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National Centre for Organic Agriculture, Yusipang
Department of Agriculture
Ministry of Agriculture and Livestock
Thimphu, Bhutan



Latitude: 27.350182
Longitude: 89.439208
Elevation: 2656.37±97.0 m
Accuracy: 4.7 m

ANNUAL REPORT

2025-2026

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Published by:

*National Centre for Organic Agriculture, Yusipang, Thimphu
Department of Agriculture
Ministry of Agriculture & Livestock
Royal Government of Bhutan
June 2026*

Editor:

Tshering Wangchuk, Sr. Agriculture Officer, Technical Support Service Program

Suggested Citation:

NCOA Yusipang. Annual Report 2025-2026, Department of Agriculture, Ministry of Agriculture and Livestock, Thimphu

Layout and design:

Tshering Wangchuk, Sr. Agriculture Officer, Technical Support Service Program

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For a copy of the report, contact:

Offig. Program Director

NCOA Yusipang

Post Box: 212

Thimphu, Bhutan

Tel: +97517290627

Email: nlepcha@moal.gov.bt



INTRODUCTION TO NATIONAL CENTRE FOR ORGANIC AGRICULTURE YUSIPANG

The National Centre for Organic Agriculture (NCOA) is located at Yusipang which is about 15 km from Thimphu city on the Thimphu-Punakha highway. The Centre falls under Chang Gewog of Thimphu Dzongkhag and it is located at an altitude of 2700 meters above sea level (masl). The Centre has a very rich and dynamic history that dates back to Bhutan's second Five-Year Plan. The important historical events and shifts in organogram ever since the establishment of the Centre is presented below in a chronological order.

- 1969 His Majesty, the Third Druk Gyalpo, Jigme Dorji Wangchuk marked the opening of the Centre on 21st May, 1969 as the Horticulture Research Station. Since then, the Centre has been working on the evaluation of temperate fruits and promotion of improved horticulture production technologies.
- 1987 Between 1981 and 1987 the International Potato Centre (CIP) initiated a nationwide program on Potato which was coordinated from Yusipang. This led to the establishment of the Applied Research Centre with the focus on potato. With support from SDC/Helvetas new infrastructures were developed and the research scope expanded to other crops.
- 1989 The Department of Agriculture (DoA) initiated the organization of the research programs by setting up commodity-focused Agriculture Research Centres. Accordingly, the Applied Research Centre Yusipang was renamed as Agriculture Research Centre (ARC) and it was recognized as one of the then five research Centres in the country. The Centre was also assigned with the national mandate to lead potato research and promote potato-based farming system.
- 1994 Livestock, forestry and agriculture which are the three sectors under Ministry of Agriculture and Forest (MoAF) were functioning independently until 1994. With ministry's new objective of integrating all sectors under one umbrella was yet another historic move to enhance collaboration between different sectors. The three sectors were formally consolidated and renamed as Renewable Natural Resources Research Centre (RNRRC) with Field Crops, Horticulture, Livestock, and Forestry as the four major research programs. Council of Renewable Natural Resource Research of Bhutan (CoRRB) was created as the administrative apex body to coordinate and regulate various research across all RNRRCs. RNRRC Yusipang was given the national mandate to coordinate forestry research.

- 2009 The MoAF further felt the need to strengthen the research and extension linkages among the line departments at the regional level by assigning development mandates to all RNRRCs. Accordingly, all four RNRRCs were re-designated as RNR Research and Development Centre (RNR RDC). By its national mandate RNR RDC Yusipang was administratively realigned to the Department of Forest and Park Services (DOFPS).
- 2016 The first Organizational Development Exercise (ODE) recommended the restructuring of all RNR RDCs under their respective departments (Forestry, Livestock and Agriculture). Accordingly, the mandate of RNR RDC-Yusipang was shifted from Forestry to Agriculture and it was subsequently renamed as the Agriculture Research and Development Centre (ARDC)-Yusipang. It was also identified as a potential Centre to coordinate the National Organic Program (NOP).
- 2017 The second ODE recommended the realignment of the National Organic Program (NOP) at Semtokha to be shifted to Yusipang and function as one unit under ARDC, Yusipang and ARDC Yusipang was assigned the national mandate to coordinate and lead the Organic Agriculture (OA) research and development programs. The same exercise recommended transfer of National Potato Program (NPP) from National Seed Centre (NSC), Paro to ARDC Yusipang and was assigned national mandate to coordinate potato research and development programs.
- 2020 ARDC-Yusipang was renamed as the National Centre for Organic Agriculture (NCOA) and it was identified as the apex body to coordinate and facilitate the overall development of organic plans and programs in the country. NCOA is also responsible for regulation and certification of organic farms in accordance with Bhutan Organic Guarantee System (BOGS) and Local Organic Assurance System (LOAS). NCOA is administratively under the Agriculture Research and Innovation Division (ARID) of Department of Agriculture (DoA). To strengthen efficient service delivery for low altitude areas, a new sub-Centre under NCOA Yusipang has also been approved at Khaibeytar, Samphelling Gewog under Chhukha Dzongkhag.

Vision

A self-reliant, productive, diverse, resilient, and sustainable agriculture food system.

Mission

Achieve food and nutrition security, agricultural transformation through innovative and sustainable technologies, diversified and competitive economic/production options, inclusive and sustainable policies and programs.

Mandates

NCOA is mandated to serve both at national and regional level as follows:

National Mandate

1. As an apex body for Organic Agriculture, NCOA develop guidelines, implement policy directives and decisions of the National Organic Board (NOB) and National technical Working Group (NWG) on Organic Agriculture.
2. Facilitate the Registration, Certification, and Regulation of Organic Sector within the purview of the Bhutan Organic Guarantee System (BOGS) and Bhutan Organic Standards (BOS).
3. Register and regulate Certifying Bodies and other stakeholders engaged in the organic value chain in the country.
4. Coordinate and lead organic research and development programs including adaptive research on crop improvement and generation of organic production technologies.
5. Develop and maintain the database in the organic sector.
6. Serve as the Secretariat for the National Technical Working Group on Organic Agriculture.
7. Facilitate knowledge management, dissemination, and capacity development needs on Organic Agriculture.
8. Coordinate the National Potato Research and Development Program
9. Coordinate the National Vegetable Research and Development Program
10. Coordinate National Oil Seeds Commodity Program
11. Coordinate and implement project plans and programs under the supervision of Department of Agriculture.

Regional Mandate

1. Provide technical support to the Dzongkhag Agriculture Sector of four client Dzongkhags namely Chhukha, Haa, Paro, and Thimphu in planning and implementation of agriculture development programs.
2. Collaborate and support other ARDCs and Central Programs under DoA in implementing nationally coordinated activities in the region.

ORGANOGRAM

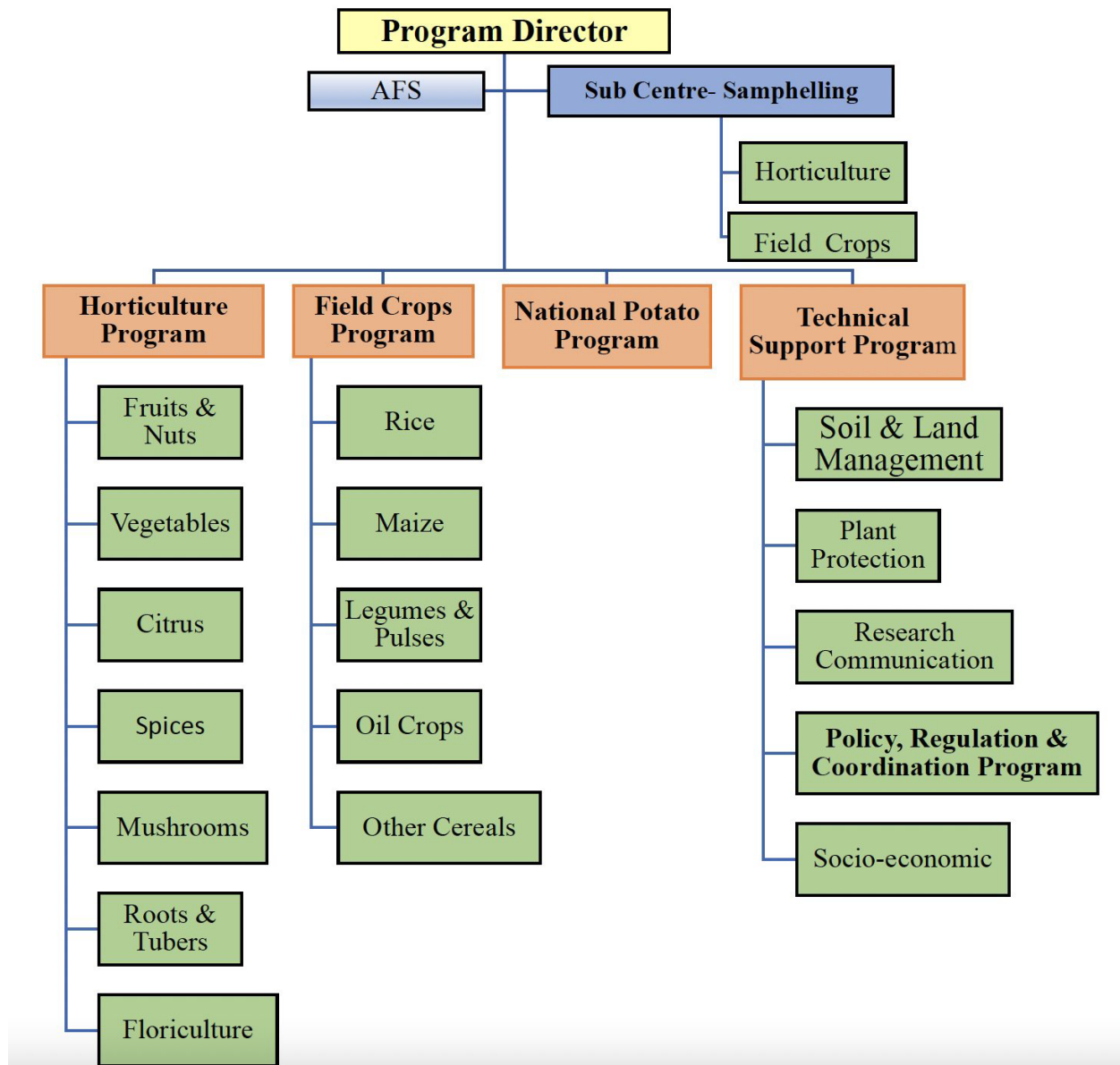


Figure i. Organogram of National Centre for Organic Agriculture-Yusipang

EXECUTIVE SUMMARY

The National Centre for Organic Agriculture (NCOA) made substantial progress during the Fiscal Year 2025–2026 in advancing organic agriculture, research and innovation, and farmer capacity development across Bhutan. During the reporting period, significant achievements were recorded in organic certification and registration activities. A total of 24.41 acres of organic land belonging to 32 households were newly registered, while 0.50 acre was certified. In addition, certification renewals were completed for seven households covering 180.782 acres. The Centre also registered and certified 15 organic aggregators and 2 processors, thereby strengthening the organic value chain and market linkages.

In line with digital transformation efforts, NCOA progressed the development of the electronic Local Organic Assurance System (eLOAS) in collaboration with GovTech. This initiative aims to fully digitize organic registration, certification, and renewal processes, improving efficiency, transparency, and traceability within the organic assurance system. Furthermore, the Bhutan Organic Guarantee System (BOGS) accreditation process was initiated to align national standards with international requirements, with technical support from the Earth Net Foundation, Bangkok.

Capacity development remained a key focus area, with training programmes on the Bhutan Organic Standard (BOS 02:2022) conducted across five dzongkhags, benefiting 201 participants. These trainings enhanced compliance awareness and strengthened certification readiness among stakeholders. In addition, the development of Model Organic Villages was initiated in Dagana, Tsirang, and Zhemgang in alignment with emerging opportunities linked to the Gelephu Mindfulness City (GMC) initiative.

In the area of research and innovation, NCOA advanced several initiatives, including the development and approval of a Semi-Automatic Poly Bag Filling Machine. Significant progress was also made in strengthening potato seed systems through in-vitro multiplication and apical rooted cutting technologies. Multi-location evaluations of vegetable varieties—such as carrot, muskmelon, sweet pepper, chili, and tomato hybrids—were conducted, alongside comparative studies on organic farming practices and organic liquid fertilizers, generating valuable insights for sustainable production systems.

Outreach programmes further supported farmer livelihoods and productivity. A total of 2,340 fruit trees were rehabilitated under the Million Fruit Tree Programme. Additionally, 280 farmers received training on citrus canopy management and fruit fly control. The Centre also supported the dissemination of improved potato and rice varieties, as well as early tomato production in greenhouse systems in Chhukha. In support of production scaling, agricultural inputs including 253 metric tons of potato seed and 791 kg of rice seed were distributed to farmers. The Centre also strengthened its research dissemination and knowledge sharing efforts by publishing four articles in reputable international journals, contributing to the global scientific literature on agriculture.

