK, with half of the nitrogen top-dressed at the panicle initiation stage.

Weed management was carried out using Butachlor 5G at 1.5 kg active ingredient per hectare, applied 2–3 days after transplanting. Additional hand weeding was done as necessary, particularly to manage *Potamogeton distinctus* (locally known as *shochum*), a common and problematic aquatic weed in Bhutanese rice fields. Irrigation was scheduled according to crop water requirements to maintain optimal soil moisture throughout the growth period. Regular monitoring for pests and diseases was conducted, and grain yield data were standardized to 14% grain moisture content. An analysis of variance (ANOVA) was performed on grain yield (kg/acre) data using Type III Sum of Squares. The results are presented in the table 1 below.

Table 1: ANOVA and descriptive statistics for grain yield among six rice varieties

ANOVA - Yield kg/acre					
Cases	Sum of Squares	df	Mean Square	F	P
Treatment	55499.450	5	11099.890	0.743	0.606
Residuals	179352.840	12	14946.070		

Note. Type III Sum of Squares

Descriptive - Yield kg/acre					
Treatment	N	Mean	SD	SE	Coefficient of variation
Hardinath 1	3	2081.743	60.368	34.854	0.029
IR98846-2-1-4-3	3	2139.040	262.032	151.284	0.122
NR2169-10-4-1-1-1-1	3	1961.410	62.888	36.308	0.032
Sukha Dhan 3	3	2022.667	19.348	11.170	0.010
Sukha Dhan 4	3	2086.000	64.117	37.018	0.031
Sukha Dhan 5	3	2061.000	94.504	54.562	0.046

As the p value is higher than 0.05(0.606), there is no significance difference in the yield between different treatment group.

Although IR98846-2-1-4-3 recorded the highest mean yield, the differences among varieties were not statistically significant. The relatively high variation observed in this variety (CV = 12.2%) may have contributed to the lack of significance. The low coefficients of variation for most entries indicate good experimental precision.

1.2 Performance Evaluation of Black Rice as NCT

Black rice, also known as “Forbidden Rice,” originated in ancient China and was once reserved exclusively for royalty. Also called purple rice, heaven rice, and long-life rice, it has gained global attention due to its health benefits and premium market value.

In Bhutan, black rice cultivation began in 2020 using seeds introduced from Nganglam, Pemagatshel. The crop has shown promising adaptability, particularly in low to mid-altitude areas (650–1400 masl). Rich in anthocyanins, lutein, zeaxanthin, and dietary fibre, black rice also has a low glycemic index, making it highly appealing to health-conscious consumers. These nutritional qualities add value for farmers through premium pricing opportunities.

Table 2: Black rice performance at ARDCs in 2024

Location	Variety	Tillers/hill (Nos.)	Plant Height (cm)	Yield (kg/acre)
ARDC Bajo	Black Rice	9.76 ^a	143.64 ^a	2655.90 ^c
	IR20913 (Improved)	14.32 ^a	128.12 ^b	2996.50 ^b
	Khamtey (Local)	15.12 ^b	147.68 ^a	4181.10 ^a
	P Value	0.0001	0.0000	0.0000
ARDSC Tsirang	Black Rice	6.13 ^b	92.73 ^b	1034.00 ^c
	Wangkhar Ray Kaap-II (Improved)	7.06 ^b	67.60 ^c	1465.30 ^b
	Chorti (Local)	8.73 ^a	129.27 ^a	1180.30 ^a
	P Value	0.0048	0.0000	0.0000
ARDSC Lingmithang	Black Rice	16.80 ^b	136.27 ^b	2199.5 ^b
	BK3 (Improved)	17.00 ^b	87.33 ^c	2776.6 ^a
	Tsirang Zam (Local)	28.05 ^a	183.11 ^a	1940.0 ^c
	P Value	0.0000	0.0000	0.0000
ARDC Samtenling	Black Rice	10.66 ^a	142.23 ^a	452.12 ^b
	Bhur Raykaap 2 (Improved)	9.26 ^{ab}	114.30 ^c	585.83 ^c
	Kalo Timburay (Local)	7.06 ^b	121.20 ^b	322.74 ^a
	P Value	0.0961	0.0003	0.0068

The 2024 crop performance evaluation across four ARDCs as NCT revealed significant varietal differences in tillering ability, plant height, and yield. At ARDC Bajo, the local variety *Khamtey* showed the best performance, with the highest tillers (15.12), tallest plants (147.68 cm), and highest yield (4181.1 kg/acre). *IR20913* (improved) followed, while black rice had the lowest yield despite good plant height. In ARDSC Tsirang, *Chorti* (local) recorded the tallest plants

(129.27 cm) and highest tillers (8.73), but its yield (1180.3 kg/acre) was only slightly higher than that of *Wangkhar Ray Kaap-II* (1465.3 kg/acre), with black rice again yielding the least (1034.0 kg/acre). At ARDSC Lingmithang, *Tsirang Zam* (local) had the most tillers and tallest plants but the lowest yield (1940.0 kg/acre), while the improved variety *BK3* yielded highest (2776.6 kg/acre). For ARDC Samtenling, black rice showed the highest yield (452.12 kg/acre), followed by *Bhur Raykaap 2*, with *Kalo Timburay* (local) yielding the least. Statistical analysis shows that most trait differences across varieties were significant ($P < 0.05$), indicating strong varietal influence on performance. Overall, improved varieties generally outperformed black rice in yield, while local varieties excelled in vegetative growth traits.

Table 3: Economic Assessment of Black Rice vs. Conventional Variety Bajo Kaap

Variety	Total Expenditure (Nu)	Yield (kg/ac)	Cost of Production (Nu/kg)	Market Price (Nu/kg)	Milling Recovery (%)	Total Revenue (Nu)	Net Return (Nu)
Black Rice	100,227.50	2,655.9	37.73	150	60	239,031.00	138,803.49
Bajo Kaap 3	100,468.90	2,776.6	36.18	120	65	216,574.80	116,105.89

The economic analysis compares Black Rice with Bajo Kaap 3 under similar production conditions. Although Black Rice had a slightly lower yield (2,655.9 kg/ac) than Bajo Kaap 3 (2,776.6 kg/ac) and a higher cost of production (Nu 37.73/kg vs. Nu 36.18/kg), it commanded a much higher market price (Nu 150/kg vs. Nu 120/kg). Despite lower milling recovery (60% vs. 65%), the premium price of Black Rice led to a total revenue of Nu 239,031 and a net return of Nu 138,803.49, which is Nu 22,697.60 more than Bajo Kaap 3. This indicates that Black Rice is a more profitable option for farmers, primarily due to its high market value, despite slightly higher production costs.



a) Flowering stage

b) Maturity

c) Rice grain

d) dehulled grain

Figure 1: Black Rice Growth Stages Captured (2024)

1.3 Black rice evaluation in the farmer's field

In addition to controlled trials conducted at various research centres following standardized practices, the variety was also tested in farmers' fields to assess its productivity and overall

performance. This approach ensures a comprehensive evaluation of its adaptability and effectiveness across different growing conditions.

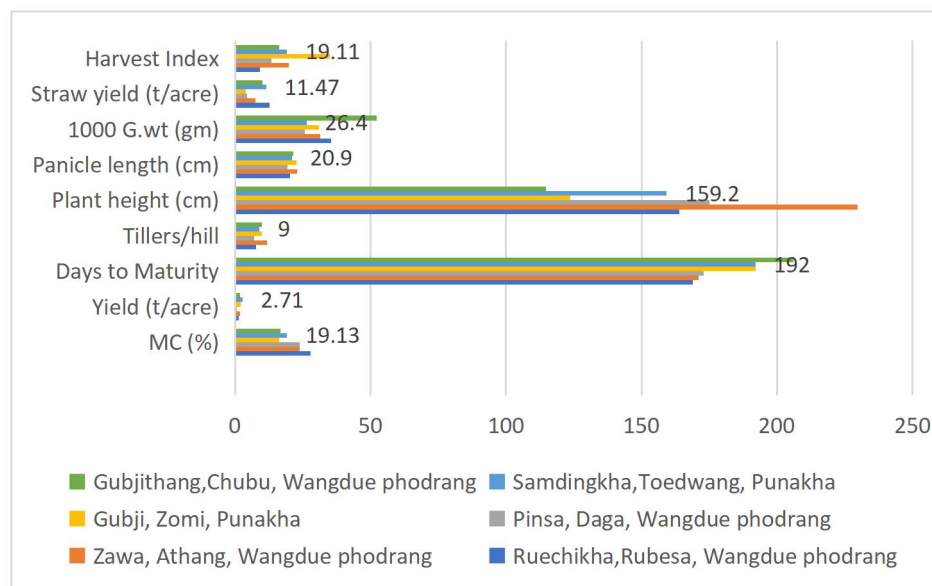


Figure 2: Black Rice Performance 2024 at different locations

A field evaluation of black rice was conducted in six locations across Wangdue Phodrang and Punakha districts to assess its agronomic performance under farmers' field conditions. Key parameters included yield, plant height, tiller number, 1000-grain weight, and harvest index. In Wangdue, Zawa recorded the highest yield (1.87 t/acre), while Pinsa had the lowest (0.68 t/acre). In Punakha, Samdingkha showed the highest yield overall (2.71 t/acre), followed by Gubji (2.19 t/acre), which also had the highest harvest index (35.07), indicating better efficiency in grain production. Gubjithang recorded a moderate yield (1.96 t/acre) but had the highest 1000-grain weight (52.3 gm), suggesting good grain quality potential.

Yield performance varied notably with altitude. Mid-altitude zones (1200–1300 masl) such as ARDC Bajo, Samdingkha, and Gubji consistently recorded higher yields (over 2.1 t/acre), while lower altitude areas like Samtenling and Lhamozingkha (below 400 masl) showed significantly lower yields. The findings suggest that black rice performs best in mid-altitude environments, making these zones ideal for its cultivation.

1.4 Characterization of premium traditional rice varieties

In its first year, a comprehensive characterization of ten traditional rice germplasm conserved in Bhutan's national crop gene bank was undertaken using the IRRI Standard Rice Evaluation System. This initiative addresses a long-standing gap—no detailed studies or documentation have been conducted on premium local rice varieties by research Centers, limiting their effective conservation, utilization, and breeding potential.

The aim of the characterization was to document distinguishing features and identify accessions with desirable agronomic traits. This will serve as a vital reference for future rice breeding and varietal improvement efforts, while also supporting long-term conservation and improved understanding of Bhutan's traditional rice diversity.

The evaluation revealed considerable variation across traits such as plant height, grain dimensions, yield, and days to maturity. Dawa Yangkum emerged as the tallest (2.33 m), while Pangbara was the shortest (1.42 m). Bondey and Shenga Maap demonstrated high tillering potential with 19.4 and 17.8 culms respectively. Tan Tshering had the longest (8.67 mm) and slimmest grains (L/W ratio of 3.06), while Dawa Yangkum had the boldest grains (3.83 mm wide). In terms of yield, Nyabja was the top performer at 2.92 t/ac, whereas Dumbja recorded the lowest at 0.88 t/ac. Early-maturing varieties such as Janam, Shenga Maap, Dumbja, and Pangbara (130 days) are promising for short-season areas, while Bondey was the latest to mature (172 days). This detailed data offers critical insights into trait diversity and supports targeted selection of parent lines for breeding programs.

Table 4: Agronomic data of premium traditional rice varieties

Parameters	Nyabja	Tan Tshering	Bondey	Wangdra kam	Janam	Shenga Maap	Dumbja	Pangbara	Dawa Yangkum
Culm Length/ Plant Height (m)	2.11	2.16	1.58	1.70	1.77	1.56	1.75	1.42	2.33
Culm Bearing/Number	10.80	13.80	19.40	8.80	9.60	17.80	9.80	13.00	11.00
Grain Length (mm)	7.67	8.67	8.00	6.97	8.33	7.67	7.33	8.00	6.33
Grain Width (mm)	3.00	2.83	3.00	3.50	3.00	3.17	3.17	3.00	3.83
L/W Ratio (Grain Type)	2.56	3.06	2.67	1.99	2.78	2.42	2.32	2.67	1.65
100 Grain Weight (g)	3.98	4.18	3.82	4.09	2.47	2.98	2.20	2.55	2.73
Moisture content	22.30	14.20	21.30	14.30	14.80	14.90	15.60	15.30	13.20
Yield (t/ac)	2.92	2.65	1.85	1.39	0.89	1.45	0.88	1.44	1.36
Days to Maturity	160.00	160.00	172.00	143.00	130.00	130.00	130.00	130.00	143.00

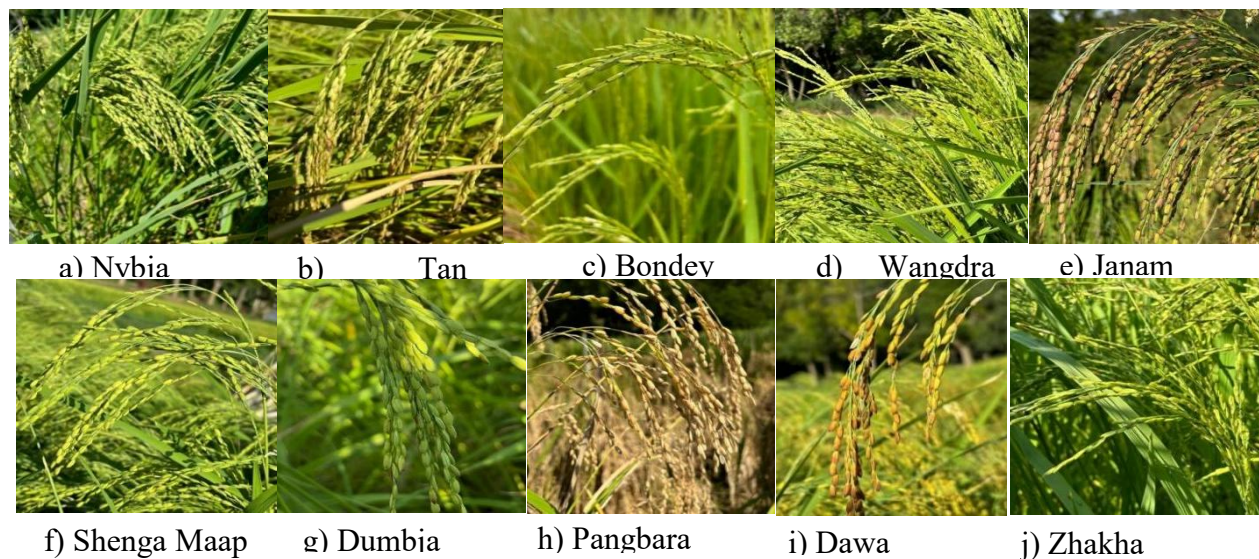


Figure 3: premium traditional rice varieties

1.5 Demonstration of Released Rice Varieties

To promote awareness and adoption of improved rice production technologies, ARDC Bajo facilitated educational visits during the 2024 cropping season for key stakeholders, including farmers, students, and extension personnel. As part of this outreach activity, a demonstration plot was established at the research station featuring eight officially released rice varieties.

The primary objective of the demonstration was to showcase varietal characteristics and agronomic performance under field conditions representative of mid-altitude rice-growing environments. This platform served to strengthen linkages between research and extension by allowing stakeholders to observe and compare varietal traits, such as plant type, maturity, and yield potential.

Table 5: Released rice varieties demonstrated at ARDC Bajo in 2024

Variety	Recommended Altitude (m)	Season	Yield potential (t/ha)
Bajo Kaap `1	600-1500	Main single	2.0-3.4
Bajo Kaap 2	600-1500	Main single	2.0-3.4
Bajo Kaap 3	600-1500	Main single	2.0-3.5
Bajo Maap 1	600-1500	Main single	2.0-3.2
Bajo Maap 2	600-1500	Main single	2.0-3.0
IR 20913	600-1500	Second double	1.6-2.4
IR 64	600-1500	Main single	2.0-3.2
Khangma Maap	Above 1500	Main Single	1.6-2.4

This demonstration not only supported knowledge transfer and awareness-building but also enabled end-users to make informed decisions on varietal selection based on ecological suitability and yield performance.

1.6 Evaluation of Upland Rice Varieties under Rainfed Conditions in Sergithang, Tsirang

In 2024, an upland varietal evaluation trial was initiated at Norbugang, Sergithang Gewog, Tsirang. The site, located at 1,230 masl in the dry subtropical zone, was selected due to fallow terraced land lacking irrigation. Four farmers participated, each receiving 5 kg seed of two out of eight Nepal-origin varieties: IR98846-2-4-3, NR2169-10-4-1-1-1-1, IR14L362, Sukha Dhan-3, 4, and 5, and Hardinath-1 and 3. Additionally, 140 kg of Khangma Maap, a locally adapted check variety, was distributed in Satmuley and Torney villages. Trials were conducted under existing farmer management practices, relying on FYM without chemical inputs.

Table 6: Agronomic performance of Nepal Lines on-farm

Location	Varieties	Plant height (cm)	Nos of tiller	Panicle length (cm)	Fresh Straw weight (kgs)	Yield per acres (kgs)
Norbugang	Khangma maap	107	5	32.30	8.00	623.00
Norbugang	NR-2169-10-1-4-1-1-1-1	84.7	4	20.40	6.20	1027.00
Norbugang	Sukha Dhan-5	86.3	6	21.50	5.90	1398.00
Drujigang	Sukha Dhan-5	89.2	6	20.80	5.80	1110.00
Drujigang	NR-2169-10-1-4-1-1-1-1	88	5	21.40	5.20	983.00

Drujigang	NR-2169-10-1-4-1-1-1-1	90.2	7	21.50	7.30	1083.00
B/shong	Sukha Dhan-4	91.3	8	21.30	9.80	1167.00
Sunkosh	Sukha Dhan-3	92	7	22.50	12.17	1660.00
Sunkosh	NR-2169-10-1-4-1-1-1-1	103.5	10	25.30	7.90	1578.00
Sunkosh	Sukha Dhan-4	95	6	23.2	7.1	1090

Agronomic observations included plant height, tillers per hill, flowering days, panicle length, and grain yield from 6 m² plots. No major pest or disease incidence was reported, though poor germination occurred in one field due to prolonged dry spells. Results indicated that Sukha Dhan-5 and NR2169-10-4-1-1-1-1 performed well, yielding 1,398 kg/acre and 1,027 kg/acre, respectively, compared to 623 kg/acre for the check variety. On wetland sites, NR2169 and Sukha Dhan lines also performed strongly, with some plots exceeding 1,500 kg/acre. However, poor growth was noted on consolidated land development sites and wildlife-affected plots.

These preliminary findings suggest that certain Nepal lines are promising for upland rice cultivation under water-limited conditions. Further multi-location and multi-season evaluations using full agronomic packages are recommended to generate reliable data and identify suitable varieties for Bhutan's dryland systems.

1.7 Comparative Study of Manual and Machine Transplanting Methods in Rice Cultivation

A simple study was conducted during the 2024 rice growing season (June to November) at ARDC Bajo to compare machine transplanting and manual transplanting methods. The study aimed to evaluate crop performance under each method. Bajo Kaap 3 variety was used for the crop cut observations to assess yield outcomes.

The comparison between manual transplantation and the use of a transplanter in rice cultivation reveals slight variations in several agronomic parameters. Manual transplantation showed a marginally higher harvest index and grain yield, indicating a slightly better conversion of biomass into grain. Additionally, paddy transplanted manually exhibited greater plant height and slightly longer panicle length compared to those transplanted using a machine. The number of tillers per hill was also slightly higher in the manual method. On the other hand, the transplanter method resulted in slightly higher straw yield and moisture content, although these differences were minimal. Notably, spikelet fertility was almost equal in both methods, suggesting that the planting approach had little impact on this particular trait.

Table 7: Agronomic and morphological performance under different transplanting methods

Transplanting method	Tiller/hills	Panicle length(cm)	Grain/panicle	Empty grain/panicle	Yield (kg/Ac)	Straw Kg/acre	Harvest index
Using transplanter	19	24.40	197	8	3848.62	10792.00	26 %
Manually transplanting	14	23.80	235	10	4539.70	8768.50	34 %

Although manual transplanting showed slightly better results, it remains highly labour-intensive. Machine transplanting is faster and may offer greater advantages, especially for larger land areas. A more in-depth study will be undertaken in the coming season to better understand its overall benefits and limitations.

1.8 Upscaling of Bajo Kaap-3 (BK III)

Bajo Kaap-3 (BK III) is a newly released rice variety developed and promoted by ARDC-Bajo for its superior yield potential, improved resistance to pests and diseases, earlier maturity, and better grain quality. In recent years, the variety has been introduced in various gewogs across the region through targeted interventions aimed at enhancing paddy productivity and resilience, particularly in areas affected by biotic stress and declining yields from traditional varieties.

In response to a request from the Wangdue Phodrang Dzongkhag Agriculture Officer, a joint technical team visited Rukha under Athang Gewog in September 2023. The visit aimed to assess pest and disease issues in local paddy fields and provide appropriate recommendations. Each household was represented during the field inspection and contributed valuable field-level information. The team observed that the traditionally cultivated variety, 'Tan Tshering,' was highly susceptible to the prevailing pest and disease problems.

Based on the field findings, ARDC-Bajo recommended replacing 'Tan Tshering' with 'Bajo Kaap-3', citing its better pest and disease resistance and higher yield potential. To support this transition, a total of 604 kilograms of BK III seeds were distributed free of cost to 17 affected households in Rukha. The initiative aimed to test the variety's performance under local conditions and encourage wider adoption. At the end of the season, random crop cuts were conducted to assess yield performance. The average yield of BK III was recorded at 2.476 MT/acre (6.147 MT/ha), while Bajo Maap II, used for comparison, yielded 2.020 MT/acre (4.991 MT/ha), indicating a clear advantage of BK III.

During the 2023 cropping season, ARDC-Bajo also distributed 20 kilograms of BK III seeds each to selected farmers in Karmaling and Lhamoizingkha Gewogs to evaluate the variety's performance across different agroecological conditions. Farmers reported favorable outcomes, noting several advantages: higher yield compared to local varieties, superior grain quality, and earlier maturity—approximately two weeks earlier—which supports better harvest management. The variety, locally nicknamed "*Raja Dhan*" by farmers, has quickly gained popularity in Lhamoizingkha Dungkhag. Many farmers have shown interest in expanding its cultivation area in the upcoming seasons. Based on this feedback, ARDC-Bajo recommended transplanting BK III by late August to synchronize its maturity with local cultivars, allowing more efficient harvesting.

The successful introduction and positive performance of Bajo Kaap-3 (BK III) in Wangdue Phodrang and Dagana Dzongkhags underscore its potential as a resilient and high-yielding rice variety for Bhutanese farming systems. Continued monitoring, timely support, and farmer engagement will be key to scaling up its adoption and ensuring long-term sustainability.

1.9 Demonstration of Promising Rice Varieties to Enhance Self-Sufficiency

As part of efforts to enhance rice self-sufficiency under the current Five-Year Plan, the Agriculture Research and Development Center (ARDC) Bajo implemented a large-scale demonstration of promising rice varieties across four Dzongkhags: Wangdue Phodrang, Punakha, Tsirang, and Dagana. A total of 100 acres was brought under paddy cultivation. Two improved rice varieties were introduced: Bajo Kaap 3 for wetland conditions and Khangma Maap for upland cultivation. To support this initiative, 2,500 kg of paddy seed was distributed to participating farmers.

1.10 Maintenance of Released Rice Varieties On-Station Trial at ARDSC Menchhuna

Released rice varieties are maintained under controlled on-station trial conditions to ensure seed purity, viability, and quality. Regular monitoring, crop management, and isolation practices are followed to preserve the genetic integrity of each variety. This maintenance supports ongoing evaluation, seed multiplication, and future dissemination to farmers, ensuring the availability of high-quality planting material for sustained rice production.

Table 8: Average Yield of released rice varieties at demonstration plots, ARDSC Menchhuna

SN	Variety	Crop cut sample	Grain yield from sample plot (Kg)	MC%	Grain yield Kgs/acre
1	Bajo Kaap-3	I	3.09	24.50	1829.00
		II	3.35	24.10	1991.00
		III	2.72	21.90	1663.00
		Average	3.05	23.50	1827.67
2	Khangma maap	I	2.30	22.40	1339.00
		II	1.79	22.00	1095.00
		III	1.95	22.30	1188.00
		Average	2.01	22.23	1207.33
3	Yousi Ray Maap-3	I	1.90	23.20	1144.00
		II	1.65	23.00	996.00
		III	1.74	23.10	1049.00
		Average	1.76	23.10	1063.00

Crop cutting was conducted on 6 msq plots for three rice varieties. Bajo Kaap-3 consistently showed the highest grain yield, ranging from 1663 to 1991 kg/acre. Khangma Maap yielded moderately, with 1095 to 1339 kg/acre. Yousi Ray Maap-3 recorded the lowest yields, between 996 and 1144 kg/acre. These results highlight Bajo Kaap-3's superior productivity under on-station conditions.

1.11 Seed production and maintenance of rice varieties

During the 2024 cropping season, seed production and maintenance activities were carried out for a range of rice varieties, including both released and promising lines. The primary objective of this initiative is to ensure a secure supply of quality seed for research continuity, contingency requirements, and to support Dzongkhags during times of seed shortage or emergency.

Maintained seed stocks also serve to meet ad hoc requests from extension centers, thereby enhancing the responsiveness and resilience of the national seed system. This strategic reserve plays a critical role in sustaining varietal purity, supporting adaptive research, and ensuring timely access to seeds in the face of unforeseen disruptions.

Table 9: Paddy seed produced from released and potential varieties in 2024

SN	Variety	Quantity (kg)	Status
1	Bajo Kaap 1	623	Released variety
2	Bajo Kaap 2	372	Released variety
3	Bajo Kaap 3	599	Released variety

4	Bajo Maap1	421	Released variety
5	Bajo Maap 2	248	Released variety
6	IR 64	325	Released variety
7	IR 20913	200	Released variety
8	Khangma Maap	20	Released variety
9	Black rice	235	Released variety
Total		3043	

1.12 Evolutionary Plant Breeding (EPB) Trial at ARDC Bajo

The EPB project is a collaborative initiative between the National Biodiversity Centre (NBC) and the four ARDCs with the involvement of Gewog agriculture extension personnel. Rice and beans have been identified as the target crops under this program. The objective of this trial is to develop evolutionary crop populations that are climate-resilient and regionally adaptive, contributing to long-term agricultural sustainability. The EPB rice mixture used in this study had previously undergone a four-year on-farm evaluation across various farmer fields. Upon project completion, ARDCs were instructed to continue the trial under controlled on-station conditions to generate further insights and validate field results.

The trial was conducted in a large single-block design comprising seven treatments, each representing a different rice genotype, including the evolutionary mixture. Seedlings were transplanted at a spacing of 20 cm × 20 cm. Fertilizer was applied at the rate of 40:40:20 kg/ha (N:P: K) as a basal dose, followed by 40 kg/ha of urea as top dressing during the panicle initiation stage. For weed control, Butachlor 5G was applied at the rate of 1.5 kg a.i./ha two to three days after transplanting.

Table 10: On-station EPB yields assessment result

Treatments	Tillers/hill	Plant height (cm)	Maturity days	Panicle length (cm)	1000 grain weight	Grain yield/plot (14% MC)	Yield kg/acre
IR 64	17.20	133.40	149	25.20	19.15	2.820	2331.00
BM 1	15.40	135.00	150	23.40	20.10	3.620	2413.33
Dawa	14.40	144.20	155	23.00	18.20	3.050	2033.33
Nabja	12.00	125.00	150	23.20	21.45	3.190	2126.67
Tan Tshering	11.00	140.00	148	24.20	20.19	3.550	2366.67
Bonday	14.00	140.60	150	21.60	16.21	3.630	2420.00
Mixture	13.60	135.20	150	21.20	20.22	3.260	2173.33

*Grain yield standardized at 14% moisture content.

Among the evaluated rice varieties, Bonday (local) recorded the highest grain yield at 2,420 kg/acre, closely followed by BM 1, while Dawa had the lowest yield at 2,033.33 kg/acre. Interestingly, Dawa also exhibited the tallest plant height at 144.20 cm, whereas Nabja recorded the shortest at 125.00 cm. In terms of tiller production, IR 64 produced the highest number of tillers per hill (17.20), while Tan Tshering had the fewest (11.00). The evolutionary mixture treatment yielded a moderate 2,173.33 kg/acre, showing balanced performance across traits, aligning with its inherent genetic diversity and potential for long-term adaptability. The EPB approach shows promising potential for developing adaptive and climate-resilient rice populations. Although the mixture did not outperform the best individual variety in the first year

of on-station evaluation, its genetic diversity offers potential for gradual adaptation over successive seasons. Continued evaluation will help identify evolving traits that enhance yield stability under changing climatic and environmental conditions.

1.13 Evolutionary Plant Breeding Trial at ARDSC Menchhuna

The final year of the trial was conducted in 2024 at ARDSC Menchhuna, situated at 1,450 masl in the dry subtropical zone with sandy clay soil and monsoon-dependent irrigation. On-station trials were complemented by on-farm trials across multiple agro-ecological zones to assess evolving rice populations under farmer management and gauge preferences.

A large single-block design with six treatments was used, including three local varieties (Attey, Chottey Masino, Gaurey Masino), two improved varieties (Wengkhar RayKaap-2 and IR-64), and an evolving population maintained through EPB trials. Seedlings were transplanted at 20 × 20 cm spacing, with on-farm trials following customary farmer practices. Data were collected on flowering, tillering, plant height, maturity, panicle length, 1,000-grain weight, blast incidence, and grain yield.

The evolving population showed vigorous early vegetative growth with minimal pest or disease pressure. However, as maturity approached, challenges such as severe lodging, chaffy grains, reduced grain quality, and yield decline were observed. These results highlight the importance of careful water and nutrient management to optimize the performance of evolving rice populations and enhance yield stability under diverse agro-ecological conditions.’

Table 11: On-Station Yield Assessment

Treatments	Tillers Numbers /hill	Plant Height	1000 grain weight (gm)	Panicle length	Yield (kg/acre)
Attey	11	109	22.70	23.50	1230.00
Chottey Masino	9	134	22.50	24.30	1169.00
Gawri Masino	7	102	23.40	24.50	994.20
WRK-II	10	92	23.30	23.70	1292.00
IR-64	10	89	22.90	23.00	1927.00
EPB Mixture	10	121	22.60	23.40	964.60

Table 12: On-Farm Yield Assessment

Name of farmers	Location	Varieties	Lodging	Yield per acres (kgs)
Sangay Wangmo	Drujigang	Mixture	No	1487.00
Karma Dorji	Barshong	Mixture	yes	1278.00
Ten chozom	Sunkosh	Mixture	yes	1178.00
Ten chozom	Sunkosh	Chottey	No	1711.00

On-farm results varied by location and management. Farmers reported acceptable yields from the mixture in fields without lodging, while yields dropped significantly where lodging occurred. The local variety Chottey showed relatively better performance under farmer conditions.

This EPB trial offers valuable preliminary insights into the potential and limitations of evolving rice populations in Bhutan. Despite strong early growth and resilience to pests and diseases, later-stage problems such as lodging and grain quality issues constrained overall performance. The findings emphasize the need for enhanced water and nutrient management and suggest that

additional seasons of natural selection are required to stabilize desirable traits and realize the full benefits of evolutionary breeding.

2. Wheat Research and Development Program

2.1. Initial Evaluation of Promising Wheat Lines (2024–2025)

An Initial Evaluation Trial (IET) was established during the 2024–2025 wheat season to assess selected entries from three nursery sets received from the International Maize and Wheat Improvement Center (CIMMYT), Mexico. These included the 54th International Durum Wheat Yield Nursery (IDYN), the 14th Elite Zinc Advanced Nursery (HZAN), and the 30th Semi-Arid Wheat Yield Trial (SAWYT). The trial entries were selected based on their performance in introductory and observational nurseries evaluated during the previous season.

In the initial introduction year (2023–2024), a total of 334 lines were received: 50 durum wheat lines, 234 zinc-bio-fortified lines, and 50 semi-arid wheat lines. Following preliminary evaluations, 16 durum, 17 zinc-bio-fortified, and 20 semi-arid lines were shortlisted for further assessment.