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1. FIELD CROPS PROGRAM

The Field Crop Program at the National Centre for Organic Agriculture (NCOA), Yusipang has the national mandate on oilseeds and high-altitude rice. The key activities of the program include research on high altitude rice, quinoa and Research Outreach Program (ROP). In the 2025-26 Financial Year, the Field Crops Program coordinated and led the implementation of Output 1 of the Flexible Voluntary Contribution Project (FVC/RAS/209/MUL) on quinoa. This project supported by FAO focused “Productivity enhancement of priority crops through piloting and upscaling of tailored, innovative, climate-resilient, and sustainable agricultural practices in South Asian countries”. For Bhutan the priority crop selected was quinoa under the FAO’s One Country One Priority (OCOP) crop initiative. The Field Crops Program is also responsible for providing technical support to four client Dzongkhags of Thimphu, Paro, Haa and Chhukha. The Field Crop Program has four researchers which include one Specialist, one Agriculture Officer and two Senior Agriculture Supervisors. The implementation of the activities is guided by the annual work plan which are then divided and reflected into the Individual Work Plans (IWP) of the individual researchers. In total the Field Crops implemented 12 planned and few assigned adhoc activities. The progress and outputs of the activities implemented in 2025-26 are reported below.

1.1. Research Activities under Field Crop Program

1.1.1. High Altitude Rice research and development activities at Ramthangkha, Tshento Gewog in Paro

The Field Crops Program has been conducting high altitude rice research and development activities at the leased land in Ramthangkha, Tshento Gewog, Paro Dzongkhag since 2017. The primary focus of high-altitude rice is for screening and selection of high-altitude rice varieties for high yield, disease tolerance, mainly rice blast and tolerance to cold temperature. The main objectives of the activities were:

- Selection and release of high yielding varieties preferred by farmers.
- To maintain germplasm and produce high quality seed of released varieties for replacement in high altitude rice growing area.
- To produce and supply basic seed to National Seed Center as source of seed.
- Conservation and restoration of traditional high altitude rice varieties through participatory partnership with farmers and the National Biodiversity Center.

1.1.1.1 Production Evaluation trial, 2025

In this trial, two Evolutionary Plant Breeding (EPB) mixtures develop locally through the Evolutionary Plant Breeding (EPB) project of the National Biodiversity Center (NBC) and three other varieties were compared with Yusiray kaap 3 as the Standard Check. The trial design followed was Randomized Complete Block Design (RCBD) with three replications with a plot size of 2 m x 5 m The EPB mixtures were generated by mixing different high-altitude varieties

and allowed to evolve over time in the high-altitude rice growing environment. The other three varieties were Sashanishiki, Sticky and Dumbja. The agronomic parameters are presented in Table 1.3 and 1.4. There was significant difference in plant height and days to maturity. Dumbja was the tallest variety while two EPB mixtures were the earliest in maturity. The Japonica varieties Sashanishiki had the highest number of tillers. There was significant difference in grain yield, straw yield and harvest index. The highest yield of 1258.82 kg/acre was recorded for improved check variety Yusiraykaap 3. All other varieties yielded lower than the check variety Yusiray kaap 3. There was significant difference in the Harvest Index (HI) with Yusiray kaap 3 giving the highest HI of 39.67% indicating that improved variety are more efficient in portioning economic yield.

Table 1. Plant height, Tiller numbers, Days to maturity, 1000 grain weight of six varieties, PET 2025

Varieties	Plant Height (cm)	Mean Tiller Numbers	Days to Maturity	1000 Grain Weight (g)
EPB Mixture- Shari	142.27 ^a	12.27	129.00 ^b	25.77
EPB Mixture- Mitse	109.07 ^b	12.27	131.00 ^b	25.40
Sashanishiki	84.60 ^d	12.53	137.33 ^a	27.93
Sticky	88.33 ^{cd}	11.00	127.00 ^a	27.70
Dumbja	140.40	11.33	138.00 ^a	29.80
Yusiray Kaap 3 (Check)	103.53 ^{bc}	10.30	137.00 ^a	26.93
P Value	p<0.001	ns	p<0.001	ns
CV (%)	4.82	10.50	1.06	9.42
SE	4.41	0.99	1.17	2.10

Table 2. Grain Yield, Straw yield and Harvest index of six varieties, PET 2025

Varieties	Grain Yield (kg/acre)	Straw Yield (kg/acre)	Harvest Index (%)
EPB Mixture- Shari	693.04 ^b	1866.67 ^b	27.00 ^{ab}
EPB Mixture- Mitse	796.00 ^{ab}	1400.00 ^b	36.00 ^{ab}
Sashanishiki	1143.66 ^{ab}	2040.00 ^b	36.00 ^{ab}
Sticky	1173.47 ^a	1800.00 ^b	39.33 ^a
Dumbja	863.94 ^{ab}	3226.67 ^a	22.00 ^b
Yusiray Kaap 3 (Check)	1258.82 ^a	1933.33 ^b	39.67 ^a
P Value	p<0.05	p<0.05	p<0.05
CV (%)	16.82	17.93	17.72

1.1.2. Quinoa Seed Germination trial with different Field level Storage Practices

Quinoa is an orthodox seed like any other cereal. It has been observed that there is very poor or no seed germination of quinoa when seeds are stored like other cereals under ambient conditions. Researchers and farmers working with quinoa are facing the issue of poor seed germination. NCOA, ARDCs, and the National Seed Center (NSC) have received complaints from Extension Agents and farmers on the lack of seed germination in quinoa. Not much is understood and known

about the cause of poor seed germination. To understand and address the issue of poor seed germination, one On-farm seed storage and germination trial was conducted at Yusipang, 2600 m asl. The objective of the trial was to evaluate different On-farm quinoa seed storage methods that can be adopted by farmers at household levels. The hypothesis of this research was that quinoa seed viability and germination are affected by seed age and storage methods. Seven different on-farm storage methods were compared. Quinoa seeds harvested in November 2023 were stored from December 2023 to April 2025 in six different storage methods under ambient conditions. The different on-farm seed storage methods are:

- SM1=Seed Stored in Polypropylene bags (bags used for rice packaging) and stacked
- SM2 = Seed Stored in Plastic buckets with lids (Research practice)/ or sealed containers
- SM3 = Seed stored in Plastic bags with Zip lock, put in carry bags, and hanged
- SM4 = Seeds stored in PET bottles – Used Mineral water bottles (Farmers Practice)
- SM5 = Seeds stored in cloth bags and hung (Research Practice) and
- SM6=Seed stored in glass bottles (washed and cleaned whisky bottles) with lids
- SM7- Seed Stored in refrigerator at 4°C.

The potted experiment was conducted two times. The first trial was sown after 7 months of storage, and the second trial was sown after 17 months of storage. For the first trial, seed was sown on 7th June 2024, and the germination count was done on 5th July 2024. After the first trial, the same seeds were stored in the same condition until the second sowing. The second trial was repeated after 17 months of storage with sowing done on the 29th April 2025 and the germination count was taken on 18th June 2026. Prior to sowing the seeds in the pots, a germination test was done in the Petri dish. The trial design followed was Completely Randomized Block Design (CRD) with three replications. In each replication, there were three pots for each treatment. 800 seeds were sown per pot. The trial was terminated after seedlings attained a height of 10-15 cm and the germination count was recorded.

Table 3. Germination percentage in soil after 7 months of storage period

Treatments	Germination %	Mean Germination (%)
SM1-Seed Stored in Polypropylene bags (bags used for rice packaging) and stacked	Before administering each treatment, the germination in petri dish was >90%	3.41
SM2-Seed Stored in Plastic Containers with lids (Research practice)/ or sealed containers.		5.64
SM3-Seed stored in Plastic bags with Zip lock, put in carry bags and hanged		10.97
SM4-Seeds stored in PET bottles – Used Mineral water bottles (Farmers Practice)		14.09
SM5-Seeds stored in cloth bags and hung (Research Practice)		4.32
SM6-Seed stored in glass bottles (washed and cleaned whisky bottles) with lids		6.02
SM 7- Seed Stored at 4 Deg C in Fridge	90	NA

Table 4. Germination percentage after 17 months of storage period

Treatments	Germination % in Petri Dish	Germination % in Soil
SM1-Seed Stored in Polypropylene bags (bags used for rice packaging) and stacked	50	0.27
SM2-Seed Stored in Plastic Containers with lids (Research practice)/ or sealed containers.	95	2.30
SM3-Seed stored in Plastic bags with Zip lock, put in carry bags, and hanged	95	2.44
SM4-Seeds stored in PET bottles – Used Mineral water bottles (Farmers Practice)	95	3.24
SM5-Seeds stored in cloth bags and hanged (Research Practice)	10	0.57
SM6-Seed stored in glass bottles (washed and cleaned whisky bottles) with lids	95	2.31
SM7-Seed stored in Fridge	95	4.33

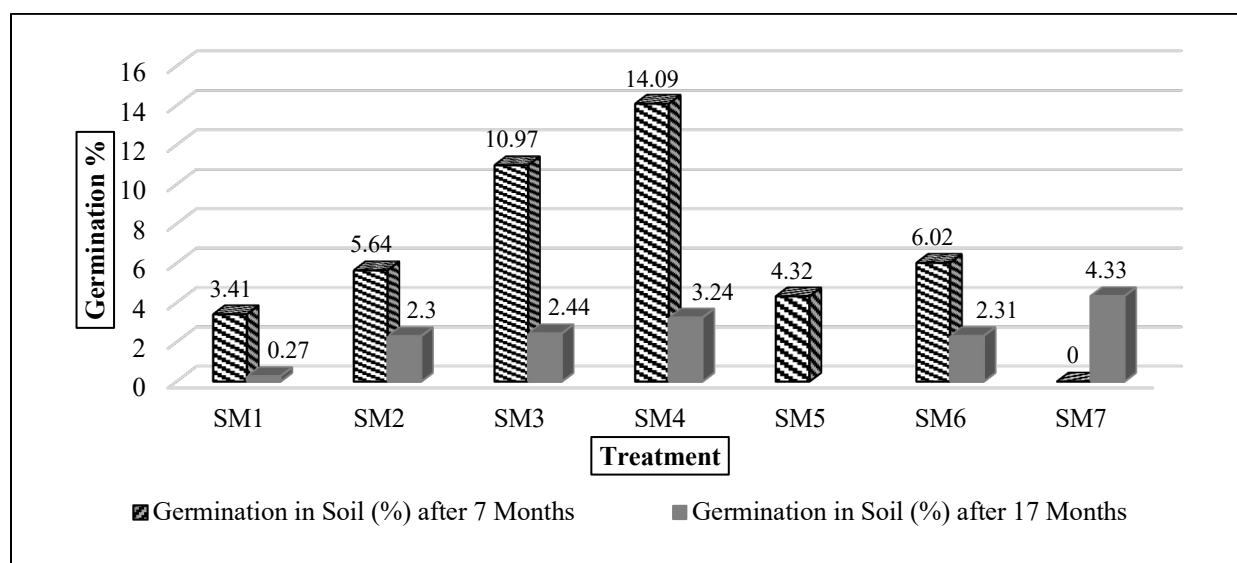


Figure 1. Comparison of germination % in soil after 7 and 17 months of storage period

1.1.3. Biopesticide trial on Quinoa

Quinoa crop is severely affected by Leaf miners (suspected to be *Agromyzidae* flies) which damage the plants in their early stages. For quinoa production under organic management, finding effective bio-pesticides is essential to protecting crop. The use of bio-pesticides could provide an organic solution to control leaf miner infestations, ensuring successful organic production. To assess the effectiveness of various bio-pesticides in managing leaf miner infestations in quinoa grown under organic regime, a replicated trial was conducted during the 2024 season at NCOA, Yusipang.

A field trial was conducted to assess five different bio-pesticides following Randomized Complete Block Design (RCBD) with three replications. The treatments included Neem oil (4 ml/liter of water), artemisia extract (1 liter/10 liters of water), Jholmol (1 liter/liter of water), Wood vinegar, and Control (no treatment). After dilution, 15 liters of each treatment was applied to the respective plots, each measuring 8 m² (4 m × 2 m) in size. For soil fertility management, 5 Mt/acre of farmyard manure (FYM) was applied at sowing. Quinoa seeds were sown in rows with spacing of 50 cm, ensuring uniform growth. Weed management involved two to three manual weeding to maintain optimal crop health. Bio-pesticide applications commenced once leaf miner infestation was observed (defined as a single tunnel on a leaf) and continued weekly until the vegetative stage, when infestation levels were highest. The treatments were applied on a weekly basis. The trial was conducted for two consecutive years (2024 to 2025 season).

Data collection was conducted one day before and after each spray, following a weekly interval. In each treatment plot, a total of five plants were selected and tagged for monitoring. These sample plants were chosen from the middle row for visual counting of leaf mines. The total number of leaves on each plant, along with the number of infested leaves showing leaf miner activity, was recorded to determine the percentage of infested leaves. Additionally, the total number of infected plants was recorded to calculate the percentage of infested plants. These observations were conducted both before and 48 hours after treatment application.

The combined analysis of variance (ANOVA) across the 2024 and 2025 growing seasons revealed that year had a highly significant effect ($p < 0.001$) on all the parameters, including mined leaves, total leaves per plant, infested plants, and grain yield. In contrast, treatment effects and Year × Treatment interactions were non-significant ($p > 0.05$) for all parameters. These findings indicate that the differences observed in pest infestation, plant growth, and yield was primarily associated with variations between growing seasons rather than the treatments applied. The large sum of squares attributed to year, particularly for yield (SS = 811167.361) and infested plants (SS = 24071.289), further emphasizes the strong influence of seasonal factors on quinoa performance.

The significant year effect suggests that environmental conditions such as rainfall, temperature, humidity, and soil moisture likely differed between 2024 and 2025, thereby affecting crop growth, pest incidence, and productivity. The absence of significant treatment effects indicates that the evaluated treatments were unable to produce measurable reductions in leaf miner infestation or improvements in yield under the conditions of this study. Likewise, the non-significant Year × Treatment interactions demonstrate that treatment responses remained consistent across years and were not influenced by seasonal conditions. Overall, the results highlight that environmental variation was the dominant factor governing quinoa growth, infestation levels, and yield, while the tested treatments had limited effectiveness. Future studies should evaluate additional management options and incorporate environmental monitoring to better understand and mitigate seasonal variability in quinoa production.

Table 5. Combine ANOVA for 2024 and 2025 season on quinoa leaf miner incidence

Variable	Source of Variation	df	SS	p-value	Significance
Mined leaves	Year	1	206.684	<0.001	***
	Treatment	4	1.746	0.948	NS
	Year × Treatment	4	2.148	0.926	NS
	Error	30	73.917	—	—
Total leaves plant ⁻¹	Year	1	1151.866	<0.001	***
	Treatment	4	15.049	0.975	NS
	Year × Treatment	4	20.483	0.957	NS
	Error	30	963.741	—	—
Infested plants	Year	1	24071.289	<0.001	***
	Treatment	4	1970.963	0.500	NS
	Year × Treatment	4	1286.500	0.693	NS
	Error	30	17231.297	—	—
Yield (g)	Year	1	811167.361	<0.001	***
	Treatment	4	107670.664	0.324	NS
	Year × Treatment	4	87326.782	0.429	NS
	Error	30	662912.705	—	—

Note: NS = non-significant ($p > 0.05$); *** = highly significant ($p < 0.001$).

1.1.4. Evaluation of Sunflower varieties for Yield and other Agronomic traits

Sunflower (*Helianthus annuus L.*) production is greatly affected by biotic and abiotic factor. Among abiotic factor, drought stress is one major limiting factor and water deficit can reduce the yield by approximately 15-50%. Despite, the low importance given to oil crops research and development, there is a need to diversify the oil crops. In keeping with this objective, sunflower varieties were introduced and evaluated for its performance. This research aimed to evaluate different varieties of sunflower for yield and adaptability to diversify oil crops to changing environment.

This study was conducted on station following the Randomized Complete Block Design (RCBD) with three treatments and seven replications. The trial plot size was 12 m² with a total of 21 experimental units, each measuring 4 x 3 meters. A planting distance of 50 cm between rows and 25 cm between plants was maintained, and thinning was carried out to ensure proper spacing. The three treatments included Bumthang White Local (T1), Kendo Europe (T2), and Bari Shurjo Mukhi (T3). To minimize border effects, data collection excluded border rows, and only data from the center rows was considered. The data was gathered using a random sampling method. Key parameters that were measured included days to 50% germination, days to 50% flowering, days to maturity, plant height, head diameter, seed yield (kg/acre), stem diameter, and 1000-grain weight. Additionally, the dates of sowing, thinning, and harvest were also recorded as part of the data collection process. The trial was sown on 16th April 2024 however; the maturity differed among the treatments. The variety of Barishurjomukhi and Kendo Europe was harvested on 15th August 2024 but for Bumthang local it was harvested on 6th September 2024.

Table 1.10 below illustrates that Bumthang White had significantly higher plant height (323.97 cm) compared to Kendo Europe (187.40 cm) and Bari Shurjo Mukhi (186.66 cm). The highly significant P-value (0.0001) suggests that Bumthang White's superior growth in terms of height is

likely due to its genetic characteristics or favorable growing conditions. However, it was found to be more susceptible to lodging. Similarly, Bumthang White had a significantly larger stem diameter (26.90 mm) than both Kendo Europe (23.11 mm) and Bari Shurjo Mukhi (22.30 mm). The significant P-value (0.0001) shows the strong stem structure of Bumthang. In terms of head diameter, no significant differences were observed across the treatments (P-value = 0.087). Kendo Europe (16.67 mm) and Bari Shurjo Mukhi (16.83 mm) had slightly larger head diameters than Bumthang White (15.17 mm). Bumthang White also had the highest 1000-grain weight (86.77 g), significantly outperforming Kendo Europe (55.84 g) and Bari Shurjo Mukhi (66.59 g), as confirmed by the highly significant P-value (0.0001).

In terms of seed yield, Bumthang White yielded the highest seed yield (1.15 Mt/acre), significantly outperforming Kendo Europe (0.55 Mt/acre) and Bari Shurjo Mukhi (0.67 Mt/acre), with a significant P-value (0.0004). The higher yield of Bumthang White suggests it has better overall plant vigor and productivity compared to the other two varieties. In conclusion, Bumthang White performed significantly better than Kendo Europe and Bari Shurjo Mukhi in terms of plant height, stem diameter, 1000-grain weight, and seed yield, demonstrating its potential as a high-yielding and robust variety however due to its longer height, it was more prone to lodging compared to other two varieties.

Table 6. Agronomic traits of different Sunflower Varieties

Treatment	Mean pH (cm)	Mean SD (mm)	Mean HD (mm)	TGW (gm)	Seed Yield (Mt/ac)
Bumthang White	323.97 ^a	26.90 ^a	15.17	86.77 ^a	1.15 ^a
Kendo Europe	187.40 ^b	23.11 ^b	16.67	55.84 ^c	0.55 ^b
Bari Shurjo Mukhi	186.66 ^b	22.30 ^b	16.83	66.59 ^b	0.67 ^b
P-value	0.0001 ^{**}	0.0001 ^{**}	0.087	0.0001 ^{**}	0.0004 [*]
CV (%)	12.96	17.07	21.15	10.88	26.27
SE	7.21	0.98	0.82	4.05	0.11

1.1.5. Evaluation of different Organic Manures on Buckwheat Yield and Soil Health

In recent years, Bhutan has witnessed a significant decline in production. It was once considered as a staple in many regions of the country but now it's regarded as a neglected and underutilized crop. Despite its declining cultivation, buckwheat holds deep nutritional, cultural, and religious significance in Bhutan. It is one of the nine traditional cereals known as *Dru-Na Gu*, considered vital to Bhutanese heritage and agricultural history. While many of these traditional grains have been overlooked in modern farming practices, certain regions continue to cultivate in a limited area following their traditional farming methods. With increasing consumer interest in safe and healthy food, and the growing potential of niche markets for organic buckwheat, there is a clear need for more research on organic buckwheat farming practices.

Objective

- To evaluate the effectiveness of different organic manures on buckwheat yield and soil organic matter.

The experiment was conducted at the NCOA, Yusipang, located at an altitude of 2,600 masl, to evaluate the effects of different organic manure sources on the growth, yield, and soil health of sweet buckwheat. This trial was laid out in a RCBD comprising seven treatments and three replications, resulting in a total of 21 experimental plots. Each plot will measure 4 m × 2 m. Sowing will be carried out in April, maintaining a spacing of 10 cm between plants and 45 cm between rows, following recommended crop management practices.

The treatments evaluated were:

T1: Vermicompost at 5 tons per hectare

T2: Farmyard manure (FYM) at 5 tons per hectare

T3: Poultry manure at 5 tons per hectare

T4: Vermicompost and FYM, each at 2.5 tons per hectare

T5: Vermicompost and Poultry manure, each at 2.5 tons per hectare

T6: FYM and Poultry manure, each at 2.5 tons per hectare

T7: Control

Soil samples will be collected before sowing and after harvesting to assess changes in organic soil matter resulting from the different organic manure treatments. Data on grain yield and straw yield were recorded, with yield measurements obtained from a 6 m² crop-cut area within each plot.

Table 7. Grain yield and straw yield of buckwheat

Treatments	Mean Yield (g/plot)	Mean Straw Yield (g/plot)
T1	61.50	4.03
T2	37.37	3.14
T3	27.77	1.6
T4	45.67	4.00
T5	25.47	1.58
T6	57.23	4.32
T7	47.00	3.28
P value	00.15	0.25

The mean grain yield and straw yield varied among treatments, ranging from 25.47 to 61.50 g/plot and 1.58 to 4.32 g/plot respectively. Treatment 1 recorded the highest grain yield (61.50 g/plot), followed by Treatment 6 (57.23 g/plot), while the lowest grain yield was observed in Treatment 5 (25.47 g/plot). The control treatment (Treatment 7) produced a grain yield of 47.00 g/plot and a straw yield of 3.28 g/plot. Compared to the control, Treatment 1 and Treatment 6 increased grain yield by approximately 31% and 22%, respectively. Similarly, Treatments 1, 4, and 6 produced higher straw yields than the control. However, analysis of variance showed that the differences among treatments were not statistically significant for either grain yield ($P = 0.15$) or straw yield ($P = 0.25$), indicating that the observed variations could not be attributed solely to treatment effects.

The absence of significant treatment effects may be partly explained by the high variability observed in the experiment, as reflected by the coefficients of variation of 39.47% for grain yield and 50.97% for straw yield. In addition, substantial bird damage was observed during the grain filling and maturity stages, which resulted in considerable grain loss across the experimental plots and likely contributed to the overall low yield levels. This bird infestation may have masked the

true treatment effects and reduced the ability of the experiment to detect statistically significant differences. Nevertheless, the numerical yield advantage of Treatments 1 and 6 over the control suggests their potential to improve crop performance.

The soil analysis after the harvest of the trial revealed significant changes in soil chemical properties compared to the initial soil status. The pre-experimental soil had a pH of 6.8, organic carbon content of 0.43%, available nitrogen of 120 mg kg⁻¹, available phosphorus of 13.6 mg kg⁻¹, and available potassium of 6.45 mg kg⁻¹. Following the application of different treatments, soil pH ranged from 5.83 to 6.16, indicating a slight decrease in soil pH across all treatments. In contrast, OC content increased substantially, ranging from 2.2 to 2.7%, with the highest value recorded in T3 (2.7%). Similarly, available N increased markedly from the initial 120 mg kg⁻¹ to values ranging between 1000 and 4000 mg kg⁻¹, with T7 recording the highest nitrogen content (4000 mg kg⁻¹). Available P also increased considerably, ranging from 39.10 to 58.41 mg kg⁻¹, with the highest value observed in T6 (58.41 mg kg⁻¹). Likewise, available K showed a substantial improvement from the initial 6.45 mg kg⁻¹ to values ranging from 101.49 to 179.11 mg kg⁻¹, with T6 recording the highest potassium content (179.11 mg kg⁻¹). The increase in organic carbon and available nutrients indicates that the treatments positively influenced soil fertility by enhancing nutrient availability and organic matter accumulation. Although a slight reduction in pH was observed, the values remained within a moderately acidic range suitable for crop growth. Overall, the results demonstrate that the treatments improved the soil's nutrient status, with T3, T6, and T7 showing superior performance in terms of organic carbon, phosphorus and potassium, and nitrogen accumulation, respectively.

Table 8. Post soil analysis

Post Soil Test					
Treatment	pH	OC (%)	N (mg/kg)	P (mg/kg)	K (mg/kg)
T1	5.83	2.4	2100	43.77	101.49
T2	6	2.5	1600	46.34	126.36
T3	6.08	2.7	1600	47.84	127.73
T4	6.01	2.2	1300	44.63	144.44
T5	6.16	2.2	1300	39.1	165.15
T6	6.03	2.6	1000	58.41	179.11
T7	6.08	2.4	4000	49.21	143.73
Pre Soil Test					
	6.8	0.4293	120	13.6	6.45

1.1.6. Research Outreach Program (ROP) on Rice

High-altitude rice cultivation in Bhutan extends up to 2,700 masl, supported by cold-tolerant, short-duration varieties adapted to cooler climates. The warm temperate zone contributes about 20% of the total rice area and remains the most productive. NCOA Yusipang has released seven high-yielding, blast- and cold-tolerant varieties for these environments, with more in the pipeline. However, adoption has been limited due to limited seed and limited awareness of the varieties. With improved seed availability and support from extension services, ROP was conducted in

Chhukha and Haa Dzongkhags to evaluate and promote these varieties along with improved package of practices, aiming to enhance rice productivity in high-altitude regions.

Objectives

- To conduct large-scale demonstrations to promote improved high-altitude rice varieties and boost production.
- To increase the adoption of new varieties through recommended practices to maximize yield and farm productivity.
- To enhance on-farm diversity with climate-resilient varieties for sustainable high-altitude rice farming.

Demonstrations were conducted in one site each in Chhukha and Haa Dzongkhags, involving three farmers per site. Three improved rice varieties (Yusiray Maap 2, Yusiray Kathramathra, and Yusiray Kaap 3) were tested alongside a local variety as a control. Nursery raising and transplanting were done following the farmers' traditional practices. Improved varieties were supplied with recommended package of practices with a fertilizer dose of 80:40:20 kg/acre (N:P:K), while the local variety was cultivated under farmers' normal practices. Irrigation was as per the farmer's practices across all varieties. Weed management was standardized using Butachlor application of 10-15 kg/acre.