From these, 28 promising lines-comprising 10 durum, 8 zinc-bio-fortified, and 10 semi-arid entries were selected for inclusion in the Advanced Evaluation Trial (AET) for the upcoming wheat season (2025-2026). These lines, along with the local check variety ‘Bumthangkaadrukchu,’ were sown in December 2024 using a Randomized Complete Block Design (RCBD).

Selection criteria emphasized grain yield and resistance to pests and diseases, with additional consideration given to plot uniformity, lodging resistance, overall agronomic performance, and spike characteristics. The performance of these selected lines will be further evaluated during the 2025–2026 wheat season to assess their adaptability to local conditions and their potential for varietal release. The agronomic traits of the selected 28 promising lines are presented in the following tables:

Table 13: Agronomic traits of the selected Durum wheat lines

Ent ries	Day to 50% Heading	Days to 50% Flowering	Plant height (cm)	Panicle Length (cm)	Days to Maturity	Kg/ Acre	Agronomic Score (5=best)
704	99	105	74	5	145	970	4
708	110	115	75	5	155	1070	3
709	110	115	75	6	155	1061	4
713	110	115	76	5	155	1079	3
714	109	114	81	6	154	1236	3
723	105	110	71	5	150	987	4
727	110	115	75	5	155	962	4
739	110	115	71	6	155	1115	3
742	110	115	77	5	155	856	4
746	103	109	79	6	149	993	4

Table 14: Agronomic traits of the selected 8 Zinc-bio-fortified lines

Entries	Days to	Days to	Plant	Panicle	Days to	Kg/Acre	Agronomic
---------	---------	---------	-------	---------	---------	---------	-----------

	50% Heading	50% Flowering	Height (cm)	Length (cm)	Maturity		Score (5=best)
54	95	105	78	10	150	776	4
36	95	105	80	9	150	776	3
58	105	115	81	10	160	870	4
57	105	115	84	11	160	1244	4
100 (CHECK)	100	110	88	10	155	661	3
84	98	108	81	10	154	1049	4
5	100	110	80	9	155	978	4
68	100	110	78	8	155	1003	4
1	100	110	82	9	155	648	3

Table 15: Agronomic traits of the selected 10 Semi-arid lines

Entries	Days to 50% Heading	Days to 50% Flowering	Plant Height (cm)	Panicle Length (cm)	Days to Maturity	Kg/Acre	Agronomic Score (5=best)
344	98	105	75	9	145	1507	4
343	98	105	85	10	146	1317	4
333	98	105	83	10	148	1106	3
328	90	98	82	9	140	1061	3
335	90	98	81	10	143	1358	4
303	90	98	84	10	147	1009	4
306	94	102	81	10	150	1122	3
336	98	106	85	10	155	1126	3
339	90	98	84	11	144	1122	4
329	98	105	77	9	148	1169	4

2.2. Second Year Evaluation of Indian Durum Wheat Semolina

Durum wheat was first introduced in Bhutan during the 2023–2024 wheat season, both at research stations and in farmers’ fields, in response to its emerging commercial significance; particularly for value-added products such as semolina and pasta. Building on the initial efforts, the 2024–2025 season marks the second year of multi-location trials aimed at evaluating the crop’s adaptability, agronomic performance, and overall potential under Bhutan’s diverse agro-ecological conditions.

These trials are currently being implemented across key research centers, including ARDC Bajo, ARDC Wengkhar, ARDC Samtenling, and the National Centre for Organic Agriculture (NCoA) in Yusipang, as well as in selected farmers’ fields through on-farm trials. The primary objective is to assess the crop’s growth, yield potential, disease resistance, and overall suitability for commercial-scale semolina production, with the long-term goal of identifying appropriate production zones and developing best management practices for wider adoption.

At ARDC, Bajo, and ARDSC, Menchuna, both stripe rust (yellow rust) and leaf rust caused by *Puccinia striiformis f. sp. tritici* and *Puccinia triticina*, respectively were observed during both the vegetative and reproductive stages of the durum wheat crop. To manage the disease outbreaks, fungicides such as Mancozeb and Propiconazole were applied as part of the integrated disease management strategy.

Similar rust infections were also reported in Wangdue, Punakha, Tsirang and Dagana Dzongkhags in farmers' fields participating in the on-farm trials. Farmers were promptly advised on appropriate fungicide application methods, including dosage, timing, and frequency, to help contain the spread and minimize yield loss. Despite these interventions, the effectiveness of fungicide treatments varied depending on the timing of application and environmental conditions, highlighting the need for timely and preventive measures.

At ARDC, Bajo, the durum wheat trial was established immediately after the paddy harvest. Whereas the crop was sown in two different seasons at ARDSC, Menchunna; initially in September following the maize harvest during the first year, and later in November after the paddy harvest in the subsequent year. Observations from ARDSC, Menchuna indicated that the crop sown in September showed significantly lower susceptibility to rust compared to the November sowing. These findings highlight that earlier planting provides a more favorable window for rust management and contributes to better overall crop performance.

The results from the second-year trials conducted at ARDC Bajo and ARDSC Menchuna are presented in Table 1 and Table 2 below.

Table 16: Evaluation of Durum wheat at ARDC, Bajo

Entries	50% Heading	50% flowering	Plant Height (cm)	Panicle Length (cm)	Yield/plot (kg)	Days to Maturity	Agronomic Score (5=best)
2/12/2024	95	100	78	7	1.4	145	2
7/12/2024	98	103	70	6	1.7	148	2
12/12/2024	96	102	74	7	2	147	2
17/12/2024	96	102	73	8	1.8	147	2
22/12/2024	97	103	73	6	2	148	2

Table 17: Evaluation of Durum wheat at ARDSC, Menchunna

Entries	50% Heading	50% flowering	Plant Height (cm)	Panicle Length (cm)	Yield/plot (kg)	Days to Maturity	Agronomic Score (5=best)
12/3/2024	102	111	53	6.7	1.1	150	1
12/8/2024	103	113	53	6.1	1.5	156	2
12/13/2024	108	117	51	6.1	1.1	158	2
12/18/2024	109	117	49	5.6	1.1	161	2
12/23/2024	112	120	49	5.7	0.8	163	2

2.3. Participatory Evaluation Trial (PET) of Three Selected Lines from the 11th Harvest Plus Yield Trial (HPYT) – CIMMYT Lines

The three wheat lines; 443, 430, and 433 originally selected from the Advanced Evaluation Trial (AET) in the previous season, were evaluated under the PET during the 2024–2025 wheat season. However, all three lines exhibited high susceptibility to yellow rust and were consequently discarded from further evaluation.

2.4. Establishment of Sentinel Plots for Rust Surveillance

In collaboration with the National Plant Protection Centre (NPPC), Simtokha, a sentinel plot comprising 28 wheat lines-including 24 advanced lines and 4 released varieties was established for the early detection and monitoring of rust diseases in wheat. Observations and data recording

were carried out on a weekly basis and submitted through the mobile application platform ‘Open Data Kit (ODK)’ to facilitate real-time data collection and reporting.

Both yellow (stripe) rust and leaf rust were detected in the sentinel plot. The majority of the lines exhibited infection by yellow rust, with severity levels ranging from trace to 30%. Most of the affected lines showed a moderately resistant to moderately susceptible (MR–MS) reaction to the pathogen. Live samples from all yellow rust-infected lines were collected and subsequently shipped to the Global Rust Reference Center (GRRC) in Denmark for further analysis and race identification.

In addition to rust diseases, symptoms of powdery mildew were also observed in some of the lines.

2.5. Seed production and maintenance of released wheat varieties

The following quantity of seeds of different released and promising varieties were produced and maintained at the research centre for future research use.

Table 18: Quantity of wheat seed produced in FY 2024-2025

SN	Varieties /Lines	Qty produced (Kg)	Centre
1	Bajosokha kaa	140	ARDC,Bajo
2	Gumasokha kaa	90	ARDC,Bajo
3	Bumthangkaadrukchu	200	ARDC, Bajo
4	Bajokaa 3	250	ARDC,Bajo
5	Durum	400	ARDC,Bajo
6	Mixture (trial borders)	250	ARDC, Bajo
7	Bajokaa 3	250	ARDSC,Menchunna
8	Durum	200	ARDSC,Menchunna
	Total	1780	

3. Quinoa

3.1 Evaluation of On-Station Tri-Colour Quinoa Varieties

During FY 2024–2025, ARDSC Tsirang conducted on-station evaluations of tri-colour quinoa varieties to assess their adaptability under mid-temperate conditions at an elevation of 1,460 MASL. The trial included four varieties—CHLI-28, CHLI-29, CHLI-1246, and CO-KA-1911—with Amarilla Marangani used as a check.

The first sowing was carried out on 30th October 2024 in 14 m² plots using line sowing with 10 cm row spacing and 2 cm plant spacing. Germination was poor across varieties, particularly for CHLI-1246 (5%), and plant growth was generally stunted. This was attributed to delayed sowing and erratic rainfall.

A second sowing on 16th November 2024 employed nursery raising in fish boxes filled with leaf mould and vermicompost. Transplanting was done under three different environments: greenhouse, green net house, and open field. While germination improved, plant performance in the open field remained weak due to dry winter conditions.

Table 19: Agronomic traits of Tri-Colour Quinoa Varieties

Variety Name	Plant Height (cm)	Panicle Length (cm)	Yield (t/ac)	Date of Sowing	Days to maturity
CO-KA-1911	220	14	0.84	16.11.24	119 days
CHLI-29	200	20	0.69	16.11.24	119 days
CHLI-28	70	15	0.42	16.11.24	119 days
CHLI-1246	30	10	-	16.11.24	124 days
CHLI-28	70	70	0.164	30.10.24	136 days
CHLI-29	200	20	0.079	30.10.24	136 days
CHLI-1246	30	10	0.008	30.10.24	136 days

The highest yield (0.84 t/ac) was recorded from CO-KA-1911 grown in greenhouse conditions. CHLI-28 also performed well under greenhouse conditions, yielding 0.42 t/ac. Amarilla Marangani, grown in the open field, yielded 0.145 t/ac, with incomplete grain filling contributing to poor yield. CHLI-1246 showed consistently poor performance across both trials and all conditions.

In conclusion, the performance of tri-colour quinoa varieties was constrained by delayed sowing and suboptimal climatic conditions. Future trials are recommended between the last week of September and the first week of October to better align with favourable weather and improve varietal assessment outcomes.

3.2 Enhancing Quinoa Production through Capacity Building and Seed Support

With support from the Flexible Voluntary Contribution (FVC) project, ARDSC Tsirang, in collaboration with ARDC Bajo, implemented key initiatives to enhance quinoa production in the region. These interventions focused on building the technical capacity of extension personnel and improving farmers' access to quality seeds. A regional Training of Trainers (ToT) program on quinoa cultivation was conducted at Tsirang on 25th and 26th September 2024, targeting extension officials from the Dzongkhags of Dagana, Punakha, Wangdue Phodrang, and Tsirang. The training aimed to strengthen the technical knowledge of frontline agriculture staff to enable effective dissemination of quinoa cultivation practices at the farmer level. Further ToT programs were conducted for Punakha and Wangdue Phodrang extension staff from 10th to 12th April 2025 at ARDC Bajo, reinforcing practical skills and field-level application of quinoa production technologies. In total, 49 extension personnel participated in these trainings.

To promote widespread cultivation and adoption, the FVC project distributed 950 kilograms of quinoa seed free of cost to farmers across the three Dzongkhags. In Dagana, 400 kg of seed benefited 138 farmers, while in Tsirang, 525 kg reached 323 farmers. In Wangdue Phodrang, 25 kg of seed was distributed to 15 farmers. These combined efforts—capacity-building through training and input support via seed distribution—are expected to significantly contribute to the expansion of quinoa cultivation, enhance productivity, and promote the long-term adoption of quinoa as a climate-resilient crop in the region.

3.3 Quinoa Promotion through Field Days in Dagana and Tsirang

As part of the OCOP and OGOP initiatives, Quinoa Field Days were organized at Thomgang, Khebisa Gewog (Dagana) on 19 March 2025 and at Tashithang, Sergithang Gewog (Tsirang) on

7 March 2025 to promote quinoa as a climate-resilient and high-value crop. The events aimed to demonstrate yield potential, share best practices, and raise awareness of quinoa’s nutritional and economic benefits.

At Khebisa, 25 participants, including gewog officials, the AEO, and ARDSC Tsirang staff, attended the field day at a farmer’s field. Two crop cuts recorded yields of 733 kg/acre and 1,133 kg/acre, corresponding to potential incomes of Nu. 76,000 and Nu. 118,000, respectively. Although delayed sowing affected yields, farmers recognized quinoa’s low labour requirements and attractive market price (Nu. 105/kg). Farm inputs such as a quinoa thrasher and knapsack sprayers were distributed, and farmers were encouraged to leverage OGOP support for inputs, training, and collective marketing.

In Sergithang, over 80 farmers and 17 officials participated in the event, chaired by Hon’ble Dasho Dzongdag and sector heads. Quinoa cultivated on 34.97 acres by 124 households showed promising results, with a crop-cut yield of 1.3 MT/acre and income potential of Nu. 130,000/acre. Farmers highlighted ease of management and emphasized timely sowing, fine tilth, proper FYM application, and sufficient moisture during germination as key factors for success.

Both field days reinforced quinoa’s viability in mid-altitude regions and its alignment with national priorities. With improved planning, timely sowing, and sustained support through the OGOP framework, quinoa has strong potential to enhance livelihoods, nutrition, and climate resilience in Bhutan.

4. Oil Seeds

4. 1. Evaluation of Peanut Varieties

The experiment aimed to evaluate the agronomic performance and yield potential of five peanut varieties—Chalipa (T1), Japanese Large (T2), Bartampa (local, T3), Japanese Small (T4), and Yabrang Badam (T5)—using various growth and yield parameters under field conditions.

The trial was laid out in a Randomized Complete Block Design (RCBD) with three replications. Standard agronomic practices were uniformly followed across all plots to ensure consistency. The parameters recorded during the trial included days to 50% germination, days to 50% flowering, plant height at maturity (average of five randomly selected plants per plot), days to maturity, and pod yield per plot (in kilograms). The summarized results for the evaluated varieties are presented in the table 20.

Table 20: Agronomic performance of peanut varieties

Variety	Days to 50% Germination	Days to 50% Flowering	Plant Height at Maturity (cm)	Days to Maturity	Pod Yield per Plot (kg)
Chalipa (T1)	35	86	68.33	174	3.64
Japanese Large (T2)	26	59	43.32	147	9.59
Bartampa (T3)	29	65	49.75	156	13.68
Japanese Small (T4)	35	70	56.42	160	55.36
Yabrang Badam (T5)	40	90	59.42	190	1.88

Analysis of the data shows that Japanese Large (T2) germinated and flowered earliest, at 26 and 59 days respectively, followed by Bartampa (T3) and Japanese Small (T4). In contrast, Yabrang

Badam (T5) and Chalipa (T1) exhibited slower germination and flowering. Regarding plant height, Chalipa (T1) and Yabrang Badam (T5) had the tallest plants, averaging 68.33 cm and 59.42 cm respectively, while Japanese Large (T2) had the shortest stature at 43.32 cm.

In terms of maturity, Japanese Large (T2) matured the earliest at 147 days, followed by Bartampa (T3) at 156 days and Japanese Small (T4) at 160 days. Yabrang Badam and Chalipa had longer maturity durations of 190 and 174 days respectively. The pod yield per plot varied significantly among the varieties, with Japanese Small (T4) recording the highest yield of 55.36 kg, followed by Bartampa (T3) with 13.68 kg and Japanese Large (T2) with 9.59 kg. Chalipa (T1) and Yabrang Badam (T5) had the lowest yields of 3.64 kg and 1.88 kg respectively.

Based on these results, Japanese Small (T4) showed superior pod yield and a reasonable maturity period, making it the most promising variety for future cultivation and evaluation. Bartampa (T3) and Japanese Large (T2) demonstrated moderate performance. However, Chalipa (T1) and Yabrang Badam (T5) underperformed considerably in terms of yield and will be excluded from evaluation in subsequent trials.