The ROP in Haa was conducted at Dorithasa Chiwog, Yangtsena village under Gakiling Gewog. Three improved varieties along with fertilizers and weedicide were supplied to 3 farmers. For Yusiray Maap 2 the local variety outperformed the improved variety in yield, adaptability, grain quality, and disease resistance. Yusiray Maap 2 also showed difficulty in threshing. Similarly, Yusiray Kathramathra and Yusiray Maap 3 recorded unsatisfactory yields with delayed maturity, and Yusiray Kaap 3 was also hard to thresh. In Chhukha Dzongkhag, ROP was conducted at Toktowom village under, Bongo Gewog. All three improved varieties were early maturing but faced severe rodent and bird damage, resulting in significant yield loss and in some cases complete crop failure. Across both locations, crop performance at the nursery stage was good and comparable to local varieties. However, field performance was inferior to the local checks. ROP will be repeated with more farmers in the next season.

2.2 Development Activities under Field Crop Program

1.2.1. Basic Seed Production and Maintenance of Released High Altitude Rice Varieties

Nine released high altitude varieties were cultivated in single large plot. The released varieties were cultivated for basic seed production to support farmers with good quality source seeds in high altitude rice growing areas across the country. The nursery was raised on 10th February 2025, and transplanted on the 27th of May, 2025. The crop was harvested in the second week of November 2025. The trial was transplanted in a line spacing of 20 cm x 20 cm using single large plot. Butachlor (Punch 10G) was applied at the rate of 14 kg per acre, 2-3 days after transplanting as pre-emergence for weed control. Fertilizer was applied at the rate of 80:40:30 NPK t/ha. Half of the nitrogen and the entire amount of P and K were applied as basal application at the time of

transplanting. The remaining nitrogen was top dressed at maximum tillering and flowering stages at the rate 40 kg/ha. The total quantity of basic seed produced is 1264 kg. In addition to the released varieties 40 kg seeds each of the two new varieties namely Sticky and Chandannath were also produced for trials in the next season. In order to have pure seed for all the released varieties, panicle selection was done to maintain the seed for next season.

Table 9. Basic seed production of released rice varieties in 2025

Varieties	Basic Seed Produced (kg)
Yusiray Maap1	70
Yusiray kaap 2	40
Yusiray Khathramathra	185
Yusiray Kaap 3	270
Yusiray Maap 2	230
Khangma Maap	345
Jakar ray Naap	89
Yusiray Maap 3	35

Table 10. Basic seed of high-altitude rice varieties supplied to different beneficiaries, 2026

Varieties	Seed Supplied (kg)	Beneficiaries	Purpose
Khangma Maap	265	Thimphu, Paro, Chhukha	Research Outreach Program, trials and seed replacement
Jakar Ray Naap	90	Paro, Chhukha	
Yusiray Kaap3	125	Thimphu, Paro, Chhukha	
Yusiray Maap 3	33	Chhukha	
Yusiray Maap 1	35	Chhukha	
Yusiray Maap 2	80	Paro, Chhukha	
Yusiray Khathramathra	123	Chhukha, Bumthang	
Yusiray Kaap 2	40	Chhukha	
Total (kg)	791		

1.2.2. In-Situ Conservation of Traditional High Altitude Rice Varieties

The Field Crops Program in collaboration with the National Biodiversity Center, Serbithang has been continuously maintaining five high altitude rice varieties namely Dumbja, Themja, Janam, and Zhuchum. The nursery was raised on 25th February 2025 and transplanted on the first week of June 2025. These varieties are maintained and conserved in-situ through participatory engagement of custodian farmers of Dopshari Gewog, Paro who share their indigenous knowledge on these varieties for seed selection. The seeds produced are made available to any farmers who are interested in cultivating these traditional varieties. These varieties are also used as local check in other variety evaluation trials. The different accessions of Dumbja initially sourced from the National Gene Bank and further selected with farmer's knowledge of this variety have been restored back at the National Gene Bank at NBC for conservation. Pure seed of Dumbja is rehabilitated back to the interested farmers.

1.2.3. Seed Production and Maintenance of Rice Varieties under Organic Management at Yusipang

NCOA Yusipang research farm is a certified Organic farm. It was certified under the Local Organic Assurance Scheme (LOAS) which follows the Bhutan Organic Standards (BOS) of the Bhutan Organic Guarantee System (BOGS). High altitude organic rice was cultivation at Yusipang was started in 2023. In 2025, the nursery for the two varieties was raised on 5th February 2025 and transplanted on 16th April 2025. The crop was harvested on 28th November 2025. Seed production of two high altitude varieties Khangma Maap and Jakar Ray Naab was done, and the total seed production of each variety was 120 kg and 90 kg respectively. To adapt the new variety Sashanishiki under Yusipang environment panicle section was carried out.

1.2.4. Relocation of High-Altitude Rice to ARDCSC Menchuna, Tsirang

The ongoing high altitude rice research and development activity at Paro since 2017 has been under analysis of the DoA. The allocation of budget for this activity has remained a key subject of discussion mainly due to the increase in travel cost. The DoA directed NCOA to explore a more viable alternative site for relocation of the current site. Accordingly, NCOA Yusipang has consolidated the justifications for DoA to assess and provide further guidance. NCOA presented the different options for realigning the ongoing high altitude rice research and development program during the 15th Research Management Committee (RMC) meeting held on 15th December, 2025 at DOA.

The RMC directed ARDC Bajo and NCOA to continue the current high-altitude rice research arrangement at Paro, with leadership transferred to ARDC Bajo, while piloting the proposed realignment at ARDC RSC Menchuna, Tsirang to assess its technical suitability. ARDC Bajo shall lead the process and develop clear technical guidelines for high-altitude rice germplasm evaluation and maintenance, under the supervision of the National Rice Coordinator, with a view to improving efficiency, reducing costs, and strengthening national high-altitude rice research in the long term.

In keeping with this directive, NCOA Yusipang has developed and shared technical guidelines with ARDC Bajo and also supplied seeds of 10 high altitude rice varieties namely Yusirey Maap, Yusirey Maap 2, Yusirey Kaap 2, Khangma Maap, Jakarray Naap, Yusiray Kathramathra – (PP₄(38-4)), Yusiray Kaap 3 (YPS 7), Yusiray Maap 3 (YP/K-Y/B-20), Sassnishiki and Chandanath for adaptation at ARDC RSC Menchuna Tsirang.

1.2.5. Upscaling Quinoa Cultivation under Chhukha Dzongkhag

Totokwom is one of the important agricultural areas in Chhukha Dzongkhag where rice farming is widely practiced. Recently, government has supported chain link fencing covering around 79 acres of paddy field. Dependence on a single crop often creates challenges such as low income, climate risks, and soil fertility problems. Introducing quinoa into the rice-based farming system as

a rice-quinoa sequence was considered an important step towards improving farming sustainability and household nutrition.

The outreach program on quinoa to promote rice-quinoa cropping system was y focused on creating awareness among farmers about the importance and benefits of quinoa cultivation and enhancing cropping intensity. Farmers were provided with training on land preparation, sowing methods, irrigation, weed management, nutrient management, and harvesting techniques. Demonstration plots were established so that farmers could practically observe the growth and performance of quinoa under local conditions. Improved seeds of quinoa were also distributed to participating farmers to encourage cultivation.

During the cultivation process, the land was properly prepared through ploughing and leveling to create a suitable seedbed. Quinoa seeds were sown in rows with proper spacing to allow healthy plant growth. Organic manure and compost were applied to improve soil fertility and support sustainable farming practices. Manual weeding was carried out during the early stages of crop growth to reduce weed competition. Since quinoa requires less water compared to rice, only light irrigation was provided when necessary.

The program showed positive results as quinoa adapted well to the environmental conditions of Totokha. Farmers observed that the crop required less water and fewer inputs than rice cultivation. The crop also demonstrated good growth and survival under local conditions. Farmers showed interest in quinoa because of its nutritional value and potential economic benefits. Quinoa is rich in protein, vitamins, minerals, and essential amino acids, making it a healthy food option for households.

Despite the positive outcomes, several challenges were also faced during the program. Many farmers had limited knowledge and experience regarding quinoa cultivation and management practices. In addition, there was limited availability of quality seeds and market opportunities for quinoa products. Lack of awareness among consumers about quinoa consumption was another challenge for future expansion.

To improve quinoa cultivation in the future, continued farmer training and awareness programs are necessary. Local seed production and distribution systems should be strengthened to ensure seed availability. Market linkages and value-added products should also be developed to encourage farmers to cultivate quinoa on a larger scale. Further research should be conducted to identify suitable quinoa varieties and improve production practices under local conditions.

In conclusion, the research outreach program on quinoa cultivation under the rice-based farming system at Totokha, Chhukha Dzongkhag successfully demonstrated the potential of quinoa as a climate-resilient and nutritious crop. The program helped farmers gain knowledge and practical experience in quinoa cultivation while promoting crop diversification and sustainable agriculture. With proper support, research, and market development, quinoa can become an important alternative crop that contributes to food security, improved nutrition, and increased farmer income

in Toktowom village. The rice-quinoa cropping system will be upscale with more farmers in the 2026-27 cropping season.

1.2.6. Support for Quinoa Production to other Dzongkhags

Support to enhance the production of quinoa was provided to the different villages under Chhukha, Haa, and Thimphu Dzongkhags during 2025 season through the ROP. The program aimed to promote quinoa cultivation as a nutritious and climate-resilient crop under different farming system. Farmers from different gewogs participated in quinoa cultivation through research outreach activities and demonstration programs.

The production data collected from the participating villages showed encouraging results. In Chhukha Dzongkhag, quinoa cultivation was carried out in Bunagu village under Chapcha Gewog, Chanachen under Geling Gewog, Sampheling Gewog, Zamsa village under Bongo Gewog, and Samerchen village under Darla Gewog. Among these areas, Zamsa village under Bongo Gewog recorded the highest production of 300 kg, followed by Chanachen village with 200 kg, Sampheling Gewog with 150 kg, Bunagu with 100 kg. and Darla with 250 kg. In Haa Dzongkhag, quinoa cultivation was conducted in Katsho and Gakiling Gewogs. Katsho Gewog recorded a production of 35 kg and Gakiling Gewogs with 250 kg.

The total recorded quinoa production from harvested areas in 2025 was 1185 kg. This ROP demonstrated that quinoa can be successfully cultivated in different agroecological conditions of Bhutan. Farmers showed interest in the crop due to its nutritional value, low water requirement, and potential for crop diversification. However, some challenges such as delayed harvesting, limited awareness, and small-scale production were observed during the program.

1.2.7. On-station Seed Production of Quinoa, Mustard, Adzuki bean and Wheat

To support the promotion of improved varieties through ROP, Field Crop Program initiated the production of source seed of quinoa, mustard, adzuki bean and wheat.

Table 11. Source Seed Production

Crop	Variety	Seed Produced (kg)
Quinoa	Amarilla Marangani	50
Mustard	Yusipeka 1	30
	Yusipeka 2	20
Adzuki Beans	Yusi Adzuki 1	80
Wheat	Durum	150

1.2.8. National Rice Survey

The National Rice Survey was coordinated by ARDC Bajo and implemented by the respective Agricultural Research and Development Centers (ARDCs) across the country. The survey was conducted to assess the adoption status of improved rice production technologies, identify factors influencing their adoption among farmers, and establish the status of rice farming in Bhutan. The survey also aimed to document production constraints, emerging opportunities, farmers'

management practices, and socio-economic factors affecting rice cultivation. The findings will provide evidence-based information to guide research priorities, technology dissemination strategies, and policy interventions for sustainable rice sector development.

A total of 2,124 households were surveyed nationwide, with a primary focus on rice-growing farmers. The Field Crop Sector of NCOA led the survey implementation in the western region, covering four Dzongkhags (Haa, Paro, Thimphu, and Chhukha) and 25 Gewogs. The sector coordinated field planning, enumerator deployment, data collection, and quality assurance to ensure the accuracy and reliability of survey data. Following completion of the field survey, the collected data were submitted to the lead agency for national compilation and analysis. In addition, an officer from the Field Crop Sector has been actively involved in data cleaning, statistical analysis, interpretation of results, and report writing. The survey findings are expected to contribute to the development of targeted interventions, strengthen rice research and extension programs, and support national efforts to enhance rice productivity, food security, and farmer livelihoods.

2. HORTICULTURE PROGRAM

2.1. Research Activities under Horticulture Program

2.1.1. Performance Evaluation of Almond under Million Fruit Tree Project (MFTP) in Western Region

The Million Fruit Tree Project (MFTP) aims to enhance fruit tree diversification and improve orchard productivity through large-scale plantation of high-value fruit crops, including almond (*Prunus dulcis*). This report presents the annual performance evaluation of almond plantings established in the western region, focusing on vegetative growth and field establishment success. The assessment provides baseline information on the adaptability and early growth performance of almond under different field conditions.

Materials and Methods

Field observations were conducted on almond trees established under the MFTP initiative in the western region. The study covered multiple sites, including Darla, Sombaykha, and Katsho, with plantings established in 2023. Systematic measurements were taken from selected representative trees to assess growth performance.

The parameters recorded included tree height (cm), canopy spread (cm), and trunk girth (mm) measured at 10 cm above ground level. Standard field measurement techniques were applied to ensure accuracy and consistency. Data were collected across different sites varying in altitude, environmental conditions, and management practices, and were compiled for analysis.