4.2 On-station Evaluation of Soya Varieties

The experiment was conducted to evaluate the agronomic and yield performance of three soybean varieties—Japanese Large (T1), Japanese Small (T2), and Khangma Labi (Local, T3). The primary objective was to assess their suitability for cultivation based on key growth parameters and pod yield under field conditions.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Standard crop management practices were followed throughout the trial. Data collection focused on five parameters: days to 50% germination, days to 50% flowering, plant height at maturity (based on the average height of five randomly selected plants per plot), days to maturity, and pod yield per plot.

Table 21: The summarized results of soya beans across the three replications

Variety	Repl.	Days to 50% Germination	Days to 50% Flowering	Plant Height at Maturity (cm)	Days to Maturity	Pod Yield per Plot (kg)
Japanese Large (T1)	R1	45	71	43.80	125	1.87
	R2	45	71	50.90	125	1.18
	R3	45	71	52.06	125	3.69
Japanese Small (T2)	R1	42	65	28.20	100	0.152
	R2	42	65	25.20	100	0.162
	R3	42	65	28.46	100	0.149
Khangma Labi (T3)	R1	36	88	60.80	132	5.03
	R2	36	88	59.36	132	3.302
	R3	36	88	56.14	132	4.33

Analysis of the trial data reveals that Khangma Labi (T3) consistently outperformed the other two varieties in terms of plant height and pod yield. It exhibited the tallest plants (average height ranging from 56.14 to 60.80 cm) and the highest pod yield, ranging from 3.30 to 5.03 kg per plot, with an average maturity period of 132 days. In contrast, Japanese Small (T2) recorded the lowest plant height (averaging between 25.20 to 28.46 cm) and the lowest pod yield across all replications, with values around 0.15 kg per plot. However, it had the shortest maturity duration

(100 days), which may be beneficial for shorter growing seasons. As shown in the above table, the variety *Japanese Small* was found to be the lowest performing among the three. This poor performance may be attributed to the fact that the trial was harvested during the peak of the rainy season, which likely resulted in significant seed loss due to fungal infection. To address this issue, the trial will be scheduled earlier in the next cropping season to ensure that harvesting can be completed before the onset of heavy rains, thereby minimizing losses and allowing for a more accurate evaluation of the variety's potential.

Japanese Large (T1) showed moderate performance with plant heights ranging from 43.80 to 52.06 cm and pod yields between 1.18 and 3.69 kg per plot. It had a uniform maturity duration of 125 days across all replications.

In conclusion, Khangma Labi (T3) demonstrated the most promising performance in terms of plant vigor and yield potential and is recommended for further promotion and evaluation. Japanese Large (T1) may also be considered a moderately suitable variety.

4. Seed Production and Maintenance of Finger Millet

In 2024, seeds from various local finger millet varieties were produced and maintained, with support from ARDC Wengkhaw, which has conducted studies on these crops under the Neglected and Underutilized Species (NUS) Project. The primary objective of this seed production is to multiply these varieties and promote their adoption among interested farmers and millet-growing communities in the region. The varieties produced include Trashigang (2453) 15 kg, Monmola (830) 20 kg, Chakhrey/Khoshomo 20 kg, and Woonthi (831) 6 kg, totalling 58 kg of seeds. In Punakha Dzongkhag, several areas have only dryland conditions, making them suitable for upland rice and other dryland crops. Over the past few years, we have supported these communities by providing upland rice seeds, and the availability of local finger millet seeds will further promote crop diversification and strengthen food security in these dryland areas.

5. Buckwheat Germplasm Collection, Evaluation and Characterization at ARDC

The collection and characterization of local buckwheat germplasm are essential for conserving and improving traditional varieties, especially in regions like Bumthang with diverse landraces. These efforts safeguard genetic resources and support breeding programs aimed at enhancing resilience, productivity, and adaptability to climate change and agricultural challenges. 19 populations—7 *Fagopyrum esculentum*, 9 *Fagopyrum tataricum*, and 3 *Ser-nye*—from Bumthang, Trongsa, and Zhemgang were evaluated for morphological traits using the Descriptors for Buckwheat (*Fagopyrum* spp.) in separate plots within the same field.

HORTICULTURE RESEARCH AND DEVELOPMENT PROGRAM

6. Fruits and Nuts

6.1 Evaluation of temperate and sub -tropical fruits and nuts germplasm

ARDC Bajo has established both warm temperate and sub-tropical fruit and nut orchards (Table 21) germplasm blocks. The germplasm blocks serve as technology hub and demonstration sites for providing hands-on training for researchers, extension agents and farmers in the long run. The technology driven demonstration orchards provides an opportunity for the agri-business minded youth to learn practically from internship program with the Centre. It is also to evaluate and identify superior cultivars for diversification of fruit cultivation.

Table 22: Fruit crop varieties established in the germplasm block

Crops	Varieties
Peach	Kurataki, Nonomewase, Floridasan, Beauty cream
Apricot	Khasha, New Castle
Pear	Yakumo, Niitaka, Hosui, Kosui, Shinko, Chojuro
Kiwi	Hayward, Wengkhari Yellow, Wengkhari Green, Enza Red, Male
Grape	Steubin, Perlette, Campbell, Kyoho, Risamate, Nsehelen
Dragon fruit	Gewai ringa
Pomelo	R3P4, R4P5, R3P9, Banpeiye
Lime	Seedless lime
Lemon	Frost Eureka
Loquat	Mogi, Tanaka
Avocado	Brogdown, Hass, Bacon, Zutano, T1, T2, T3, M1, M2, M3
Persimmon	Jiro, Fuyu, Yubeni, Zinjimaru, Taishu
Plum	Honey Rosa, Santa Rosa, Soldum, Kiyo, Oishi wase
Kumquat	Marumi
Pecan nut	Wichita, Western Schley
Wine grape	Cabernet Sauvignon 337, Syrah 470, Cot 598, Sauvignon Blanc 906, Chardonnay 96, Pinot Noir 72, Merlot 181, Petit Manseng 573
Guava	Pink Flesh, Thai Giant, Allahabad Safeda, Local
Pomegranate	Chaula, Bedana, K5, K3
Grape fruit	Star ruby

ARDSC Menchhuna has also maintained germplasm collection of different fruit crops. They are peach (5 varieties), plum (5 varieties) pear (4 varieties), sub-tropical apple (1 variety), pecan (4 varieties), kiwi (4 varieties), and citrus (5 rootstock varieties) and persimmon (2 varieties). The varieties of these fruit crops have been planted mainly for bud wood and fruit production. The scion wood is used for seedling production and is also supplied to private nursery growers.

6.2 Performance Evaluation Trial of Passion Fruit

A performance evaluation trial of passion fruit was initiated in 2023, coordinated by ARDC Wengkhari as part of the National Coordinated Trial (NCT). The trial compared the ‘Summer Queen’ variety against a local variety used as a check. Plants were arranged in a Completely Randomized Design (CRD) with five replications, each spaced at 3 m × 2 m. A total of 300

observations were recorded, sampling 50 fruits per replication. The ‘Summer Queen’ variety is proposed for release this year.

Table 23: Fruit quality analysis of summer queen passion fruit variety at Bajo

Rep	Fruit weight (gm)	Fruit Height (cm)	Fruit Diameter (cm)	TSS (%)	Pulp weight (gm)	Juice Content (ml)	No. of fruits per plant	No. of seeds	Rind Thickness (mm)
1	48.37	5.72	4.92	15.73	26.14	15.49	22.70	135.88	4.68
2	53.20	5.96	5.15	16.54	28.84	17.87	21.83	127.32	4.61
3	50.98	5.97	5.04	15.96	29.15	18.26	19.83	168.75	7.11
4	51.17	5.92	5.14	15.72	30.99	18.75	16.98	116.51	7.00
5	39.39	5.48	4.71	15.64	21.40	14.74	17.55	112.01	5.97
Check	51.64	5.87	5.09	16.52	26.58	16.71	12.70	124.14	4.57



Figure 4: External and internal views of the ‘Summer Queen’ passion fruit variety

Note: All replications produced purple-colored fruits with a noticeable fragrance.

6.3 Evaluation of Pure Germplasm of Langra and Himsagar Mango Varieties

Mango cultivation worldwide faces challenges such as alternate bearing, low productivity, short shelf life, and inconsistent fruit quality. Conserving and evaluating diverse mango germplasm is therefore essential to improve productivity and maintain high-quality cultivars. Langra (also known as Malda in some regions) and Himsagar are prominent Indian mango varieties valued for their superior flavour and aroma. Although these varieties are reportedly grown in parts of Bhutan, their genetic purity had not been previously confirmed.

To address this gap, the Department of Agriculture, Bhutan, procured authentic grafted seedlings of Langra and Himsagar from the ICAR–Central Institute of Subtropical Horticulture (CISH), Lucknow, in July 2023. ARDC Samtenling subsequently initiated a multi-location trial to assess their yield performance and fruit quality under different agroecological conditions in Bhutan.

The experiment was conducted using a Randomized Complete Block Design (RCBD) with three replications at each location, comprising three plants per replication. The locally grown cultivar ‘Tommy Atkins’ (Samtenling Amchukuli 4) was included as the check variety.

Table 24: Mean Growth Parameters of Mango Varieties

Plant Variety	Height of mango (From ground)	Girth measurement	Height from the graft union	Incidence of pest and diseases
Malda	132.28	2.06	89.25	No
Tommy Aktins	60.66	1.25	49.32	No
Himsagar	78.90	1.52	72.00	No
Rootstock	79.00	1.50	72.00	No

6.4 Evaluation of Irwin Mango under Protected Cultivation

Mango (*Mangifera indica* L.) is a valuable tropical fruit, sensitive to environmental factors like temperature and humidity, especially in early growth stages. In Bhutan, mango cultivation is part of climate-resilient horticulture. However, cold and frost-prone areas hinder its successful establishment. Protected cultivation (e.g., greenhouses) has emerged as a promising solution to mitigate environmental stress, though little data exists for Bhutan. This study evaluates Irwin mango performance under protected cultivation in two locations: Bajo (Wangdue Phodrang) and Samtenling (Sarpang).

The study was conducted at two sites in Bhutan—ARDC Bajo and ARDC Samtenling—as part of a NCT to evaluate the early growth performance of Irwin mango under protected cultivation. Eight mango saplings were planted at each site between March and April, following pit preparation and application of farmyard manure (FYM), urea, single super phosphate (SSP), and muriate of potash (MoP). Tree height and trunk diameter were measured, while environmental data (temperature and humidity) were recorded hourly using digital data loggers. Statistical analyses included independent samples t-tests to compare growth parameters between locations and multiple linear regressions to assess the influence of environmental factors on growth. Due to high multicollinearity between temperature and humidity, only temperature and flowering were retained in the regression models.

Table 25: Means (SD) of Growth and Environmental Variables in Bajo and Samtenling

Centre	Height (cm)	Trunk Dia (cm)	Lowest Temp (°C)	Highest Temp (°C)	Highest Humidity (%)	Lowest Humidity (%)
Bajo	62.13 (20.80)	1.10(0.28)	2.8	44.5	93.9	19.4
Samtenling	53.37 (17.62)	1.5(0.34)	5.6	47.2	54	13.2
<i>P-Value</i>	0.34	0.03				

In the first year of the Irwin mango trial under protected cultivation, average plant height was higher in Bajo (62.13 cm) than in Samtenling (53.37 cm), but the difference was not statistically significant ($p = 0.34$). However, trunk diameter was significantly greater in Samtenling (1.50 cm) compared to Bajo (1.10 cm), with a p -value of 0.03. Bajo experienced lower temperatures (min 2.8°C, max 44.5°C) and higher humidity (max 93.9%), while Samtenling had higher temperatures (min 5.6°C, max 47.2°C) and lower humidity (max 54%). Regression analysis showed that temperature had a significant positive effect on trunk diameter ($p = 0.0416$), while plant height and flowering were not significantly affected.

These results suggest that Samtenling’s warmer conditions supported better early structural growth, especially trunk thickening, which is vital for long-term productivity. The inability of saplings to survive in the open field at Bajo highlights the importance of protected cultivation in frost-prone areas. While both sites showed potential for mango establishment under greenhouse conditions, Samtenling proved more favourable. The findings underscore the need for multi-year evaluation and consideration of other factors such as soil properties, light availability, and irrigation in future assessments.

6.5 Evaluation of Germination Enhancement Techniques for Persimmon (*Diospyros spp.*)

In FY 2024–25, ARDSC Menchhuna carried out a study on persimmon (*Diospyros spp.*) seed collection, pre-treatment, and sowing, with a focus on improving germination through scarification and cold-moist stratification. A total of 100 seeds were divided into four treatment groups: control (no treatment), scarified only, stratified only, and both scarified and stratified. Germination was observed 4–8 weeks after sowing, with the highest success rate (~20–25%) in seeds that received both scarification and stratification, while the control group recorded only ~5% germination.

Despite applying recommended pre-treatment methods, overall germination remained below 30%. This low rate may be attributed to variability in seed maturity, insufficient stratification duration or moisture conditions, or more complex dormancy mechanisms. Nevertheless, the germinated seedlings showed healthy and vigorous growth, supported by appropriate nursery practices such as partial shading, regular watering, and pest and disease management.

Minor signs of nutrient deficiency and fungal infection were observed in some seedlings, despite good care. The findings suggest the need for refining seed pre-treatment protocols, including ensuring uniform seed maturity, exploring warm stratification prior to chilling, or sowing fresh seeds immediately after collection. The seedlings are currently in a stable growth phase.

6.6 Pomelo Varietal Evaluation Trial

The Pomelo Varietal Evaluation Trial study aimed to assess the performance of three pomelo varieties; Banpeiyu, R3P4, and R4P5 under Bhutanese agro-climatic conditions to identify the most suitable cultivar for commercial cultivation. The trial was carried out at the Agriculture Research and Development Centre (ARDC), Bajo, and data on morphological and physicochemical traits were collected during the 2024 and 2025 harvests. Various analytical methods including Principal Component Analysis (PCA), quality index formulation, and mass modeling were used to evaluate and compare the varieties.

The results revealed distinct varietal differences as follows,

- Banpeiyu stood out with the largest fruit size (0.74 kg), highest pulp and juice content (138 ml), and the highest citric acid concentration. It also ranked first in the overall quality index, making it suitable for both fresh consumption and juice processing. However, its high seed content and relatively lower sweetness (TSS 11.6%) could reduce its appeal to certain consumers.
- R3P4, while having the smallest fruits, exhibited the highest total soluble solids (TSS 12.1%) and TSS/acid ratio (11.2), indicating a sweeter and less acidic flavor profile. It also had the lowest seed weight and best seed to pulp ratio, ranking second in the quality index.

- R4P5 displayed moderate performance in most traits and showed the strongest correlation between fruit dimensions and weight, making it useful for non-destructive yield prediction and efficient sorting. However, its lower juice content and higher seed load contributed to its lowest quality index ranking.

Correlation and PCA analyses helped in providing deeper insights into trait relationships. In R3P4, larger fruit size positively correlated with pulp and juice yield, whereas in Banpeiyeu, external size did not reliably indicate internal quality. PCA identified two key dimensions of variability PC1 (size and mass attributes) and PC2 (shape and sweetness) which captured 65.1% of the total variation. These findings highlighted the importance of variety specific strategies in pomelo breeding and commercialization.

The study concluded with Banpeiyeu being best suited for mainstream markets, R3P4 for niche markets focusing on sweetness and seedless, and R4P5 for mechanical processing.

7. Citrus

7.1 National Citrus Repository

The National Citrus Repository (NCR), under the Department of Agriculture, continued its mandate in FY 2024–2025 as Bhutan’s central institution for conserving and promoting citrus genetic resources. Key highlights include the maintenance of 120 citrus germplasm accessions and the successful acquisition of six additional unique citrus varieties from the relocated ARDC Samtenling, now quarantined for safety. Though the in-vitro propagation techniques such as shoot tip grafting and micropropagation were initiated, no successful plant regeneration was achieved due to technical and infrastructure limitations, which NCR plans to address going forward.

NCR also managed 17 on-farm citrus evaluation trials across Tsirang and Dagana to assess the adaptability and productivity of citrus varieties in different agro-ecological zones. Additionally, phenological characterization of 39 citrus varieties was carried out in two greenhouse facilities, with standardized data collection focused on traits like flowering, fruit set, and maturation. These efforts support the development of region-specific citrus recommendations to improve farm-level outcomes.

7.2 On-farm performance evaluation of different citrus varieties

The National Citrus Repository (NCR) conserves 120 citrus germplasm varieties, both local and exotic, and has developed several public access varieties (PAVs) with promising traits. In recent years, citrus production—especially mandarin cultivation below 1000 masl—has declined sharply due to changing climatic conditions, pest outbreaks, and disease prevalence. This has severely impacted the livelihoods of citrus farmers in affected areas. To address this challenge, the NCR initiated the Citrus Research Outreach Program (ROP) in 2019, establishing on-farm evaluation trials across various agro-ecological zones in Tsirang and Dagana districts. The ongoing program aims to identify climate-resilient and high-performing citrus varieties that can sustain production and improve farmer incomes.

The primary objective of the Citrus ROP is to evaluate promising citrus varieties across different altitudes and recommend the best-performing ones for mass cultivation. The propagation process

begins with seed sowing of disease-resistant rootstocks like Trifoliate and Rangpur lime, followed by side grafting using scions from selected citrus varieties. The grafted plants are carefully managed with proper watering, pest protection, and monitoring to ensure healthy growth. This propagation method ensures the production of high-quality, disease-tolerant citrus plants suited for Bhutan's diverse agro-climatic conditions.

Experimental trials were carried out in Tsirang and Dagana districts, covering a wide altitudinal range from 330 to 1600 masl to represent Bhutan's distinct agro-ecological zones—low (<1200 masl), mid (1200–1800 masl), and high (>1800 masl). These zones vary in temperature, humidity, rainfall, and soil type, influencing citrus growth and adaptability. This stratified site selection strengthened the experimental design, enabling effective evaluation of citrus varieties under diverse climatic conditions.

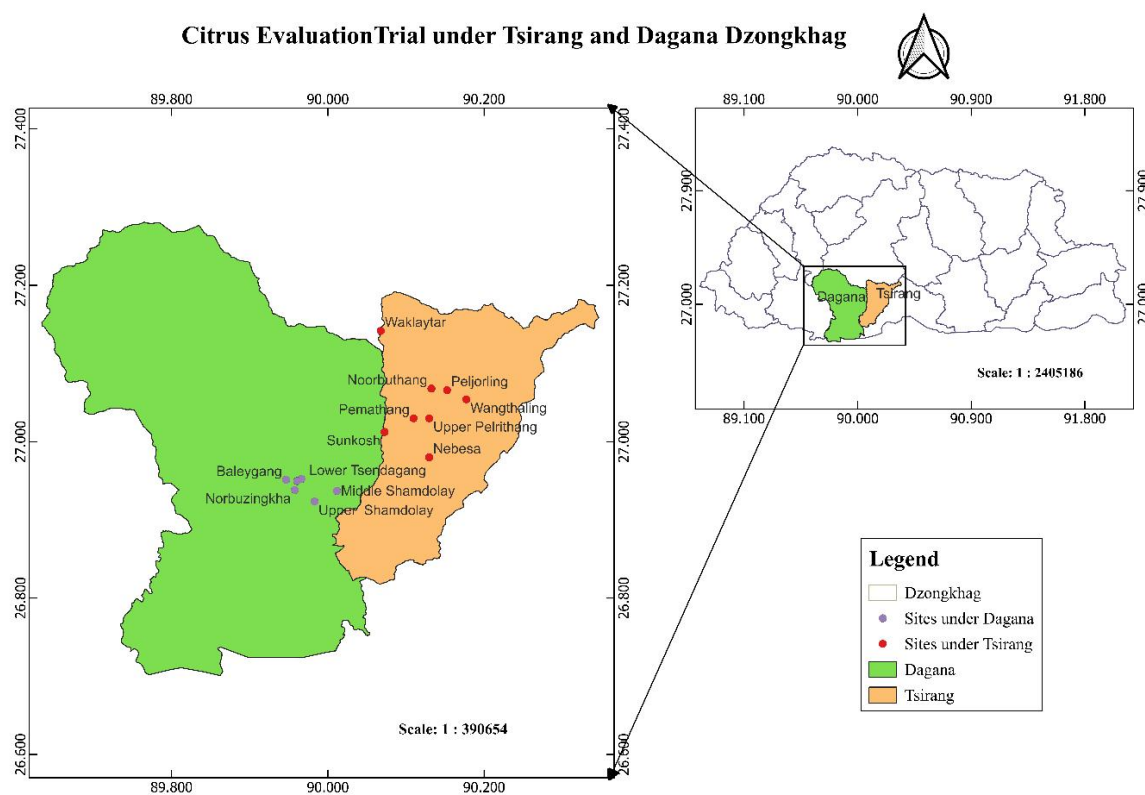


Figure 5: Map showing location of trial sites

Data collected from the trial sites included mortality rate, tree growth parameters, and pest and disease assessments, with common issues such as leaf miners, trunk borers, and the Chinese citrus fruit fly affecting fruit quality. While some sites were removed due to land disturbances, others—especially in Tsendagang Gewog—showed excellent vegetative growth and fruiting across multiple citrus varieties. Statistical analysis using the Kruskal-Wallis test revealed significant differences among varieties, and a Dunn's post hoc test helped identify the top five performing varieties based on tree height, diameter, and canopy size.

Fruit testing was conducted on 14 citrus varieties, assessing traits like fruit size, juice content, taste, and TSS (measured via refractometer). Due to small sample sizes, fruit data were analyzed as a single group, while growth data were categorized by altitude. The Kruskal-Wallis test

showed significant differences among varieties ($p = 0.004926$), with a bar chart illustrating the top five based on key fruit traits. Star Ruby showed excellent fruit quality, while Hamlin and Dorokha local performed best in growth. Many fruits were affected by *Bactrocera minax*, and some varieties were still immature. Continued assessment is recommended.

7.5 Development of Virus-Free Citrus Plants through Shoot Tip Tissue Culture

The National Citrus Repository (NCR) laboratory has initiated efforts to produce virus-free citrus plants using shoot tip tissue culture, a crucial technique to combat Huanglongbing (HLB or Citrus Greening), which severely impacts citrus production and growers' livelihoods. This method involves aseptically excising very small shoot tips (0.1–0.5 mm) to regenerate disease-free plants.

Initial trials with eight Kumquat shoot tips under a standard 16-hour light and 8-hour dark photoperiod resulted in tissue browning, likely due to light stress. To mitigate this, the photoperiod was adjusted to 6 hours of light and 18 hours of darkness, aiming to promote regeneration. Subsequent culturing of 46 Kumquat shoots showed early signs of growth but then entered dormancy without further development, suggesting that growth hormone concentrations—applied based on general guidelines rather than Kumquat-specific protocols—may have been suboptimal.

To further explore organogenesis, 49 Kumquat shoot tips were cultured in hormone-free MS media; despite some initial growth, these tissues also remained dormant. It was inferred that harsh surface sterilization methods using ethanol, sodium hypochlorite, and Tween 20 may be stressing the tissues, particularly due to prolonged exposure during sterilization. While surface sterilization is essential to prevent contamination by external microorganisms, reducing exposure time to these reagents is now being considered to improve tissue viability.

Overall, while the NCR's tissue culture efforts show promise, challenges such as light sensitivity, hormone optimization, and sterilization protocols need refinement. Future work will focus on adjusting these variables to establish an effective, species-specific tissue culture protocol for producing healthy, virus-free citrus plants.

7.6 Citrus Phenology Study at NCR

Table 26: Citrus Phenology Summary (2024–2025)

Phenology Stage	Timing	Remarks
Bud Break	27 Feb – 12 Mar 2024	Etrog Citron and Trifoliata broke early (Feb 27).
Flowering & Bloom	Late March – Early April	50% flowering by late March; full bloom by early April.
Fruit Set	Early to Mid-April	Valencia and Bearss Lime showed poor fruit set and natural drop.
Cell Division & Expansion	May – October	Sinking (cell division) and floating (expansion) varied by cultivar.
Colour Break & Maturity	Nov – Dec	TSS ranged from 9° to 15° Brix, depending on cultivar.
Harvest Period	Dec 2024 – Jan 2025	Fruits harvested from 15 varieties.
Vegetative Growth Only	—	Bajo Pomelo, Poncirus Pomeroy, P. rubidoux 4x, Sasaki, Orlando Tangelo.

Phenology Stage	Timing	Remarks
Natural Fruit Drop	—	Bearss Lime, Valencia, Chukha Local, Okitsu Wase, Star Ruby.

The citrus phenology observations during the 2024–2025 season indicated distinct variations among cultivars. Bud break occurred between 27 February and 12 March 2024, with Etrog Citron and Trifoliolate showing the earliest bud emergence. Flowering commenced in late March, reaching approximately 50% flowering by the end of the month, and full bloom was observed in early April. Fruit set took place from early to mid-April; however, Valencia and Bearss Lime exhibited poor fruit set accompanied by notable natural fruit drop.

The cell division and fruit expansion phase extended from May to October, with differences in growth dynamics across cultivars. Colour break and fruit maturity were recorded during November and December, with total soluble solids (TSS) ranging from 9° to 15° Brix depending on the cultivar. Harvesting was carried out from December 2024 to January 2025 across 15 citrus varieties. Some cultivars, including Bajo Pomelo, Poncirus Pomeroy, P. rubidoux 4x, Sasaki, and Orlando Tangelo, exhibited only vegetative growth, while natural fruit drop was particularly evident in Bearss Lime, Valencia, Chukha Local, Okitsu Wase, and Star Ruby.

7.7 Citrus Phenology Study at ARDC Bajo

To understand the impact of climate change on the phenological cycle of citrus, ARDC Bajo conducted a phenological observation study in 2024. The study was based on data collected from a citrus varietal trial plot established at the Centre, comprising six varieties: *Tarocco Ippolito* / Trifoliolate; *MC. Mahan* / Rangpur Lime; *Cant Star Rubby* / *P. Rubidoux*; *Caffin Clementine* / *Bigamate*; *Aflourer* / C35; Dorokha Local / *Volkameriana* (used as the check variety).

Table 27: Fruit quality analysis of different citrus variety at ARDC Bajo

Variety	Fruit Weight (gm)	Fruit Diameter (mm)	Fruit Length (mm)	TSS (%)	Citric acid content (mol/l)	Juice content (ml)	Rind Thickness	Fruit Colour
Ragpur Lime	202.14	74.73	67.28	10.63	0.011	62	3.98	Yellow
Dorokha local	83.96	54.99	46.22	8.66	0.005	28.91	2.97	Orange
Aflourer	72.52	53.26	45.23	10.14	0.009	26.07	2.07	Dark Orange

7.8 Performance Evaluation of different Citrus Variety in Patshaling Gewog, Tsirang

A citrus varietal evaluation trial was established in Patshaling Gewog, Tsirang Dzongkhag, to assess the performance of five introduced citrus varieties—Okitsu Wase, Hamlin, Cara cara, Naveline, and Afourer—against the widely cultivated local mandarin. The study responds to concerns over declining productivity and rising disease pressure in existing citrus orchards and aims to support varietal diversification suitable for different agro-ecological zones.

The trial was set up across three sites ranging from 1520 to 1837 meters above sea level, using a randomized complete block design with five replications per variety. A total of 25 plants were

planted at a spacing of 5m × 5m, with standard orchard practices adopted for land preparation, planting, and maintenance. Key data will be collected on vegetative growth, phenological traits, yield attributes, fruit quality, pest and disease incidence, and plant survivability.

This initiative is expected to generate comparative performance data and help identify high-yielding, adaptable, and resilient citrus varieties. The outcome will inform varietal recommendations tailored to Tsirang’s agro-climatic conditions and potentially contribute to enhancing citrus productivity in the region.

8. Million Fruit Tree Plantation (MFTP)

8.1 Key Achievements under MFTP Phase IV

The Million Fruit Tree Plantation (MFTP) initiative, now in its fourth phase, has significantly advanced Bhutan’s horticultural development goals through a coordinated approach involving fruit tree grafting, establishment of demonstration orchards, and capacity-building programs. Implemented across the Dzongkhags of Wangdue Phodrang, Punakha, and Gasa, this phase focused on expanding the cultivation of high-value fruit crops, enhancing technical skills of farmers, and promoting climate-resilient agriculture.

A total of 563 fruit trees were grafted across the three Dzongkhags, with walnut, peach, pear, apricot, almond, persimmon, and plum being the primary species. Wangdue alone accounted for 349 grafted plants, followed by 130 in Punakha and 84 in Gasa. Grafting activities were accompanied by hands-on training sessions to strengthen local capacity in propagation techniques.

In parallel, 10 demonstration orchards were established in strategic Gewogs to showcase best practices in orchard layout, crop diversification, and integrated fruit management. Wangdue Phodrang set up orchards featuring kiwi, citrus, walnut, almond, pecan, and avocado, while Punakha’s orchards highlighted crops like dragon fruit, persimmon, and pomegranate.

Pruning and training activities covered a total of 282 trees in Wangdue. Additionally, 295 temperate fruit trees were pruned and managed at the Gyalsung Royal Project in Khotokha, reflecting the initiative’s support for youth-centric national programs. Below is a consolidated table summarizing the key interventions across the Dzongkhags:

Table 28: Summary of Key Activities under MFTP Phase IV (2025)

Dzongkhag	Activity	Fruit Types	Quantity / Details	Location/Gewog
Wangdue Phodrang	Grafting	Walnut, Peach	349 grafted trees	Daga, Gasetshowom
	Demo Orchards	Kiwi, Citrus, Walnut	193 trees planted	Nahi and Rubesa
	Training & Pruning	Mixed	282 trees pruned	8 Gewogs
	Training & Pruning	Mixed	295 trees pruned	Royal Gyalsung Project, Khotokha
Punakha	Grafting	Walnut, Peach, Apricot	130 grafted trees	Toedwang, Barp
	Demo Orchards	Avocado, Citrus, Dragon fruit	60 trees planted	Kabisa, Barp, Toedwang
Gasa	Grafting	Walnut, Peach, Plum	84 grafted trees	Khamey, Khatoed

These collective efforts reflect the MFTP's strong alignment with Bhutan's 13th Five Year Plan, driving rural development, food self-sufficiency, and economic diversification.



Figure 6: MFTP activities during the FY 2024-25

8.2 MFTP Subtropical Seedling Distribution (Phase IV)

Under Phase IV of the Million Fruit Tree Plantation (MFTP) Program, focal persons were designated at each Agriculture Research and Development Centre (ARDC) to coordinate and monitor the distribution of subtropical fruit seedlings. Their key responsibilities include ensuring that healthy, pest- and disease-free seedlings are procured from certified government and private nurseries, verifying quality standards, and facilitating timely delivery to the respective gewogs.

For the West-Central Region, the recorded demand for subtropical fruit seedlings was as follows:

- Wangdue Phodrang: 15,618 seedlings
- Punakha: 3,587 seedlings
- Tsirang: 22,956 seedlings
- Dagana: 64,278 seedlings

This distribution initiative contributes to national objectives of improving fruit self-sufficiency, enhancing farmers' incomes, and promoting landscape greening through the expansion of perennial fruit cultivation.

9. Vegetable Research and Development

9.1 Adaptability and performance of new watermelon variety (Summer sweet)

A field trial was conducted at the Agriculture Research and Development Centre (ARDC), Bajo, to evaluate the adaptability and performance of a new F1 hybrid watermelon variety, *Summer Sweet*. The variety was introduced through the Bhutan Agrifood and Trade Investment Forum (BATIF) and supplied by Oshiye & Co. Ltd., Japan. The performance of Summer Sweet was compared with the released variety Sugar Baby using a Randomized Complete Block Design (RCBD) with three replications.

Seedlings were raised in poly pots and transplanted on 19 March 2025. Plastic capping was applied during the early growth stage to protect young plants from pest damage and to promote early establishment. Major insect pests, including red pumpkin beetle and fruit fly, were effectively managed through the application of neem oil and cypermethrin. No disease incidence was observed in either variety during the cropping period. Flowering commenced in early April, with both male and female flowers observed, and harvesting was completed by 2 June 2025.