Results and Discussion

The results indicated that almond trees generally established well under field conditions in the western region. Most trees showed progressive growth in height, canopy spread, and trunk girth,

reflecting good vegetative vigor and successful establishment. However, variation in growth performance was observed across sites, mainly due to differences in environmental conditions, management practices, and plant survival.

Table 12. Average Growth Performance and Mortality of Almond Trees by Location

Location	Avg. Tree Height (cm)	Avg. Canopy Spread (cm)	Avg. Trunk Girth (mm)
Darla	200.4	96.1	97.3
Sombaykha	141.5	48.3	73.0
Katsho	131.9	75.3	106.3
Overall	175.1	90.7	96.8

Tree height varied considerably among individual plants, with some showing strong vertical growth while others remained relatively shorter. Similarly, canopy spread differed across locations, reflecting variations in pruning practices and site conditions. Trunk girth measurements further confirmed steady structural development in most surviving trees. A few cases of tree mortality were also recorded, indicating site-specific constraints. Overall, the findings suggest that almond is adaptable to the western region, although improved and standardized orchard management practices are recommended to ensure more uniform growth and better establishment.

2.1.1. Evaluation of Grafting Success of Almond (*Prunus dulcis*) on St. Julien and Wild Peach Rootstocks Using Side Grafting

Almond (*Prunus dulcis*) is an important temperate nut crop valued for its nutritional and economic importance. Successful propagation of almond depends largely on the compatibility between scion and rootstock, which influences plant vigor, adaptability, and tolerance to biotic and abiotic stresses. In this study, two rootstocks—St. Julien and wild peach—were evaluated for their compatibility with almond under local conditions. St. Julien is widely used as a clonal rootstock for stone fruits due to its adaptability and moderate vigor, while wild peach is commonly used locally because of its availability and hardiness. The study was conducted to compare graft success between these two rootstocks using the side grafting technique.

Materials and Methods

The experiment was conducted under open field conditions using side grafting technique. A total of 120 grafts were performed, with 60 grafts on each rootstock. Healthy, one-year-old almond shoots with 2–3 buds were used as scion material. Two rootstocks were used: St. Julien (60 plants) and wild peach (60 plants). The treatments were designated as T₁ (almond on St. Julien) and T₂ (almond on wild peach), with each graft considered as an individual replicate. Side grafting was carried out by making a 3–4 cm downward cut on the rootstock and preparing a matching slant cut on the scion to ensure proper cambial contact. The graft union was tightly secured using grafting tape. After grafting, plants were maintained under regular aftercare, which included irrigation, removal of rootstock suckers, and mulching with black polyethylene to suppress weeds. Graft unions were regularly monitored, and grafting tape was removed once establishment was achieved.

Data were collected on number of successful and failed grafts, graft success percentage, and early growth performance.



Figure 2. Image of trial

Result and discussion

The results showed variation in graft success between the two root stocks. St. Julien recorded a higher graft success rate of 63.3%, with 38 successful grafts out of 60, while wild peach showed a success rate of 55.0%, with 33 successful grafts. This indicates that almond scions were more compatible with St. Julien under the given conditions compared to wild peach.

The higher success rate in St. Julien may be attributed to better cambial compatibility and improved graft union formation, leading to enhanced survival and establishment. Although both rootstocks supported successful grafting, differences in success percentages suggest variation in physiological compatibility and adaptation. Overall, the findings indicate that St. Julien is a more promising rootstock for almond propagation under the study conditions. However, further evaluation of long-term growth, vigor, and field performance is recommended before making final recommendations for large-scale propagation. Nevertheless, continued monitoring of graft growth, vigor, and field performance is recommended before making final recommendations for large-scale adoption.

2.1.3. Evaluation of Yield Performance and Feasibility of Wengkhar Tshelu 1 and 2 at Higher Altitudes

As part of the ongoing efforts to identify and promote improved citrus selections suitable for diverse agroecological conditions, evaluation plots of Wengkhar Tshelu 1 and Wengkhar Tshelu 2 were established at Bjabcho Gewog under Chhukha Dzongkhag and Mochu Village, Gakidling Gewog under Haa Dzongkhag. Due to unavailability of the varieties locally, local citrus rootstocks have been planted for this year. Grafting will be performed in the coming season (March-2027) to all the evaluation plots with the two varieties of citrus. The activity is being supported by World Bank RNR Job Project and it's undertaken to assess the yield performance and technical feasibility of the two citrus selections under higher altitude conditions and to generate information for future varietal recommendations.

The selected sites were identified based on their suitability for citrus cultivation, taking into consideration factors such as altitude, slope, soil conditions, accessibility, water availability, and farmers' willingness to participate in the evaluation program. These locations represent higher elevation areas where the adaptability and productivity of improved citrus varieties require further assessment. Proper orchard layout and planting positions were designed and marked following recommended spacing to facilitate optimum plant growth, canopy development, and future orchard management operations.

The evaluation plots were established to systematically monitor the growth, flowering, fruiting behavior, yield performance, and overall adaptability of Wengkhar Tshelu 1 and Wengkhar Tshelu 2 under farmer field conditions. In addition to yield assessment, observations on fruit quality, tree vigor, pest and disease incidence, and tolerance to prevailing climatic conditions will be recorded to determine the suitability of these selections for cultivation in higher altitude regions.

The activity also provided an opportunity to strengthen collaboration with participating farmers and enhance their understanding of proper orchard establishment and management practices. Technical guidance was provided on land preparation, pit digging, nutrient management, irrigation requirements, and post-planting care to ensure successful establishment and maintenance of the evaluation plots.

The establishment of these evaluation sites represents an important step towards expanding citrus cultivation into suitable higher altitude areas and diversifying production systems. The information generated from the study will provide valuable evidence on the productivity and adaptability of Wengkhar Tshelu 1 and Wengkhar Tshelu 2 and support the development of location-specific recommendations. In the long term, successful performance of these selections is expected to contribute to increased citrus production, improved fruit quality, and enhanced income opportunities for farming communities while strengthening the resilience and sustainability of Bhutan's citrus industry.

Table 13. Site details of orchards

Location	GPS Coordinates	Altitude (masl)	No. of Plants
MoChhu, Sangbeykha, Haa	27°08'10.79"N 89°07'08.19"E	1493.27	200
Bjabcho, Chhukha	27°02'27"N 89°34'43"E	1714.15	50
Bjabcho, Chhukha	27°02'31"N 89°34'58"E	1620	50
Bjabcho, Chhukha	27°02'27.62"N 89°34'42.99"E	1736	100

2.1.4. Fast-track Evaluation of Hybrid Carrot Varieties

Carrot (*Daucus carota* L.) is a cool season crop grown all over the globe as the edible part of the crop is characterized by its high beta carotene content, a precursor of vitamin A and act as an excellent source of iron, calcium, phosphorus, vitamin B, sugar and folic acid. Carrot is comparatively easy to grow crops and due to their high nutritional value, its demand is quite high in the market. There are several factors like variety, time of sowing, nutrition management and irrigation which play a major role in yield and quality production. Among these factors, variety

plays a predominant role in quality yield production. However, it was observed that availability of high yielding carrot varieties along with high consumer preference is lacking. Hence, the present investigation was conducted with the objective to evaluate and compare new hybrid carrots for its yield performance under temperate Bhutanese condition.

Materials and methods

The experiment was laid out in RCBD with five replications. The treatments were randomly assigned to plots within each replication. Each experimental plot size was 1.5 m², with a length of 2 m and width of 0.75 m, prepared on fine tilth soil. The seeds were sown on 17th April 2025. The plant spacing was maintained at 2-3 inches (7-8 cm) by manual thinning at the time of true leaf formation. The row-to-row spacing was maintained at 25 cm with three rows sown per plot.

A uniform seed rate of 8 g per plot was used across the treatments. Prior to sowing, 1.94 kg of vermicompost uniformly applied to each plot. The same quantity of vermicompost was top-dressed at 19 and 47 days after sowing (DAS). The plant thinning was carried out at 32 and 46 DAS, respectively. The carrot was harvested at 83 DAS on 9th July 2025, followed by the second harvest 91 DAS on 17th July 2025. Experiment was conducted on station with four treatments.

Table 22. Varieties tested in the experiment

Treatment	Variety	Source	Supplied by
1	Nantes 2 (Lot no. 531)	Oshiye & Co LTD	DoA, HQ
2	Nantes 2 (Lot no. 534)	Oshiye & Co LTD	DoA, HQ
3	New Kuroda (improved)	NSC, Paro	NSC, Paro
4	All season	NSC, Paro	NSC (CHECK)

Ten plants from per plot were selected randomly for data collection. Days taken for harvest were calculated as days from sowing to first harvest. Based on the net plot yield, root yield per acre was calculated and expressed in kgs. Data on marketable and non-marketable yield was recorded for an appropriate yield calculation. For non-marketable yield; forking and distorted and small roots that cannot be considered for marketing was recorded.

Data on yield, percentage plant survival and fruit characteristics were subjected to analysis of variance (ANOVA). The statistical analysis was performed using R software version. Multiple comparisons among the means were conducted using Fisher's protected least significant differences (LSD) test with statistically significant ($p = 0.05$).

Results and Discussion

Results indicated that check line (*all season*) provided the highest root weight, root diameter and root length compared to all new lines. In terms of performance on root diameter and root weight *all season* was closely followed by *New Kuroda*. There was no significant effect of treatments on marketable yield and non-marketable yield of tested carrot varieties at $p > 0.05$.

Although the mean marketable yield of check line *All season* showed slightly higher yield than the new lines, there was no significant differences cross the varieties in terms of marketable and yield. All varieties also showed no significant differences in non-markable yield. The mean of Nantes 2 (Lot 531) and New Kuroda showed higher percent of non-marketable yield than check line (*All season*) and Nantes 2 (Lot 534).

Three new carrot varieties with one check variety were tested under temperate agroecological condition of Yusipang, Thimphu from April 2025 to July 2025. There was a significant difference in root length, root weight and root diameter amongst the varieties. Check line (*All season*) and new variety (New Kuroda, improved) were significantly higher than Nantes 2, Lot 531 and Nantes 2, Lot 534. The check line performed better in terms of root weight, root length and root diameter followed by New Kuroda. Besides check, amongst three new tested lines, New Kuroda, performed better in terms of root length, root diameter and root weight. New Kuroda, therefore, could be considered for production under temperate conditions. However, considering the data on non-marketable yield of New Kuroda which showed slightly higher percentage of non-marketable yield, a follow up trial to validate its potential for commercial production is recommended.

Table 15. Mean yield per plot of marketable and non-marketable yield

Treatments/variety	Marketable yield (kg)	Non-marketable yield (Kg)	Total yield (kg)	Non-marketable yield %
Nantes 2 (Lot 531)	2.30	3.25	5.55	58.56
Nantes 2 (Lot 534)	3.42	1.84	5.26	35
New Kuroda	3.48	2.44	5.92	41
All season	3.99	2.37	6.36	37
<i>p- value</i>	0.37	0.78		

Table 16. Means of Morphological characteristics

Treatments	Root length (cm)	Root diameter (mm)	Root weight (kg)	Leaf length (cm)
Nantes 2 (Lot 531)	12.7 ^a	24.1 ^a	0.056 ^a	49.3 ^{bc}
Nantes 2 (Lot 534)	12.4 ^a	23.8 ^a	0.054 ^a	46.3 ^a
New Kuroda	13.2 ^a	25.3 ^{ab}	0.065 ^b	49.9 ^c
All season	14.4 ^b	26.9 ^b	0.071 ^b	47.2 ^{ab}

Means within a column followed by the same letter(s) are not significantly different at $P \leq 0.05$, while means with different letters differ significantly according to Bonferroni-adjusted mean separation.

2.1.5. Comparative study of organic practices recommended by NCOA and practice recommended by Sun Smile Co., Ltd.

National Center for Organic Agriculture (NCOA) has implemented a range of organic farming practices adapted to Bhutan's agroecological conditions. In parallel, Mr. Terunuma, a Japanese expert in low-input organic cultivation from Sun Smile Co. Ltd., has proposed techniques emphasizing minimal external inputs, ecological balance, and concept of natural farming. Although both systems share the common goal of promoting sustainability and improving soil and crop health, differences in methodology and efficiency remain largely unexplored. This study was

therefore conducted to compare the organic farming practices currently implemented in NCOA and the techniques recommended by Mr. Terunuma. The research aims to identify strengths, gaps, potential areas of improvement in Bhutan's organic farming practices to support the development of more effective and sustainable organic farming strategies.

Materials and Methods

Chili (*Capsicum annuum* L.) was selected as the test crop for this comparative study due to its economic importance and wide cultivation across Bhutan. Two local varieties of chili – Begup Ema and Sha Ema were cultivated in the trial.

The experiment was carried out on station at NCOA. It followed a comparative layout where each treatment represented one farming approach. Standard organic management practices were maintained throughout the cropping period.

NCOA's practice: raised beds of 15cm height, 1 m width, and 5m length were prepared, each covering an area of 5m². A total of 20 chili seedlings were transplanted per bed, arranged in two rows with a row-to-row and plant-to-plant spacing of 50cm. During transplantation, farmyard manure (FYM) and vermi-compost were incorporated into each planting hole to enhance soil fertility. To minimize weed growth and moisture loss, plastic mulch was used. 20 plants each of two chili varieties, Begup emma and Sha emma, were transplanted.