Table 29: Agronomic means of Summer Sweet watermelon variety

Variety	Fruit Weight (g)	Fruit Length (cm)	Fruit Diameter (cm)	TSS (°Brix)	Vine Length (cm)	No. of Primary Branches
Summer Sweet	2232.00	17.81	16.31	11.78	239.80	3.93
Sugar Baby	2821.33	18.23	16.57	8.95	205.87	4.40

Sugar Baby recorded higher fruit weight, fruit length, and fruit diameter compared to Summer Sweet. However, Summer Sweet exhibited significantly higher sweetness, with a total soluble solids (TSS) value of 11.78°Brix compared to 8.95°Brix in Sugar Baby. Although Summer Sweet produced relatively smaller fruits, its higher sweetness and potentially greater number of fruits per plant may align better with Bhutanese consumer preferences, particularly for small households. Overall, the trial indicates that Summer Sweet performs well under local

agroecological conditions and shows promise as a viable alternative to existing watermelon varieties.

9.2 Adaptability performance of new muskmelon varieties

field trial at ARDC-Bajo evaluated the adaptability of two new F1 hybrid muskmelon varieties, RS1 and Sparkling Moon, introduced by Oshiye & Co. Ltd., Japan, through the Bhutan Agrifood and Trade Investment Forum (BATIF). The trial followed a Randomized Complete Block Design (RCBD) with three replications, planting 15 seedlings per variety on 19 March 2025. Seedlings were raised in poly pots from 4 February 2025. Early-stage protection included 1 m × 1 m plastic capping to increase soil warmth, suppress weeds, and protect seedlings from pests such as red pumpkin beetles. Pest and disease management involved neem oil, cypermethrin, Captan, Chlorpyrifos, manual beetle removal, and yellow sticky traps for fruit fly control.

Despite these measures, severe pest and disease pressure—mainly from red pumpkin beetles and citrus fruit flies—resulted in complete fruit loss, making harvested fruits non-marketable. Consequently, comparative fruit performance data could not be collected. Growth parameters, including vine length and number of primary branches, were recorded.

The trial indicates that RS1 and Sparkling Moon are highly susceptible to pest and disease under Bajo conditions. Additionally, both varieties exhibited extended fruit expansion and ripening periods, limiting their suitability for cultivation in this agro-ecological zone.

9.3 Evaluation of varieties of Chinese cabbage (Japanese varieties)

A varietal evaluation trial was conducted at ARDC Bajo and ARDSC Tsirang to assess the adaptability and performance of four Japanese open-pollinated Chinese cabbage varieties—Kaga, Nozaki, Neo Kyoto-3, and Ousho—against the locally established check variety, Kyoto-1. The study aimed to identify superior varieties suitable for local cultivation and mitigate varietal degeneration caused by the continued use of limited genetic material. Seeds were sown and transplanted in September 2024 at both locations, and the crops were harvested in January 2025. A randomized complete block design (RCBD) was used with four replications. Despite differences in climate and timing, none of the varieties formed heads at either location, likely due to high temperatures exceeding 20–22°C during early growth stages, which is known to inhibit head development. Additional factors such as nutrient imbalances and environmental stressors, including temperature fluctuations and photoperiod sensitivity, may also have contributed.

Table 30: Comparison of Fruit Quality Parameters at ARDC, Bajo

Fruit Girth (mm)	Fruit Weight (g)	Fruit Length (mm)	Heads Formed
133.29 (a)	1075.64	243.84 (a)	0
119.79 (ab)	1152.85	229.94 (ac)	0
118.71 (ab)	1082.58	221.02 (c)	0
NA	NA	NA	NA
116.36 (b)	983.12	195.90 (b)	0
0.03	0.71	2.55e-07	0.88

At ARDC Bajo, Kaga showed significantly greater fruit girth (133.29 mm) and length (243.84 mm) than Kyoto-1, while other varieties displayed intermediate values with no significant difference in fruit weight. A Kruskal-Wallis test indicated significant differences in fruit girth (P

= 0.03) and fruit length ($P < 0.000001$), but not in weight ($P = 0.71$). At ARDSC Tsirang, significant variation was also observed in fruit weight ($P = 0.03$) and fruit length ($P = 0.001$), with Kaga, Neo Kyoto-3, and Kyoto-1 performing better than others in fruit size and length. However, fruit girth differences were not statistically significant ($P = 0.07$).

Overall, Kaga consistently performed well in both locations in terms of fruit size, particularly fruit length, although no variety achieved proper head formation. This trial highlights the importance of site-specific adaptation in variety selection and underscores the need for further studies on soil nutrition, temperature control, and photoperiod effects to optimize Chinese cabbage production in Bhutan.

9.4 Performance evaluation of Japanese pumpkins

Pumpkin (*Cucurbita moschata*) is a warm-season crop of high nutritional and economic importance in Bhutan. However, locally grown pumpkins are generally large and sold in cut portions, raising concerns related to hygiene and market convenience. To address this issue, a field study was conducted at ARDC Bajo to evaluate two Japanese pumpkin varieties, AVPU-1394 and Kuri, with emphasis on marketable fruit size, pest and disease resistance, vine growth, and yield performance under local agro-climatic conditions.

Seeds were sown on 4 February 2025 and transplanted on 27 February 2025. The trial was laid out using beds measuring $19 \text{ m} \times 1.5 \text{ m}$, with 12 plants per bed and three replications for each variety. Pumpkins were harvested on 23 May 2025. Data were collected through random sampling and included number of fruits per plant, fruit size (weight, diameter, and length), vine length, yield per plot, and yield per acre.

Table 31: Performance of Japanese pumpkin varieties under field conditions

Variety	Avg. no. of Fruits/Plant	Avg. Fruit Weight (g)	Avg. Fruit Diameter (cm)	Avg. Fruit Length (cm)	Avg. Vine Length (cm)	Avg. Yield/Plot (kg)	Yield/acre (kg)
Kuri	1	1493.7	15.64	11.04	309.13	21.7	3083.6
AVPU-1394	2	1092.7	14.57	9.76	261.7	18.7	2657.3

Kuri produced a higher yield (3,083.6 kg/acre) compared to AVPU-1394 (2,657.3 kg/acre). However, AVPU-1394 exhibited several desirable traits, including a higher number of fruits per plant, smaller and more market-preferred fruit size, shorter vine length suitable for better space management, improved shelf life, and greater tolerance to pests and diseases. Despite its relatively lower yield, AVPU-1394 is recommended for cultivation due to its superior marketability and adaptability under similar growing conditions.

9.5 Effect of Rice Husk Biochar and Bokashi on Chilli Yield and Productivity

A field study at ARDC, Bajo evaluated the effects of rice husk biochar and bokashi on chilli yield and productivity. These organic amendments are gaining attention in Bhutan for improving soil fertility and crop performance, but data for chilli are limited.

A Randomized Complete Block Design (RCBD) was used with four treatments: T1 (Bokashi), T2 (Biochar), T3 (Bokashi + Biochar), and a control (FYM only), each replicated four times. Standard NPK fertilizer application, paddy straw mulching, irrigation, staking, and harvesting at the color-turning stage were followed.

Statistical analysis using the Kruskal-Wallis test showed no significant differences among treatments for plant height, fruit number, fruit weight, fruit size, or yield per plot. The control (FYM only) performed best across all parameters, though differences were not statistically significant ($p > 0.05$). The results are summarized table 32.

Table 32: Fruit quality parameters among different treatments

Treatments	Plant Height (cm)	Avg. Total Fruits	Total Weight (g)	Avg. Weight (g)	Diameter (mm)	Length (cm)	Yield/plot (kg)
Bokashi applied	35.15	9	17.80	0.82	2.84	2.35	0.15
Biochar applied	34.75	8	10.50	0.97	2.90	2.07	0.19
Bokashi + Biochar	34.35	6	6.25	0.95	3.16	2.38	0.18
FYM applied (Control)	40.95	19	30.65	1.40	4.00	3.33	0.23
<i>P-Value</i>	0.09	0.32	0.30	0.42	0.38	0.53	0.33

The limited effectiveness of biochar and bokashi in this trial may be due to stunted plant growth and severe aphid infestation, which likely masked potential benefits. Absence of post-trial soil testing also restricted assessment of soil changes.

While rice husk biochar and bokashi have shown positive effects elsewhere, their impact on chilli in this trial was limited. Further studies with long-term trials, integrated pest management, and detailed soil analysis are recommended to better evaluate their potential.

9.4 Fast Track Evaluation of Green Pia (Hybrid Broccoli)

The fast-track evaluation of the hybrid broccoli variety Green Pia was conducted to assess its yield performance and adaptability in comparison with the check variety, Centauro. The trial followed a randomized complete block design with two treatments and five replications, covering a total of 10 plots. Each plot measured 4 meters by 1 meter and contained 16 plants, with a total experimental area of 40 m². Plants were spaced at 50 cm both between and within rows. Data were randomly collected from 10 plants per plot and included observations on head weight, diameter, length, overall yield per plot, and pest and disease incidences.

Table 33: Agronomic Performance of Green Pia and Centauro Broccoli Varieties

Variety	Yield (kgs/acre)	No. of Days to Harvesting	Pest Incidence	Disease Incidence
Centauro	5400	76–81 days	Aphids, Cabbage white butterfly	Nil
Green Pia	4800	76–81 days	Aphids, Cabbage white butterfly	Nil

The results showed that both varieties performed similarly in terms of yield and growth duration, with Centauro yielding 5400 kg/acre and Green Pia yielding 4800 kg/acre. Both matured within 76 to 81 days after transplanting. Pest incidences such as aphids and cabbage white butterfly were noted in both varieties, but no disease issues were recorded. The pest problems were minor and could be effectively managed with appropriate chemical treatments. Overall, Green Pia

demonstrated good growth and adaptability, indicating its potential as an alternative variety to Centauro for broccoli cultivation.

9.5 Fast Track Evaluation of Hybrid Cabbage

Eight hybrid cabbage varieties were evaluated using a Randomized Complete Block Design (RCBD) with three replications, resulting in 24 plots, each measuring 4 × 1 m and containing 16 plants. Agronomic data were collected from 10 randomly selected plants per plot, focusing on head weight, diameter, length, yield per plot, and pest and disease incidence. All hybrid varieties outperformed the check variety, Golden Cross, in yield, although they required slightly longer maturity (81–86 days for hybrids versus 56 days for Golden Cross). Grand Blue recorded the highest yield at 19,502 kg/acre, followed by 561 (18,529 kg/acre), G26 (18,292 kg/acre), and 102 (16,031 kg/acre). All varieties experienced some aphid and cabbage white butterfly infestation, but no diseases were observed. The hybrids also exhibited better head development, indicating their suitability for commercial cultivation with proper pest management.

Table 34: Performance of Hybrid Cabbage Varieties

Variety	Yield (kg/acre)	Days to Harvest	Pest Incidence	Disease Incidence	Remarks
Grand Blue	19,502	81–86	Aphids, Cabbage white butterfly	Nil	Blue-green, waxy, dense leaves, vigorous growth
561	18,529	81–86	Aphids, Cabbage white butterfly	Nil	Ball type, slow bursting
G26	18,292	81–86	Aphids, Cabbage white butterfly	Nil	Ball type, green
102	16,031	81–86	Aphids, Cabbage white butterfly	Nil	Semi-flat, larger head, blue-green
8686	15,997	81–86	Aphids, Cabbage white butterfly	Nil	Flat head, dark green
Marvel 135	8,066	94–109	Aphids, Cabbage white butterfly	Nil	Semi-flat round, compact outer leaves
Golden Cross	7,391	56	Aphids, Cabbage white butterfly	Nil	Smaller head, faster head formation

9.6 Fast Track Evaluation of Hybrid Cauliflower

The fast-track evaluation of hybrid cauliflower included three varieties—Superdome, Snowy, and Snow Mystique—using an RCBD with five replications (15 plots, 16 plants per plot) and 50 cm spacing between and within rows. Data were collected from 10 randomly selected plants per plot, focusing on head weight, diameter, length, yield per plot, and pest and disease incidence. Snowy recorded the highest yield at 8,186 kg/acre and matured earliest (66–73 days), followed by Superdome (7,567 kg/acre) and Snow Mystique (6,332 kg/acre). All varieties experienced similar pest incidences, mainly aphids and cabbage white butterfly, with no diseases observed. Snowy’s early head formation and light green leaves make it suitable for early harvests. Superdome showed vigorous vegetative growth but delayed head formation, while Snow Mystique had smaller heads and minimal foliage, suggesting Snowy as the most promising variety for commercial cultivation under the prevailing field conditions.

Table 35: Performance of Hybrid Cauliflower Varieties

Variety	Yield (kg/acre)	Days to Harvest	Pest Incidence	Disease Incidence	Remarks
Snowy	8,186	66–73	Aphids, Cabbage white butterfly	No	Early head formation; light green leaves
Superdome	7,567	80–90	Aphids, Cabbage white butterfly	No	Vigorous vegetative growth; late head formation
Snow Mystique	6,332	80–87	Aphids, Cabbage white butterfly	No	Smaller heads; minimal foliage

Overall, the fast-track evaluation demonstrated that hybrid cauliflower varieties achieved higher yields and better agronomic traits compared to standard checks. These varieties are suitable for commercial cultivation under Bhutanese conditions, with Snowy cauliflower and Grand Blue cabbage identified as the most promising for early maturity and high yield. Proper pest management is recommended to ensure optimal performance.

9.7 Evaluation of World Vegetable Chili Lines

The evaluation of chili lines from the World Vegetable Center (Taiwan) was conducted to assess yield performance, adaptability, and disease resistance under the agro-climatic conditions of Bhutan. The trial aimed to identify high-yielding and open-pollinated chili varieties suitable for future release. A total of 24 chili lines were evaluated under field conditions at an altitude of 1300 masl during the normal chili-growing season.

The trial followed a randomized complete block design (RCBD) with three replications. Each bed measured 2 m × 1.5 m with 12 plants per plot, spaced at 45 cm between plants and 50 cm between rows, arranged in two rows per plot. Border rows were planted around each plot to minimize edge effects. Data were collected from three harvests and analyzed based on yield per plot and extrapolated per-acre yield.

Preliminary results showed significant variation among the lines. AVPP 1339 recorded the highest yield at 11,122 kg/acre, followed by AVPP 1325 with 9,282 kg/acre. AVPP 1334 and AVPP 1341 also performed well, yielding 8,968 kg/acre and 8,684 kg/acre respectively. Other notable performers included AVPP 1345 and AVPP 1107, indicating strong yield potential and adaptability. Several lines such as AVPP 1502, AVPP 9813, and V1012260 recorded significantly lower yields and are less suitable under the tested conditions. The findings suggest that lines such as AVPP 1339, 1325, and 1334 should be prioritized for further multilocation trials and possible release as open-pollinated varieties in Bhutan's chili program.

9.8 Varietal Performance Evaluation Trial of Sweet Potato

A varietal evaluation trial was conducted to compare the growth performance, yield, and quality of three sweet potato varieties: Gorojima, Orange Flesh, and Purple Flesh. The objective was to assess their adaptability and productivity under the agro-climatic conditions at the trial site. The experiment followed a Randomized Complete Block Design (RCBD) with three treatments and three replications. Each variety was assessed for yield per acre and the descriptive statistics and ANOVA results are summarized in the tables below.

Table 36: Descriptive Statistics for yield per acre

Variety	N	Mean (kg/acre)	SD	SE	Coefficient of Variation
Gorojima	4	11,075.40	3,153.55	1,576.78	28.5%
Orange Flesh	4	12,739.52	4,244.11	2,122.06	33.3%
Purple Flesh	4	10,515.55	7,057.88	3,528.94	67.1%

ANOVA Summary for Yield per Acre

Source	Sum of Squares	df	Mean Square	F	p-value
Treatment	10,700,000	2	5,352,000	0.206	0.817
Residual	233,300,000	9	25,920,000		

Note: Type III Sum of Squares used.

The results indicate that there were no statistically significant differences in yield per acre among the three sweet potato varieties ($p = 0.817$). Although Orange Flesh showed a slightly higher mean yield compared to the others, the large within-treatment variability, particularly for Purple Flesh, contributed to the lack of statistical significance.

9.9 Performance Evaluation of White Dwarf Beans

An evaluation trial was conducted to assess the yield potential, adaptability, and disease resistance traits of Japanese White Dwarf Beans under local agro-climatic conditions. These beans are characterized by their short growth cycle, making them ideal for crop rotation and intercropping systems. The trial demonstrated good plant vigor, early maturity, and promising yield performance compared to the existing check variety. Given the positive preliminary results, further evaluation through a NCT in collaboration with NCOA-Yusipang is planned across multiple locations to support varietal release and farmer-level promotion.

Table 37: Comparative performance of white dwarf and dwarf borloto beans

Variety	Avg. Pod Length (cm)	Avg. Pod Width (cm)	Avg. No. of Pods	Yield per Acre (kg)
Dwarf Borloto (Check)	11.06 ^a	1.20 ^a	12.3 ^a	0.80 ^b
White Dwarf	11.30 ^a	1.23 ^a	7.0 ^a	3.98 ^a
P-value				0.01

Significant differences ($P < 0.05$) were observed in yield between the two varieties, with the White Dwarf bean showing a substantially higher yield than the check. However, no significant differences were found in pod length, width, or the number of pods, indicating that yield advantages may be due to better seed filling or pod density.

10. Medical and Aromatic Plants

A collaborative evaluation trial on German chamomile (*Matricaria chamomilla*) and Roman chamomile (*Chamaemelum nobile*) was carried out in partnership with NCOA-Yusipang and Terra Himalaya (FDI) to assess their adaptability under Bhutanese agro-ecological conditions and their potential for essential oil production. The study aims to support the introduction of

chamomile as a high-value aromatic crop, promote organic farming practices, and enhance livelihood opportunities for rural communities.

In addition, the Centre's horticulture program supported herb production focusing on cultivation and processing of aromatic herbs. Rosemary recorded the highest fresh and dried yield (8.5 kg fresh and 1.89 kg dried), followed by thyme, chocolate mint, and oregano. These activities demonstrate the potential for value addition through fresh-to-dried herb processing and contribute to the promotion of diversified horticultural enterprises.

11. Floriculture

The Floriculture Unit at ARDC Bajo continued to conserve and promote both indigenous and exotic flower species under the Horticulture Program. Key activities included maintenance of flower germplasm, seed and flower production, propagation of planting materials, and capacity-building programs on nursery management and seed production. Germplasm collections were conducted in Chimipang, Zhemgang, and Thimphu to enhance floral and ornamental diversity, with materials maintained for multiplication and future distribution.

During FY 2024–2025, a total of 2,500 potted flower saplings were distributed to schools, gewogs, monasteries, training centres, government agencies, and private individuals, supporting landscaping and greenery promotion. A modest revenue of Nu. 3,020 was generated from the sale of planting materials. Overall, the program contributed to strengthening floriculture development and raised community awareness on sustainable flower cultivation.

SUPPORT SERVICES RESEARCH AND DEVELOPMENT PROGRAM

12. Mushroom Development Program

Mushroom cultivation, particularly Oyster and Shiitake varieties, is rapidly growing in popularity across Bhutan as an alternative income-generating activity. Many farmers and entrepreneurs are embracing locally cultivated mushrooms over imports due to their better taste, nutritional benefits, and organic production methods. Unlike seasonal crops, mushrooms thrive year-round in controlled environments, offering a sustainable and profitable farming option.

The Centre provides hands-on training in Oyster mushroom cultivation, supplies quality Oyster spawns exclusively to trained individuals, and offers continued technical support during the initial cultivation cycles. The Centre also assists growers with Shiitake mushroom cultivation by helping inoculate billets using spawns provided by the National Mushroom Centre (NMC), ensuring that even those without specialized equipment can establish their operations successfully. Shiitake mushroom cultivation support was extended to entrepreneurs in the WC region.

Table 38: Number of hhs trained and oyster spawn supplied

SN	Dzongkhag	No. HH trained (oyster)	Spawn supply (oyster)	Shiitake inoculation	billet	Remarks
1	Punakha	247	829	1740		11 gewogs
2	Gasa	26	800	0		3 gewogs
3	Wandgue Phodrang	0	1441	600		Bajo HSS & Gasethogom
4	Dagana	0	127	2600		Teza & Kana gewogs
5	Tsirang	0	20	7000		
Total		273	3217	11940		



a) oyster mushroom training, Talo



b) oyster mushroom, Kana



c) shiitake billets, Tseza

Figure 7: Capacity building and cultivation practices in mushroom production

In the fiscal year 2024–2025, ARDC Bajo trained a total of 273 households from Punakha and Gasa Dzongkhags in Oyster mushroom cultivation. These trainings ensured that aspiring mushroom growers received practical, hands-on knowledge essential for successful mushroom

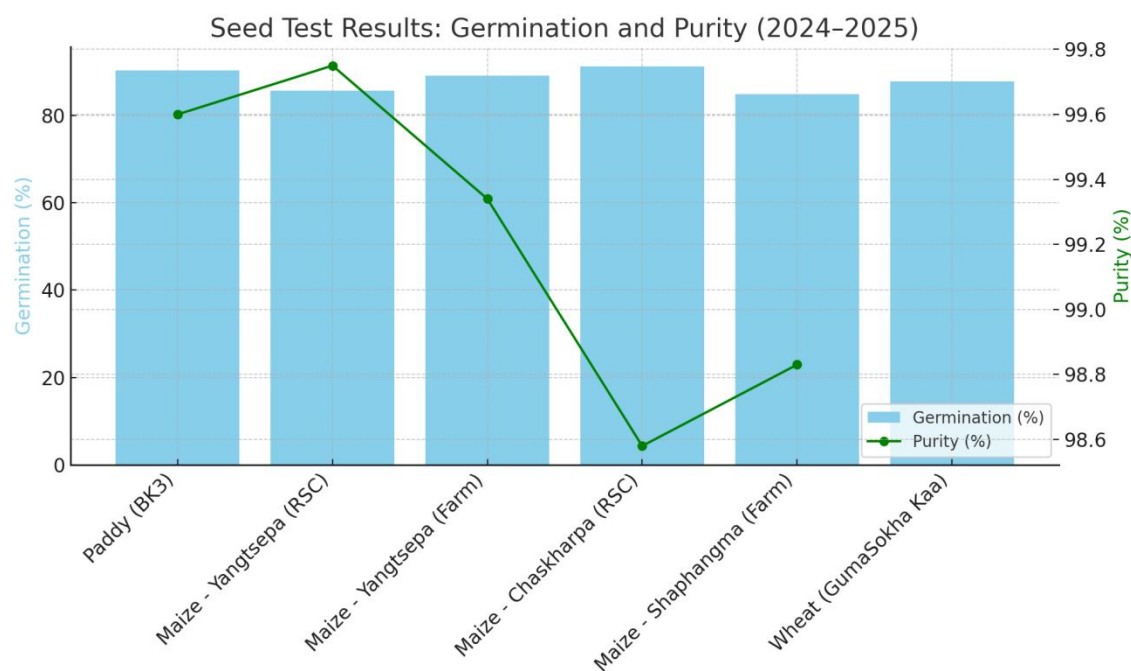
production. Following the training, the center distributed 3,271 Oyster mushroom spawns exclusively to farmers and entrepreneurs who had undergone formal training—either through the center or other recognized agencies. This approach ensures proper cultivation practices are followed, supporting better success rates and encouraging the production of quality, locally grown mushrooms.

13. Seed Samples Tested for Quality Parameters

The National Referral Seed Testing Laboratory (NRSTL) at ARDC-Bajo conducts seed quality testing following ISTA standards. Tests performed include Germination %, Purity %, and Moisture Content based on client requirements.

Table 39: Summary of results of sampled seed tested in the FY 2024-25

Client	Crop & Variety	Germination (%)	Purity (%)	Moisture (%)	Remarks
BFDA Wangdue	Paddy (BK3)	90.25	99.6	7	seed covers, damaged deformed seeds
BFDA Trashigang	Maize - Yangtsepa (RSC)	85.65	99.75	NA	No contaminants detected
BFDA Trashigang	Maize - Yangtsepa (Farm)	89.09	99.34	NA	-
BFDA Trashigang	Maize - Chaskharpa (RSC)	91.15	98.58	NA	-
BFDA Trashigang	Maize - Shaphangma (Farm)	84.81	98.83	NA	-
RSC Wangdue	Wheat (Gumasokha Kaa)	87.75	NA	NA	Abnormal seedlings with green mold



14. Plant Protection

14.1 Effectiveness of Wood Vinegar to Control Weeds of Potato

A study was conducted on-farm at NSC in Phobjikha, Wangdue, to evaluate the potential of wood vinegar as an alternative herbicide to glyphosate for controlling weeds in potato cultivation. Glyphosate is widely used in Bhutan's potato-growing regions such as Phobjikha and Gangtey, but concerns about its impacts on human health, environment, and potential pesticide residues have prompted the search for safer and sustainable alternatives. Wood vinegar, a byproduct of charcoal production rich in acetic acid and phenolic compounds, has shown promising herbicidal properties, functioning as a non-selective contact herbicide that causes rapid wilting of sensitive plants.

The trial was arranged in a randomized complete block design with four treatments: control (no treatment), 20% wood vinegar, 30% wood vinegar, and metribuzin (a commonly used herbicide). The plot size was 3m by 2m, and treatments were applied at regular intervals—every five days for wood vinegar and every 14 days for metribuzin. Weed species and density were recorded seven times using random quadrants. Data on weed biomass, tuber yield, and soil properties will be collected after harvest.

The effect of different treatments on weed species was analyzed using one-way ANOVA. Results indicated statistically significant differences among treatments ($p < 0.001$). Post-hoc Bonferroni tests revealed that both the 30% wood vinegar and metribuzin treatments significantly reduced weed populations compared to the control.

Table 40: Effect of different treatments on weed species

Treatment	N	Mean $\pm$ SD
Control	30	75.60 $\pm$ 51.50
20% Wood Vinegar	30	47.27 $\pm$ 26.73
30% Wood Vinegar	30	30.47 $\pm$ 15.03
Metribuzin	30	40.80 $\pm$ 32.74
p-value		< 0.001

The strong weed suppression observed in metribuzin-treated plots is consistent with its known function as a photosystem II inhibitor, which disrupts photosynthesis and causes weed mortality. Similarly, the effectiveness of the 30% wood vinegar treatment can be attributed to its high acetic acid content, which acts as a contact herbicide by damaging plant cell membranes, leading to rapid wilting and death.

Previous studies support this mechanism, indicating that wood vinegar acts quickly on foliage and has a strong initial impact on weed suppression. However, unlike metribuzin, wood vinegar lacks residual soil activity. As a result, while it may effectively eliminate existing weeds, it does not prevent new germination, which limits its long-term effectiveness under field conditions.

Although 30% wood vinegar and metribuzin both significantly reduced weed populations compared to the control, wood vinegar cannot yet be considered a full alternative to synthetic herbicides. Its short residual activity and the potential for weed regrowth mean further analysis is necessary. The trial is ongoing, and a complete assessment—including final potato yield, long-

term crop performance, and soil health before and after treatment—will be required to draw firm conclusions.

14.2 Evaluation of wood vinegar as a fungicide against early blight in tomato cultivation

Tomato (*Lycopersicon esculentum* L.) is an important vegetable crop in Bhutan, cultivated over 151.55 acres with an annual production of 232.66 metric tons. It is highly valued for its nutritional content, especially vitamins A, C, and E. However, tomato production is severely impacted by diseases, particularly early blight caused by *Alternaria solani*, which can reduce yields by up to 86%. While synthetic fungicides offer effective disease control, their overuse can cause environmental damage and lead to health risks and pathogen resistance. Wood vinegar, a natural byproduct of wood pyrolysis, has shown antifungal potential in international studies, making it a candidate for sustainable disease management.

This study aimed to assess the efficacy of wood vinegar in controlling early blight in tomatoes under field conditions in Bhutan. Trials were conducted at ARDC Bajo, Samtenling, and Yusipang using five treatments: Control, 0.1%, 0.5%, 1%, and 2% concentrations of wood vinegar. The tomato variety used was 'Bajo Lambenda'. Disease severity was measured using a 0–9 scoring scale and analyzed through the Area Under the Disease Progress Curve (AUDPC). Crop yields were also recorded, and all data were analyzed statistically using ANOVA and Bonferroni post hoc tests at a 5% significance level.

In Bajo, Treatment 5 (2%) recorded the lowest AUDPC value of 417.4, suggesting better disease suppression, though the differences across treatments were not statistically significant. Treatment 3 and Control showed the highest disease progression (AUDPC 500.37). At Samtenling, surprisingly, the Control plot had the lowest AUDPC (751.85), while Treatment 2 (0.1%) had the highest (925.55), again without significant statistical differences. High humidity and temperature at this site may have favoured fungal growth and reduced treatment efficacy. At Yusipang, Treatment 2 showed the best disease control with the lowest AUDPC (534.07), and a significant difference was observed among treatments. Treatment 3 had the highest disease severity.

Yield data showed no significant differences among treatments in Bajo and Samtenling. In Bajo, yields were low overall, likely due to both disease and fruit fly infestation. Samtenling showed high variation, with Treatment 4 (1%) showing the highest average yield but with no statistical significance. In contrast, Yusipang showed a significant difference in yield ($p = 0.01$), where the Control plot yielded significantly more than Treatments 4 and 5, suggesting that certain concentrations of wood vinegar may have had negative effects or were ineffective under the prevailing weather conditions.

The study concludes that under the conditions tested, wood vinegar did not consistently exhibit significant antifungal activity against early blight in tomatoes. While some treatments showed promise at specific sites, overall effectiveness was limited. Differences in environmental conditions, application timing, and concentration likely influenced results. For future research and application, it is recommended to optimize the concentration and application strategy of wood vinegar, integrate it with other control methods, and analyze its chemical composition through GC-MS to better understand its antifungal properties.

14.3 Efficacy of wood vinegar as herbicide on broad leaves of tomato

This study evaluated the effectiveness of wood vinegar as a natural herbicide for controlling broadleaf weeds in tomato (*Solanum lycopersicum*) cultivation across three locations in Bhutan: Bajo, Samtenling, and Yusipang. Tomato is an economically and nutritionally important crop in Bhutan, but its production faces significant threats from weed competition, which can cause severe yield losses. While chemical herbicides are commonly used for weed control, their excessive use has led to environmental concerns, resistance in weeds, and potential health hazards. As an alternative, wood vinegar—a byproduct of wood pyrolysis—has shown promise in previous international studies due to its herbicidal and growth-promoting properties.

The trial included four treatments: a control (no wood vinegar), and three concentrations of wood vinegar (2%, 5%, and 10%), applied every ten days. The experiment followed a randomized complete block design with 12 plots in each location, and data were collected on weed count, plant height, and yield over four weeks. The hybrid tomato variety 'Garv' was used.

Results showed that there were no statistically significant differences in weed counts among the treatments at any location. Though minor visual effects such as leaf desiccation were observed at higher concentrations, complete weed suppression was not achieved. This may be due to the rapid dissipation and volatile nature of wood vinegar, which reduces its residual activity. Similarly, no significant effects were found on plant height or yield across all sites, although treated plots generally showed slightly better yield performance compared to controls.

Statistical analysis also revealed no significant interaction between location and treatment, meaning treatment effects were consistent across sites. However, location alone significantly influenced weed abundance, with Samtenling recording the highest weed density. This variation is likely due to differences in environmental conditions like altitude and climate among the sites.

The study concludes that under the given conditions and concentrations, wood vinegar did not produce a significant herbicidal effect. Nonetheless, its potential as a sustainable weed management tool remains promising if adjustments in application strategy are made. Recommendations include using higher concentrations, applying it more frequently (e.g., weekly), and conducting further studies, particularly targeting herbicide-resistant weeds. The study also identified limitations, such as lack of detailed chemical profiling of wood vinegar and weather-related disruptions during fieldwork. Further research is needed to optimize the use of wood vinegar in Bhutanese agroecological conditions.

14.4 Citrus Fruit Fly Management Training and Awareness Campaign

The hands-on training and awareness campaign on citrus fruit fly (*Bactrocera minax*) management was conducted by ARDC Bajo in collaboration with the National Citrus Repository, targeting citrus farmers in Gozhi, Drukjigang, and Mendrelgang Gewogs of Dagana and Tsirang Dzongkhags. The initiative was launched in response to the growing threat posed by citrus fruit fly, which has caused significant yield losses in citrus crops across the region. The campaign aimed to educate farmers on effective pest management techniques, safe pesticide use, and ways to enhance citrus production sustainably.

The program included both theoretical and practical components. Presentations covered citrus pest management strategies, safe pesticide use, trends in the citrus industry in Bhutan, and approaches for community-based fruit drop collection. Field demonstrations were conducted to showcase fruit drop collection techniques and pit digging methods for proper disposal.