Terunuma's Technique: ridges of 50cm width were prepared, maintaining a 60 cm between adjacent ridges and a length of 8 m. Well-decomposed compost was sieved and uniformly applied on the surface of the prepared ridges. The plant-to-plant space of 40 cm was maintained. 20 plants each of two chili varieties, Begup emma and Sha emma, were transplanted.

The growth parameters such as plant height (cm) and plant stem diameter (mm), fruit number and yield data were recorded. In addition, the fruit morphological traits including fruit weight (g), length (cm), width (mm) and pedicel length (cm) were also measured. The average of parameters was calculated in Microsoft excel. Total sample plants taken for data collection was 20 numbers or the entire plot.

Result and Discussion

The trial nursery was raised on 12th February 2025 and transplanted on 6th May 2025. The crop was harvested three times respectively on 104, 141, and 162 days after transplanting. Begup emma under the NCOA's practice exhibited higher average plant height whereas stem diameter, fruit number and fruit yield were all higher under Terunuma's practice. A similar trend was observed in Sha emma, where Terunuma's practice consistently produced higher average values across all measured parameters compared to NCOA's practice as shown in table below.

Table 17. Growth and yield performance of two chili varieties (Begup ema and Sha ema) under NCOA's and Terunuma's cultivation practice.

Varieties	Treatments	Plant height (cm)	Stem diameter (mm)	Total No. of Fruit	Fruit Yield (kg)
Begup ema	NCOA	84.67	18.14	41	1.05
	Terunuma	81.25	20.87	70	1.46
Sha ema	NCOA	57.83	16.14	47	0.88
	Terunuma	64.14	17.69	80	1.28

Begup ema exhibited a higher fruit weight and fruit width under NCOA's cultivation practice compared to Terunuma's. In contrast, fruit length and pedicel length were higher under Terunuma's practice. On the other hand, Sha ema showed increased fruit weight, fruit width, and pedicel length under Terunuma's practice, while fruit length was greater under NCOA's practice. These findings suggest that Terunuma's cultivation practice may enhance certain morphological traits, particularly fruit weight, fruit width, and pedicel elongation in Sha ema, while Begup ema appears to exhibit more consistent morphological traits across the treatments.

Table 18. Morphological traits of two chili varieties under NCOA's and Terunuma's practices

Variety	Treatment	Fruit weight (g)	Fruit length (cm)	Fruit width (mm)	Pedicel length (cm)
Begup ema	NCOA	30.05	13.14	26.01	3.89
	Terunuma	29.85	13.43	20.24	4.71
Sha Ema	NCOA	19.65	7.90	23.72	2.86
	Terunuma	21.99	7.52	27.61	3.40

The enhanced performance observed under Terunuma's cultivation practice suggests that his low-input, ecologically oriented techniques may offer greater effectiveness in promoting crop growth and productivity. Therefore, incorporating selected components of Terunuma's approach into Bhutan's current organic farming system could strengthen its efficiency and contribute to more sustainable and productive organic cultivation

2.1.6. Performance evaluation of Muskmelon F1 varieties at Yusipang condition

Despite the release of the muskmelon variety Honey Dew by RDC Bajo in 1990, the crop has not gained commercial significance in Bhutan. While not grown domestically, it is imported for consumption. Given the suitable climatic conditions prevailing in many parts of the country, systematic studies on muskmelon cultivation are warranted to explore its adaptability, productivity, and potential for commercial production.

Materials and methods

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications at a plant spacing of 1.5 m × 1.0 m with five hybrids (08W4, 11H1, 10SS, 08T3, 10H1 sourced from TAKII seeds) as treatments. Each plot comprised four plants planted in a single

row. A total of 80 plants were established in the trial. Data were collected from all five plants in each replication, and the mean values were used for statistical analysis.

Result and discussion

The performance of the five hybrid varieties differed considerably in terms of fruit characteristics, total soluble solids (TSS), and seedling mortality. Hybrid 10SS produced the largest fruits, with the highest average weight (1.54 kg), length (42.58 cm), and diameter (43.01 cm). However, it recorded the lowest TSS value (7.07 °Brix) and the highest seedling mortality (56%). In contrast, Hybrid 10H1 exhibited the highest TSS (13.84 °Brix), indicating superior sweetness, despite producing comparatively smaller fruits with an average weight of 1.16 kg, length of 26.39 cm, and diameter of 36.65 cm. Hybrids 08W4 and 11H1 showed intermediate performance, with TSS values of 11.24 and 11.60 °Brix, respectively, while 08T3 produced the smallest fruits and moderate sweetness (10.20 °Brix). Seedling mortality ranged from 13% in 10H1 to 56% in 10SS.

Table 19. Mean Fruit Characteristics, Total Soluble Solids, and Seedling Mortality of Hybrid Varieties

Treatment	Average Weight (kg)	Average of Length (mm)	Average of diameter (mm)	Average of TSS (mm)	Mortality (%)
08W4	1.36	32.60	38.82	11.24	44%
11H1	1.33	39.61	42.20	11.60	38%
10SS	1.54	42.58	43.01	7.07	56%
08T3	0.90	36.36	30.85	10.20	44%
10H1	1.16	26.39	36.65	13.84	13%

In order to assess consumer acceptance of the fruits, tasting sessions were conducted during meetings and trade shows, where participants evaluated key quality attributes such as taste, sweetness, texture, and overall appeal. The results indicated that the fruits were well accepted by consumers, with participants expressing willingness to purchase them.

Based on overall field performance and fruit quality, Hybrid 10H1 was the most preferred variety due to its appropriate fruit size, high sweetness, and excellent adaptability under Yusipang conditions. The variety also demonstrated the highest tolerance to stem blight, with less than 13% seedling mortality, and matured consistently throughout the growing season. Hybrid 08W4 was the second preferred variety, followed closely by 11H1, both of which combined acceptable fruit quality with moderate disease tolerance. Although 10SS produced the largest fruits, its high susceptibility to stem blight and failure to reach full maturity before the end of the growing season rendered it unsuitable for cultivation under Yusipang conditions. The delayed maturity of 10SS likely contributed to its low TSS values, indicating poor fruit quality despite its larger size. Therefore, 10H1 appears to be the most promising hybrid for production in Yusipang, offering a balance of fruit quality, disease resistance, and consistent maturity.

Ongoing trials in both farmers' fields and on-station sites are being carried out to verify the consistency of these findings with the identified better performing hybrids.

2.1.7. Preliminary observation trial of sweet pepper

Sweet peppers (*Capsicum annuum*), commonly known as capsicum or bell peppers, are a globally important vegetable valued for their mild flavor, high nutritional content (high vitamin C, vitamin A, and antioxidant content), and various uses (culinary, pharmaceuticals and cosmetics). Unlike chili, sweet peppers lack capsaicin, the compound responsible for pungency, making them widely preferred by consumers.

In Bhutan, demand for sweet peppers is increasing, particularly in urban areas and resorts, due to consumer preference for nutritious and non-pungent vegetables. Currently, only one sweet pepper variety “California Wonder” was introduced and cultivated in the country. To enhance productivity and varietal diversity, a trial evaluating forty open-pollinated sweet pepper varieties from the World Vegetable Center, with California Wonder as the check, was initiated. The objective is to identify high-yielding and adaptable varieties for commercial cultivation in Bhutan.

Materials and Methodology

Since the seeds were not enough for replicated trial, preliminary yield trial (PYT) was conducted in the open field at on-station. The seeds were sown on 27 February 2025 in plug tray of nursery medium (soil, sand, topsoil and vermicompost ration of 2:1:1:1). Out of the 40 lines sown, 36 lines were transplanted on a plastic mulched beds measuring (4m x 1m). The plants were spaced 50 cm in a single row bed. Eight plants were planted in a bed. Rest of the lines could not be transplanted due to very low germination and California Wonder (Check variety) failed to germinate.

Table 20. Treatment (Entries received from WorldVeg Centre, 2024)

WorldVeg No.	Crop name	Species name	Total seed Qty(g)
AVPP1358	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1360	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1363	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1367	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1371	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1376	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1378	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1386	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1391	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP0019	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP0301	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1114	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1506	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1112	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1115	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1513	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1505	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1516	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP0119	Sweet Pepper	<i>Capsicum annuum</i>	1

AVPP0114	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1901	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP0910	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP0601	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP0912	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP2020	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP2021	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP2023	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP2024	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP9814	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP2025	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP2027	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP2029	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP2030	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1949; AVPP22016	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1952; AVPP22019	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP1959; AVPP22026	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP0402	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP0504	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP0408	Sweet Pepper	<i>Capsicum annuum</i>	1
AVPP0417	Sweet Pepper	<i>Capsicum annuum</i>	1

Results and discussions

Out of the 40 lines, 20 lines between the yield of 29.02 MT/acre to 16.4 MTt/acre was selected as provided in the table below. The lines under 16 Mt/acre were screened out. These lines will be further evaluated in replicated trial. These lines will be distributed to ARDC for further evaluation as NCT.

Table 21. Yield of capsicum lines

Variety	Yield/plot (kg)	Yield /acre(kg)	Yield (Mt/acre)	Selected lines
AVPP 1378	12.91119	20916.13	20.91613	9
AVPP 2021	11.87693	19240.63	19.24063	12
AVPP9814	13.99574	22673.1	22.6731	6
AVPP1363	9.3314	15116.87	15.11687	
AVPP1505	15.35977	24882.83	24.88283	4
AVPP1513	7.25494	11753	11.753	
AVPP2027	6.91768	11206.64	11.20664	lodging resistance
AVPP2030	13.98252	22651.68	22.65168	7
AVPP2025	8.5689	13881.62	13.88162	
AVPP0601	9.13374	14796.66	14.79666	
AVPP1386	17.91351	29019.89	29.01989	1
AVPP2020	15.81493	25620.19	25.62019	2
AVPP0402	8.622645	13968.68	13.96868	
AVPP1506	10.15419	16449.79	16.44979	19

AVPP1376	10.865	17601.3	17.6013	17
AVPP1360	12.68924	20556.57	20.55657	10
AVPP1949	12.135	19658.7	19.6587	11
AVPP1371	8.56543	13876	13.876	
AVPP0417	11.03487	17876.49	17.87649	14
AVPP2029	8.895	14409.9	14.4099	
AVPP1115	8.33428	13501.53	13.50153	
AVPP0119	14.835	24032.7	24.0327	5
AVPP1959	10.11	16378.2	16.3782	20
AVPP1367	5.04	8164.8	8.1648	
AVPP0912	3.685	5969.7	5.9697	
AVPP1112	6.18	10011.6	10.0116	
AVPP1114	10.32598	16728.09	16.72809	18
AVPP1952	11.675	18913.5	18.9135	13
AVPP2023	10.715	17358.3	17.3583	16
AVPP2024	4.86062	7874.204	7.874204	
AVPP1391	15.43112	24998.41	24.99841	3
AVPP0408	9.09	14725.8	14.7258	
AVPP0301	7.671	12427.02	12.42702	
AVPP1516	10.99	17803.8	17.8038	15
AVPP1901	13.485	21845.7	21.8457	8
AVPP0910	6.495	10521.9	10.5219	



Figure 3. Capsicum varieties selected for further evaluation

During the participatory variety evaluation of chili varieties, scoring for color preferences of the capsicum varieties were also made. Table above (Table 3. reflects the colour preferences for capsicum varieties by the participants. Yellow colour was the most preferred varieties followed by orange and red respectively.

2.1.8. Evaluation of Watermelon Variety (Summer Sweet) under different agroecological condition of Bhutan

In Bhutan, watermelon is usually cultivated in an open field and is recommended to grow during the month of early spring when the season is dry. Watermelon is a dry season crop. Watermelon production is gaining momentum in recent years among growers in Bhutan. Watermelon is one of the important emerging cash crops in Bhutan, contributing to the generation of farmers' income.

Considering the current market demand and Agriculture Research Coordination Meeting (ARCM) resolution, the study focused on small-sized watermelons.

In 2024, the National Seed Center (NSC), Paro in collaboration with Oshiye and Company Ltd. (Japan), a participant in the Bhutan Agri-Food Trade Investment Forum (BATIF) 2024, provided the seeds of the Japanese watermelon variety known as Summer Sweet for research and study purposes to the ARDCs. Watermelons imported from India are usually not the preferred size, as the Bhutanese customer prefers small-sized watermelons rather than the bigger ones. Secondly, large volumes of watermelon are imported from India every year, although there is potential to upscale domestic production. The objective of this study was to evaluate the adaptability and performance of new watermelon variety (Summer sweet) for size and taste against the check variety Sugar Baby.

Materials and Method

The new watermelon varieties (Summer Sweet) were evaluated against the check variety, Sugar Baby. The seed source of Summer Sweet was from Oshiye and Company Ltd. (Japan). Seeds of these watermelon cultivars were sown in the greenhouse and potted in plastic poly pots (4”X6”). The research design was a Randomized Complete Block Design (RCBD) with two treatments (T1: Sugar Baby and T2: Summer Sweet) and four replications.

The treatments in the replication were randomized using Star software. Thus, the field was divided into four replications having three plots in each replication, with a total of nine plots. Each plot size was 18 m² (5 m x 2 m x 1.8 m) with 5 plants per plot with a spacing of 2 m x 1.8 m per plant in a single row at the center of the bed on a raised bed of 30 cm height. Thus, the size of the bed was 9 x 2 m. The size of the planting hole was 30 cm wide and 30 cm long, and seedlings were planted 10 cm deep in the hole. Farmyard Manure (FYM) was applied during land preparation at the rate of 20 t/ha. The basin was prepared by mixing 7.2 kg each of sand, FYM, and topsoil at the ratio of 1:1:1. Rice straw was used for mulching.

Pest incidences were not noted. To prevent fungal infection, the trial plots were sprayed with copper oxychloride twice. The plants were top-dressed with 100gm of vermicompost in each plant twice once in flowering and once in fruiting stage was also applied during the fruiting stage.

For data collection, one fruit of marketable size from each plant per plot was randomly selected to determine during each harvest to measure the fruit parameters, such as fruit weight, fruit height, fruit diameter, and TSS%. A handheld refractometer was used for measuring fruit TSS, a digital weighing balance for fruit weight measurement, and a simple measuring tape for measuring the fruit height, fruit diameter, and vine length. The plot yield was determined by multiplying the mean yield of the plot by the total number of fruits per plot.

All the data collected from the field trial was subjected to analysis of variance (ANOVA) in STAR

Results and Discussion

Analysis of variance showed that fruit weight differed significantly between the two watermelon varieties ($P = 0.00$), with Sugar baby producing heavier fruits (4093.57 g) than Summer Sweet (1719.55 g). Fruit length, fruit diameter, rind thickness, and total soluble solids (TSS) did not differ significantly ($P > 0.05$).

The coefficient of variation (CV%) ranged from 3.08% (TSS) to 39.12% (fruit weight), indicating relatively high variability for fruit weight. This may be attributed to harvesting over the entire fruiting period and the effects of decreasing temperature towards the end of the harvesting period, which may have influenced fruit size and weight.

Table 22. Mean fruit parameters by variety

Treatment	Fruit weight	Fruit length	Fruit diameter	Rind thickness (mm)	TSS
Summer sweet	1719.55 ^b	15.42	14.42	9.31	10.28
Sugar baby	4093.57 ^a	21.22	21.50	13.46	10.32
P value	0.00	0.08	0.09	0.0569	0.9093

Significant differences were observed in the number of fruits per vine and vine length. Summer sweet produced a higher number of fruits per vine (6.45) than Sugar baby (3.35) ($P < 0.05$), whereas Sugar baby had longer vines (1.83 m) compared to Summer Sweet (1.44 m) ($P < 0.05$). Male flower anthesis occurred significantly earlier in Summer sweet but no significant difference was observed for female flower anthesis occurrence. There were no significant differences in the number of primary vines or days to first and last harvests ($P > 0.05$).

Table 23. Mean vine characteristics and phenology by variety

Treatment	No. of fruits per vine	Vine length (m)	No. of Primary vine	Days to First Harvest	Days to Last Harvest	Days to first female flower anthesis	Days to first Male flower anthesis
Summer sweet	6.45 ^a	1.44 ^b	3.9	144.55	205.3	93.8	81.70 ^b
Sugar baby	3.35 ^b	1.83 ^a	5	156.55	211.65	108.45	88.75 ^a
P value	0.0002	0.0185	0.1599	0.0636	0.2382	0.46	0.0062

The coefficient variation ranged from 2.93% to 18.8%, indicating relatively low to moderate variability among the traits measured. Overall, Summer sweet appears more prolific in terms of fruit number, while Sugar baby exhibits greater vine growth, with similar phenology between the varieties.

Sugar baby produced significantly heavier fruits, while summer sweet had a higher number of fruits per vine. Vine length was greater in Sugar baby, but other traits, including rind thickness, TSS, and days to first and last harvest, did not differ significantly. High variability in fruit weight may be due to harvest timing and decreasing temperature. While both varieties showing similar

growth and phenology, Summer Sweet's smaller fruit over Sugar baby's heavier ones fits the average Bhutanese consumer and market preference while its shorter vine length and a greater number of fruits per vine ensures farmers reap more per unit square meter.

The study found that Summer Sweet variety is best suited for Bhutanese consumer preferences as it produced relatively smaller (3.12 kg) and sweeter (14.40%) fruits with greater yields and produced more fruits per plant as compared to other two varieties. The outcome of the study fulfilled the objective of evaluating watermelon varieties for fruit size and taste hence the challenge posed by large-sized imports is addressed. As a result, Summer Sweet is recommended for domestic cultivation as it aligns with local market demand and shows potential for enhancing commercial production in Bhutan. However, the success of its adoption is subject to the availability of its seeds.

2.1.9. Evaluation of Eight selected WorldVeg Chili Lines for Yield Performance and Desirable Traits Under Yusipang (temperate conditions)

Chili evaluation trial to evaluate and screen WorldVeg chili lines for its yield and desirable pungency in Bhutanese condition was completed. The trial was set up at NCOA with the selected lines of chili. The lines were selected in 2024 with high scoring of pungency level through Participatory variety selection (PVS).

Materials and Methods

The experiment was laid out in a randomized complete block design (RCBD) with 3 replications in an open field. Bed size of 4m x1.5 m bed was prepared to grow chili plants spaced at 45cm between the plants and 50cm between the rows. There were two rows in each plot. A total of 12 plants were planted in each plot and 6 plants per row were maintained. Trials were managed in organic conditions.

Data for yield, yield components and pest and diseases were collected using the standard format for variety evaluation of the WorldVeg Centre. Yield data were analyzed using ANOVA to identify statistically significant differences among the tested varieties. Pungency was measured using the rating system through sensory evaluation during harvesting time.

In September 2025, when plants were in fruiting stage, participatory variety evaluation on chili variety was conducted with fifteen farmers from four western Dzongkhags.

The participants were asked to visit the trial plots where standing plants are available and observe the plant for diseases. Then they were asked to taste the fruits that were presented without any tag to gauge the pungency. The participants were then provided with six grains and vote as per the following instruction:

- a. 3 grains for the most tolerant to disease
- b. 2 grains for moderate tolerance to disease
- c. 1 for least tolerance to disease

Similarly for pungency with the higher number of grains corresponding to higher pungency. Pungency was rated at four levels: (1) Very high (2) High (3) Low (4) Very Low.

Treatments: (1) AVPP 1609-022, (2) V1037449, (3) AVPP1811, (4) AVPP 1609-085, (5) V1044930, (6) AVPP2004, (7) AVPP 1130, (8) V1037607.

Result and Discussions

Plant characteristics: AVPP 2004 was the most preferred variety in terms of overall plants height, shape and health which was followed by AVPP1609-085 and AVPP 1811 respectively. Fruit shape of AVPP2004 was most preferred which was followed by AVPP1609-085 and AVPP 1130. In terms of fruit taste AVPP 2004 was the most preferred which was closely followed by AVPP1609-085 and AVPP 1811.

Overall, AVPP 2004 stood out to be the most promising line, however, statistical data on yield revealed that the yield potential of AVPP 1609-085 was higher than AVPP 2004. Both the varieties can be considered potential lines for promotion in Bhutan. AVPP 1609-085 is the second most preferred line by the farmers through the PVS scoring in terms of taste as well.

Table 24. Mean yield, plant height and fruit size of selected lines

Treatment	Yield per plot (kg)	yield per acre (kg)	Mean fruit weight(gm)	Mean fruit length(mm)	Fruit width(mm)	Plant height(cm)	Yield rank
AVPP 1609-022	4.09	4143.49	5	50	13	72.3	7
V1037449	5.75	5823.23	3	44	12	82.73	5
AVPP1811	7.09	7175.93	11	95	15	63.66	2
AVPP 1609-085	7.56	7652.81	6	82	11	70.66	1
V1044930	4.75	4809.38	4	60	12	68.6	6
AVPP2004	5.81	5877.56	8	96	11	61.8	4
V1037607	6.17	6247.46	5	45	14	70.87	3
AVPP 1130	1.42	1436.74	5	85	10	82.8	8

The mean yield of the varieties revealed that AVPP 1609-085 produced the highest with 7.6 Mt per acre followed by AVPP 1811 with 7.2Mt/acre and V1037607 with 6.2 Mt per acre



Figure 4. AVPP 1609-085 (left) and AVPP 2004 (right)

2.1.10. Breeding in Chilli and Tomato

Chili hybridization was initiated at NCOA, Yusipang. The objective of the chili hybridization is to develop F1 chili with better yield performance and acceptable taste and fruit quality. Performance of Chili hybrids of F1 generation of parental lines;Sha ema (SE) x AVPP1337 (Samtelling ema 2), AVPP 1337 x Sha ema, AVPP 1111 x Sha ema and Sha ema x AVPP 1111 was tested in the mega green house while due to limited seedlings only three lines Sha ema (SE) x AVPP1337 (Samtelling ema 2), AVPP 1111 x Sha ema and Sha ema x AVPP 1111 was tested in the open field conditions. Single variety *sha ema* was tested as the control line. The lines were tested in a single plot design in the mega greenhouse and open field of Yusipang from April 2025 to October 2025.

Table 25. Fruit characteristics and plant height of four F1 chili lines and sha ema in mega greenhouse condition

Treatment/ Variety	Fruit weight (kg)	Fruit weight (g)	Fruit Length (mm)	Fruit width (mm)	Plant height (cm)
SE X AVPP1337	0.02704	27.0	148.9	17.1	123.4
SE X AVPP1111	0.011232	11.2	94.1	13.4	149.4
AVPP1337 X SE	0.0137	13.7	126.6	12.8	160
AVPP1111 X SE	0.01356	13.6	95.8	17.0	147.4
Sha ema	0.01926	19.3	85.1	24.7	140.8

Table 26. Mean yield of the four F1 chili lines in the mega greenhouse conditions

Treatment	Mean weight/ plant (kg)	Total number of fruits/ plants	Total Weight/plot (kg)	Yield (kg/acre)	Yield (MT/acre)
SE X AVPP1337	1.85	91.20	20.86	16899.84	16.90
SE X AVPP1111	1.80	169.60	17.39	14089.14	14.09
AVPP1337 X SE	1.45	133.00	9.58	7756.56	7.76
AVPP1111 X SE	1.21	114.20	8.38	6788.61	6.79
Sha ema	0.77	45.40	8.76	7091.55	7.09

The evaluation under the greenhouse showed that SE x AVPP 1337 produced the biggest and most desirable characteristics. Fruits length and width was uniform and highest amongst the three other F1 lines (SE x AVPP1111, SE x AVPP1111, AVPP1337 x SE, AVPP1111 x SE) and sha ema. Results revealed that SE x AVPP1339 had highest yield followed by SE x AVPP1111. Sha ema (control) yielded the lowest.

Table 27. Open field evaluation of three F1 chili hybrids

Treatment	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	No. of Fruits/ plant	Plant height (cm)	Weight (kg)/plot
SE X 1337	35.912	110.447	26.355	39	71.6	1.4
SE X 1111	17.431	108.108	20.277	28	58.4	0.4
1111 X SE	21.316	105.227	23.786	27	54.6	0.6
Sha ema	20.493	79.303	28.38	22	66.4	0.5

In the open field condition, it was found that SE x AVPP 1337 yield the highest amongst all F1 lines. During the PVS participants actively carried out Participatory Variety Evaluation (PVS) of four F1 Hybrid developed by the NCOA. As a result, the participants scored Sha emaXAVPP1337,

Sha ema x AVPP1111 and AVPP1111 x Sha ema and Sha ema in three important characters identified by growers. In all the selected parameters of fruit characteristics, shape and fruit taste: SE x AVPP 1337 (Samtenlling ema 2) was rated the highest.

Breeding activities on tomato was continued during the year. The objective of tomato breeding is to produce F1 tomato lines resistance to late blight (*phytophthora infestans*) with preferred fruit quality. One of the major diseases affecting the tomato cultivation in Bhutan is a fungal disease called the late blight disease caused by *Phytophthora infestans*. In Bhutan, the tomato producing season coincides with the rainy season. Consequently, tomato cultivation is impeded by elevated humidity and precipitation, which may result in pests and disease during the development phase of tomato.



Figure 5. Open field production of 3 chili crosses at NCOA field

The F1 lines produced in 2024 with parent line (AVTO 1712 x AVTO 1954, AVTO1954 x AVTO1712, KT Cherry x AVTO 1954, AVTO 1954 x KT cherry) were tested in the open field condition.

Table 28. Mean fruit size and weight of four F1 lines in the open field of NCOA, Yusipang

Lines	Weight of fruits (g)	Fruit length (mm)	Fruit width (mm)
AVTO 1954 x KT	26.65	32.50	35.72
KT x AVTO1954	28.64	31.91	36.68
AVTO1954 x AVTO1712	20.27	28.35	34.46
AVTO1712 x AVTO1954	26.89	35.45	36.55

The fruit size of AVTO1712 x AVTO1954 was bigger compared to the rest of three lines (KT x AVTO1954, AVTO1954 x AVTO1712, AVTO1954 x KT). Weight of all four lines were similar with AVTO1954 x AVTO1712 producing the smallest fruit in the open field condition. AVT1712 x AVTO 1954 was the least damaged lines amongst other lines. The highest infected were AVTO 1954 and AVTO1954 x KT in the open field condition. The result indicated that AVT1712 x AVTO 1954 could be one of the potential lines (F1) for production in the open field condition of temperate condition.