Additionally, farmers with larger orchards were provided with 200-liter barrels to support fruit collection and composting efforts. In total, 176 citrus growers and 12 gewog agriculture extension staff participated in the program.

In continuation of the effort, protein hydrolysate bait traps (McPhail and plastic bottle types) were installed in April 2025 in selected locations of Dagana and Tsirang to monitor and control citrus fruit fly populations. These traps are being observed fortnightly until August 2025 to assess their effectiveness. To ensure the long-term success of the initiative, it is recommended to provide continuous follow-up support, encourage consistent fruit drop collection, and promote the use of affordable and sustainable pest management practices.



Figure 8: Awareness campaign on fruit fly management and dumping of fruit drops

14.5 Evaluation of Maize-Legume Intercropping for Fall Armyworm Management

To address the threat of fall armyworm (*Spodoptera frugiperda*) in maize cultivation, ARDC Bajo's Plant Protection Unit, in collaboration with the National Plant Protection Centre and supported by AFACI, initiated an evaluation of maize-legume intercropping at Rilangthang, Sergithang Gewog, Tsirang. Fall armyworm is a major pest causing severe crop damage globally, and intercropping with legumes has shown potential in reducing pest incidence while improving soil health and maize performance.

The trial uses a randomized block design with four treatments replicated thrice: (i) maize monocrop (farmer's practice), (ii) maize + grey pole bean, (iii) maize + borlotto bean, and (iv) maize + soybean. Yangtsepa maize variety was used, with data collected fortnightly on larvae count, egg masses, and leaf damage using the Leaf Damage Index. Observations also include the presence of beneficial insects and other pests. Legume yield is being recorded at the marketable stage, while soybean will be harvested at seed maturity. The trial is ongoing, and results will be reported upon completion.

15. Soil and Land Management Services

15.1 Climate Smart Agriculture (CSA) Technologies

The promotion and adoption of Climate Smart Agriculture (CSA) technologies is a key mandate of the Centre. These technologies are primarily showcased to visitors as part of awareness and promotion initiatives to encourage field-level adoption. Among the promoted technologies, biochar has been introduced as a soil amendment in farmers' fields due to its potential for carbon

sequestration and its role in mitigating climate change. Bokashi, a fermented organic fertilizer, is promoted as a direct substitute for chemical fertilizers. These technologies are upscaled through farmer training programs, on-station demonstrations, and online platforms.

While most of the bokashi and biochar are utilized internally, the Centre distributed around 500 kg of bokashi and 250 kg of biochar to visitors for awareness and promotional purposes. Annually, the Centre produces approximately 8,500 kg of bokashi and 3,500 kg of biochar. Another CSA technology introduced is the Bhutan Agri Microbial Solution (BAMS), similar to Effective Microorganisms (EM). BAMS serves as a composting decomposer and a microbial agent in bokashi preparation. Around 1,500 liters of BAMS were produced.

15.2 Agriculture Land Development (ALD)

Agriculture Land Development involves terrace consolidation and new terracing to improve land workability, especially in sloped terrains. Heavy machinery like excavators facilitates efficient terracing and leveling, particularly in fragmented and rugged landscapes.

Under the C-SUCSeS Project, 5.7 acres of farmland in Nichula, Dagana, were developed using ALD, with farmers contributing labor and tools. The site maintained a slope gradient of 6–12 degrees with contour intervals of 6–8 meters.

Similarly, 12 acres of land at the Open-Air Prisoner (OAP) farm in Yarju, Wangdue, were developed with ALD, funded by the Royal Government of Bhutan (RGoB). The slope gradient ranged between 7–22 degrees, maintaining 6–7 meters of contour interval.

ALD contributes to improving soil structure, organic matter, and nutrient retention, thereby enhancing land productivity. It is also recognized as a CSA technology for its role in conserving soil resources and minimizing nutrient leaching.

15.3 Soil Test Results

Soil testing was carried out using mini-lab kits and rapid test tools provided by the National Soil Services Centre (NSSC), Thimphu. Samples were collected from both farmers' and Centre's fields, with 117 samples tested in total.

15.4 Soil Fertility Assessment of Citrus Orchards in Dagana

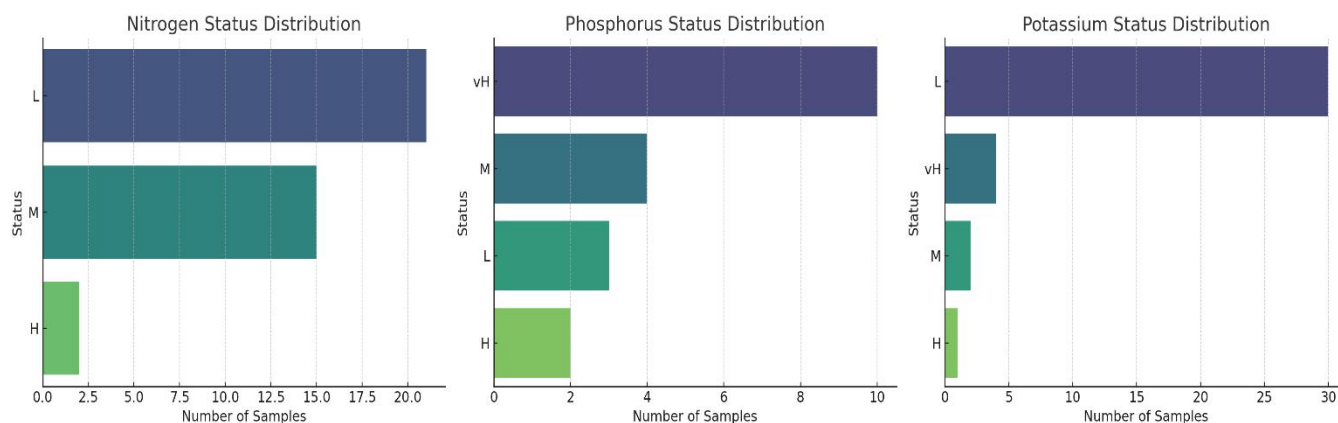


Figure 9: Figure 9: Distribution of nutrient status across all samples

The soil test results from 38 samples indicate that the majority of the soils fall within the slightly to moderately acidic range (pH 5.0–6.5), which is generally suitable for most crops. However, several samples were strongly acidic (pH < 5.0), particularly from Rangthaling and Gaserling, which may affect nutrient availability and require liming.

The nutrient status chart provides a visual summary of the availability levels of key macronutrients—Nitrogen (N), Phosphorus (P), and Potassium (K)—across 38 soil samples analyzed from different locations. The results indicate that Nitrogen levels are predominantly low to medium in most samples. This suggests that a significant number of plots are likely to benefit from either the recommended dose of nitrogen fertilizer (RDF) or a slightly increased dose where nitrogen is particularly low.

For Phosphorus, the data show a more variable trend. While several samples recorded very high phosphorus levels, many plots either have no data or are classified as low to medium. This implies that phosphorus application must be site-specific, avoiding over-application in areas already rich in phosphorus, while addressing deficiency in others to ensure balanced nutrient availability.

Potassium, on the other hand, shows a clear and consistent deficiency. The majority of soil samples fall under the low category, indicating a widespread shortage of this essential nutrient. Very few samples fall into the medium or high categories. This highlights an urgent need for potassium supplementation across most of the tested areas to improve plant health, yield, and stress tolerance.

In conclusion, the soil fertility status reveals that most fields require immediate attention in terms of potassium fertilization, tailored nitrogen management, and cautious phosphorus application based on individual field conditions.

15.5 Soil Nutrient Status of Yarjugang OAP Farm

During the Fiscal Year 2025–2026, soil testing and analysis were carried out for the Yarjugang Open Air Prison (OAP) farm.

Table 41: Summary of Soil Test Results – Yarju, OAP

Parameter	Status Overview	Recommendation
Soil pH	3.85 to 5.80 (acidic)	Most plots are acidic and require liming to improve nutrient uptake.
Organic Carbon (OC)	0.32% to 0.79% (mostly low)	Indicates low organic matter—apply FYM, compost, or bokashi to improve soil health.
Available Nitrogen	7 plots – Low 6 plots – Medium 2 plots – High	Low N plots need 25% more than RDF; medium apply RDF; high apply 25% less than RDF.
Available Phosphorus	6 plots – Zero (Low) 3 – High 1 – Very High Others – Low to Medium	Severe P deficiency in many plots; phosphorus application is essential except where already high or very high.
Available Potassium	All plots – Low or Too Low	Potassium is critically deficient in all samples—requires urgent K supplementation.

Soil samples from Yarju, OAP, revealed widespread acidity and nutrient imbalances. Organic carbon is low across most sites, pointing to poor soil organic matter. Nitrogen is mostly in the low to medium range, and potassium is critically low in all samples. Phosphorus levels are inconsistent, with some areas showing complete deficiency and a few with very high levels. The results call for liming to correct soil pH, extensive use of organic amendments, and site-specific fertilizer application to enhance soil fertility and crop productivity.

15.6 Demonstration of biochar charging

A two-day biochar charging training was conducted across eight gewogs in Tsirang and Dagana Dzongkhags under the Green Climate Fund (GCF) project. The initiative, led by ARDC Bajo in collaboration with gewog extension officers, aimed to build farmer and extension agent capacity on biochar preparation and application. A total of 308 farmers (177 male, 131 female) participated, learning about biochar's role in improving soil fertility, water retention, and resilience under changing climatic conditions.

Biochar, a stable, carbon-rich product of pyrolysis, acts as a long-lasting soil amendment and carbon sink. The training emphasized the importance of charging biochar—enriching it with nutrients and microbes—before soil application to prevent nutrient immobilization. Participants were introduced to both rice husk biochar (noted for high silica content and additional benefits such as husk vinegar) and open-field biochar methods suitable for non-paddy farming communities.

Hands-on demonstrations covered the use of Bhutan Agri-Microbial Solution (BAMS) and locally available materials such as compost, farmyard manure, cow urine, and bokashi for biochar charging. Mixing ratios, moisture retention techniques, and composting timelines were also discussed. Farmers learned about integrating biochar into nursery soil, compost pits, and orchard planting.

Key observations included high farmer interest, especially where rice husks were previously wasted, and a strong demand for open-field methods in non-paddy areas. A recurring challenge was the lack of accessible biochar-making equipment. Overall, the training successfully

introduced a climate-smart technology with significant potential for enhancing soil health and sustainable agriculture, particularly if future support can address equipment constraints.

Table 42: Beneficiary list on demo of biochar charging

Dzongkhag	Gewog	Beneficiary		Total
		Male	Female	
Dagana	Laja	19	7	26
	Khebesa	26	17	43
	Tseza	19	26	45
	Karmaling	16	12	28
Tsirang	Gorsaling	25	22	47
	Patsaling	16	12	28
	Sergithang	30	16	46
	Mendrelgang	26	19	45
Grand total		177	131	308

16. Visitors' information

During the fiscal year 2024–2025, ARDC-Bajo received a total of 44 visitor groups, comprising 587 individuals across different categories such as farmers, international delegates, government officials, and students/trainees.

Students and trainees formed the largest category of visitors with 271 individuals (124 males and 147 females), reflecting strong educational interest and institutional collaboration in agricultural learning and exposure. Farmers were the second-largest group, totalling 160 visitors (107 males and 53 females) across 8 groups. Their visits primarily focused on observing high-yielding crop varieties and field demonstrations. International delegates accounted for 97 visitors (67 males and 30 females) from 19 groups, indicating sustained global engagement and collaboration with ARDC-Bajo. Government officials represented 59 visitors (30 males and 29 females) from 6 groups, showing interest in policy support, monitoring, or oversight of agricultural initiatives.

All groups showed a fairly balanced gender distribution, except among farmers and international delegates where males were notably higher. This high turnout of diverse stakeholders highlights ARDC-Bajo's role as a center of excellence in agricultural innovation, demonstration, and knowledge dissemination. The variation in visitor backgrounds also reflects the center's multidisciplinary approach and relevance to both national and international audiences.

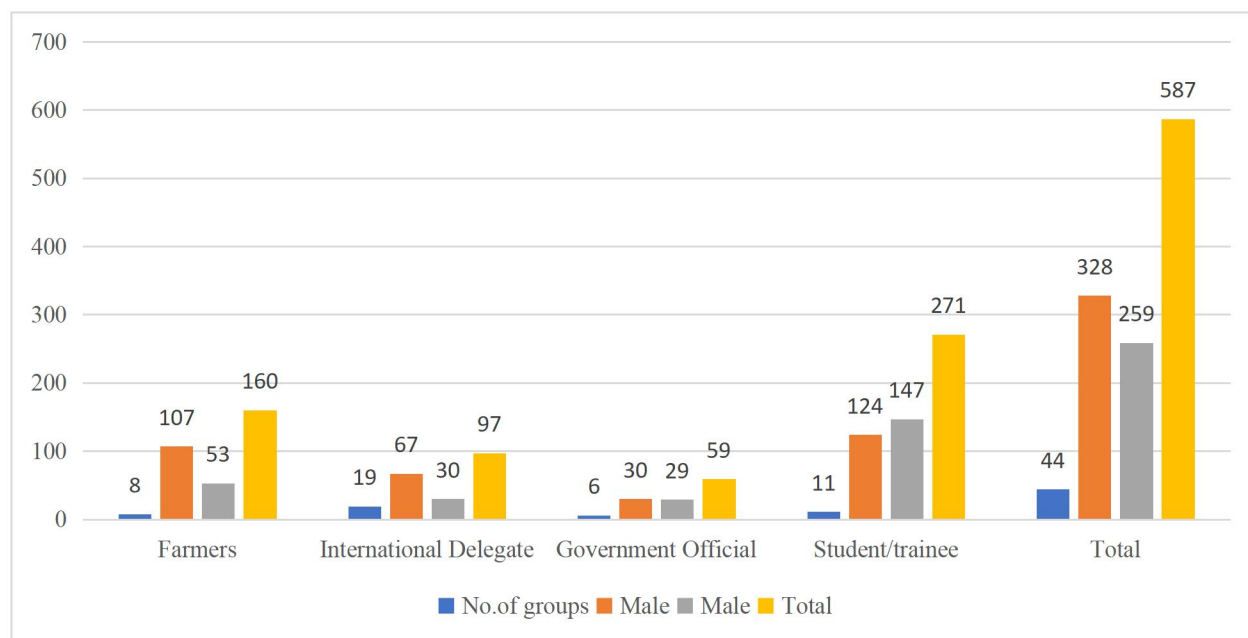


Figure 10: Visitor Engagement Summary at ARDC-Bajo



CENTRE AT A GLANCE

The Centre was founded as Agricultural Demonstration Station in 1965. In 1982 it was re-established as the Centre for Agricultural Research and Development (CARD) basically to undertake research in rice and rice-based crops. Research and farming systems was also started in the late 1980s. In 1994, the Centre was renamed as RNR Research Centre to incorporate research in livestock and forest that are inseparable components of Bhutanese farming systems. Subsequent to realignment exercise by the Ministry of Agriculture and Forest to enhance the efficiency of the service delivery to farmers, development mandate was added to Research Centres in July 2008. Following the organizational development exercise undertaken by RCSC in 2016 the Research Centres is now renamed as Agriculture Research and Development Centre (ARDC).

The Centre is located at Bajo (1100masl) in Wangdue Phodrang which is 70 km west of the capital city Thimphu.

At the national level ARDC Bajo is mandated to coordinate field crops research while at the regional level it undertakes relevant research and development for West-Central Region (Gasa, Punakha, Dagana, Tsirang and Wangdue. Phodrang). The Centre has 50.90 acres of research farm, furnished office space, modest laboratory and library facilities.

Sub-centre at Menchhuna, Tsirang was opened in 2006 to cater to the humid sub-tropical Dzongkhags of Tsirang and Dagana. It has about 36 acres of research area, office space and the National Citrus Repository is being developed.

Contact Address:

Agriculture Research and Development Centre, Bajo, Wangdue Phodrang,
Department of Agriculture
Ministry of Agriculture & Livestock
P.O Box: 1263
Phone No: +975 02 481209; 482260; Fax: +975 02 481311
Email: ardcbajo@moal.gov.bt Webpage: www.rcbajo.gov.bt