Table 29. Percentage of damage by late blight in tomato in the open field condition

Lines	Standing plants	No. of Infected plants by late blight					Damage (%)
		8/7/2025	18/7/2025	28/7/2025	8/8/2025	Total	
AVTO1712x	12	0	0	0	1	1	8
AVTO1954	12	0	4	1	1	6	50
KT x AVTO1954	12	0	1	8	10	10	83
AVTO 1712	12	0	0	2	3	5	42
KT (cherry) x	12	0	0	2	2	4	33
AVTO 1954	12	0	3	2	1	6	50
F2 (F1 x KT)	12	0	3	3	3	9	75
AVTO1954 x KT	12	0	3	1	1	5	42
KT (cherry)	12	0	3	1	1	5	42

2.1.11. Evaluation of Dwarf Beans at NCOA (NCT)

The Department of Agriculture has prioritized bean cultivation to enhance production and contribute to national revenue. Most traditional bean varieties grown by farmers are climbing types that require staking, resulting in higher labor and production costs. Dwarf bean varieties offer a low-cost alternative as they do not require support, are easier to manage, and are less prone to damage. Therefore, a trial was conducted to evaluate the performance of dwarf beans as Nationally Coordinated Trial by ARDC Bajo. Only the results of the trial conducted at the center is presented.

Materials and methods

Three varieties were evaluated: Borlotto -Check variety (T1), Japanese Bean (T2), and Top Crop (T3). The experiment was laid out in a RCBD with seven replications. Each plot measured 2 m × 2 m and consisted of 24 plants spaced at 30 cm between plants and 50 cm between rows. Standard crop management practices, including manure and fertilizer application, irrigation, and weeding, were carried out as recommended. Harvesting was done at the marketable green pod stage.

Data were collected for pod length, pod width, pod weight, marketable yield. Yield data were recorded from tagged plants, while pod characteristics were assessed from randomly selected marketable pods.

The data were arranged and organized using Microsoft Excel 365 and analyzed using analysis of variance (ANOVA) in STAR (Statistical Tool for Agricultural Research) version 2.0.1. Treatment means were compared at a significance level of $p < 0.05$.

Result and discussion

Significant differences were observed among the bush bean varieties for fruit weight, fruit length, fruit diameter, and seed count per fruit. Japanese Bean produced the longest fruits and the highest number of seeds per fruit, fruit weight and yield per acre. Borlotto recorded the largest fruit diameter and was statistically comparable to Japanese Bean in terms of fruit weight.

Top Crop exhibited significantly lower fruit weight than the other two varieties and showed intermediate performance for fruit length and seed count. Although differences in the number of marketable fruits were observed among varieties, Japanese Bean produced the highest number of marketable fruits, followed by Borlotto and Top Crop.

Japanese Bean showed superior performance for most yield and fruit quality attributes, indicating its potential for cultivation under the test conditions. Borlotto also performed well, particularly in fruit size, while Top Crop demonstrated comparatively lower performance across most parameters.

Table 30. Mean fruit characteristics and marketable fruit production of bush bean varieties

Treatment	Fruit weight (g)	Fruit length (cm)	Mean fruit diameter (cm)	Seed count per fruit	No. of marketable fruit	Yield per acre (Mt)
Borlotto	8.22 ^a	11.83 ^c	15.75 ^a	4.96 ^b	52.90	6.07 ^a
Japanese beans	8.84 ^a	16.02 ^a	9.10 ^b	6.99 ^a	56.59	5.66 ^a
Top crop	6.17 ^b	13.71 ^b	9.46 ^b	5.23 ^b	49.95	3.62 ^b

2.1.12. Fast-track evaluation of cauliflower

Cauliflower is one of the most widely cultivated and consumed vegetable crops in Bhutan, valued for its nutritional importance and market demand. The introduction of F1 hybrid began very recently with the vegetable commercialization movement and the cultivation of hybrids among the farmers is gaining popularity these days. The hybrids with high yielding ability and other desirable traits have not only helped farmers for domestic consumption but have also enabled export of vegetables. Upon instruction of the department, evaluation of hybrid cauliflower for export market opportunities under the BATIF collaboration to enhance our farmer's income thereby contributing to the national economy was undertaken.

Materials and methods

Two cauliflower varieties received through BATIF collaboration and one variety from Reva Seeds were evaluated for their growth, yield, and adaptability under local conditions against Snow Mystic as check. The experiment was conducted using a randomized complete block design (RCBD) with four treatments and eight replications. Each plot contained 8 plants arranged in a 2 m × 1 m bed, with 50 cm row-to-row and plant-to-plant spacing and 60 cm between beds.

Curd parameter data were collected from 7 randomly selected plants per plot (approximately 87.5% of the plant population) at maturity. The data were arranged and organized using Microsoft Excel 365 and analyzed using analysis of variance (ANOVA) in STAR (Statistical Tool for Agricultural Research) version 2.0.1. Treatment means were compared at a significance level of $p < 0.05$.

Result and discussion

Significant variation was observed among the cauliflower varieties for all measured traits, including curd weight, curd diameter, curd length, and yield. The check variety performed consistently better across all parameters and was significantly superior to most of the tested varieties. The coefficient of variation (CV) ranged from 6.91% to 16.64%, indicating low to moderate variability and suggesting that the experimental conditions were sufficiently controlled for reliable comparison among treatments.

Table 31. Mean performance of cauliflower varieties for curd characteristics and yield with ANOVA significance

Treatment	Mean curd weight in kg	Mean Curd diameter in cm	Mean Curd length in cm	Yield per acre in Mt
Snow Mystic (Check)	0.60 ^a	12.96 ^a	10.56 ^a	9.74 ^a
Snowy	0.38 ^c	10.79 ^c	7.85 ^c	6.14 ^c
Super Dome	0.46 ^{bc}	11.73 ^b	9.49 ^b	7.51 ^{bc}
White Castle	0.53 ^{ab}	12.18 ^{ab}	8.90 ^b	8.70 ^{ab}

Among the introduced varieties, White Castle showed comparatively better performance and was statistically at par with the check for key yield and curd traits, indicating good adaptability under the test conditions. Super Dome exhibited intermediate performance, while Snowy recorded the lowest values across all parameters and was significantly inferior to the other varieties.

In conclusion, the results indicate clear varietal differences in performance, with the Check variety remaining the most productive.

2.1.13. Evaluation of Blue Chamomile Varieties

German chamomile (*Matricaria chamomilla* L.) is valued for its medicinal, cosmetic, and nutritional properties and has a strong market in Europe, particularly in Germany, the United Kingdom, and France. Growing consumer demand for organically produced herbal products presents an opportunity for Bhutan to develop a niche market and premium brand. This study evaluates five imported Blue Chamomile varieties for their growth performance and yield under Bhutanese conditions. The research was initiated and supported by Terra Himalaya, an FDI company, which has identified a ready export market in Germany.

Materials and methods

The study was conducted at the National Centre for Organic Agriculture (NCOA), Yusipang, using a Randomized Complete Block Design (RCBD) with five varietal treatments and four replications. The crop was harvested four times, and data were collected during each harvest. Data analysis was performed using Analysis of Variance (ANOVA) in the Statistical Package for Social Sciences (SPSS). Data collection was carried out from 30% of the total plant population.

Results and Discussion

The aim of the research was to identify a suitable variety which will perform better in the given climate conditions with high yielding characteristics. Therefore, yield parameters were closely observed. Goral recorded the highest total flower yield (9,415 g), followed closely by Lutea (7,726.5 g) and Bodegold (7,173 g). ANT09X had the lowest total yield (4,540 g), despite producing a relatively high number of flowers (29,400), indicating smaller or lighter flowers.

Goral produced the highest number of flowers (32,292), showing strong flowering capacity and vigor. Bodegold and Lutea had comparable flower numbers (27,500), while Zloty lan and ANT09X followed closely with ~29,000 flowers each. Zloty lan exhibited the heaviest average flower weight (238.49 mg), suggesting larger, more compact flowers with higher essential oil potential. ANT09X showed the lowest flower weight (129.24 mg), which, along with its low total yield, indicates less biomass accumulation per flower. Lutea and Goral maintained moderate flower weights (185.93 and 165.30 mg respectively), contributing to their higher overall yields.

The comparative analysis across three harvests shows that Goral maintained the highest and most consistent yield, confirming its strong adaptability and production potential. Lutea demonstrated a remarkable increase in yield over successive harvests, highlighting its capacity for sustained regrowth. Bodegold remained steady, while Zloty lan showed yield fluctuations that may reflect sensitivity to environmental conditions. ANT09X consistently lagged behind, suggesting lower genetic yield potential under the given conditions.

Goral produced the highest total flower yield (9,415 g) with balanced vegetative growth, while Lutea showed robust canopy development and sustained yield increase over time. Both varieties demonstrated desirable plant height and spread, contributing to better biomass accumulation and productivity.

Overall, Goral and Lutea are the most promising varieties for further agronomic evaluation and potential commercial cultivation under Yusipang conditions.

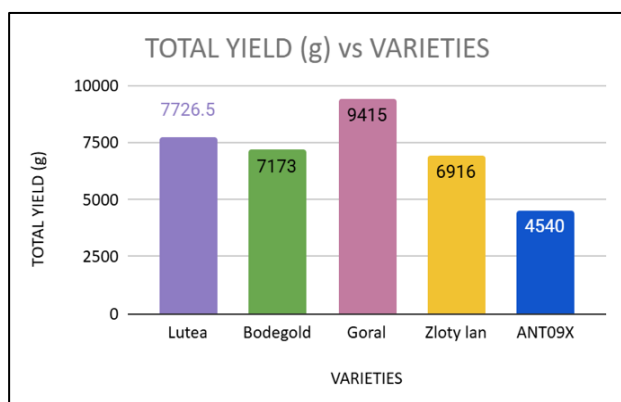


Figure 6. Yield by variety

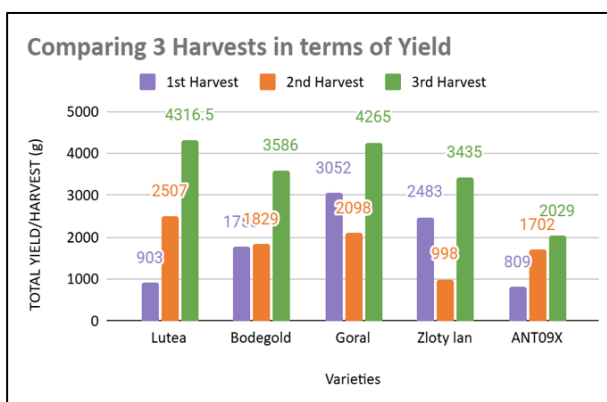


Figure 7. Yield trend over three harvests

2.1.14. Evaluation of Sweet Basil using Different Organic Manure Treatments

Sweet basil (*Ocimum basilicum* L.) is a high-value herb widely recognized for its aromatic, culinary, and therapeutic properties. Rich in essential oils with antibacterial, anti-inflammatory, and antioxidant activities, it has growing demand in the food, pharmaceutical, and processing industries. Despite its popularity, sweet basil has not yet been evaluated and released for cultivation in Bhutan, resulting in continued dependence on imports to meet demand from high-end hotels and other consumers. As a short-duration crop with low input requirements and the potential for multiple harvests, sweet basil offers promising opportunities for local production, value addition, and import substitution. This study aims to assess its performance and suitability under Bhutanese growing conditions.

Materials and methods

The research trial was conducted on-station in NCOA, Yusipang at an altitude of about 2700m above mean sea level. The evaluation of sweet basil using different organic manures was conducted using Randomized Complete Block Design (RCBD) with five manure treatments which includes T1-Control; T2-.FYM; T3-Chicken manure; T4-Vermicompost; T5-Greenure and four replications.

Results and Discussion

The research was conducted to assess the yield content of sweet basil when different organic manures were applied at the same rate. The results showed that the average yield per plant was 662.78 g with maximum yield of 1471g and minimum of 102 g per plant. The overall production yield from about 80 m² land was 131.154 kg. In comparison to the yield in India, which is 20-35 MT per hectare, the estimated yield per hectare is less which is about 16.4 MT. The fresh biomass yield over four harvests shows that sweet basil yielded the maximum during the third harvest with 42.3 kg and the least during the 1st harvest with 27.9 kg.

The mean yield per plant ranged from 609.6 g in Treatment 1(Control) to 760.45 g in Treatment 4 (Vermicompost). Treatment 4 recorded the highest average yield followed by T3, T5, T2 and T1.

Therefore, this suggests that Treatment 4 -Vermicompost was the most effective in enhancing plant productivity. Similarly, the mean plot yield was the highest in Treatment 4 (3.43 kg) and least was observed in Treatment 2 (2.99 kg). Despite the observed variation, treatment 4 consistently produced the highest mean yield indicating its efficacy in the increasing production of sweet basil. Therefore, following deductions can be drawn; though the sweet basil yield was lower than the production yield elsewhere in the world, sweet basil exhibited satisfactory productivity across four harvests. Among organic manure treatments, vermicompost consistently recorded the highest mean yield per plant as well as the highest plot yield.

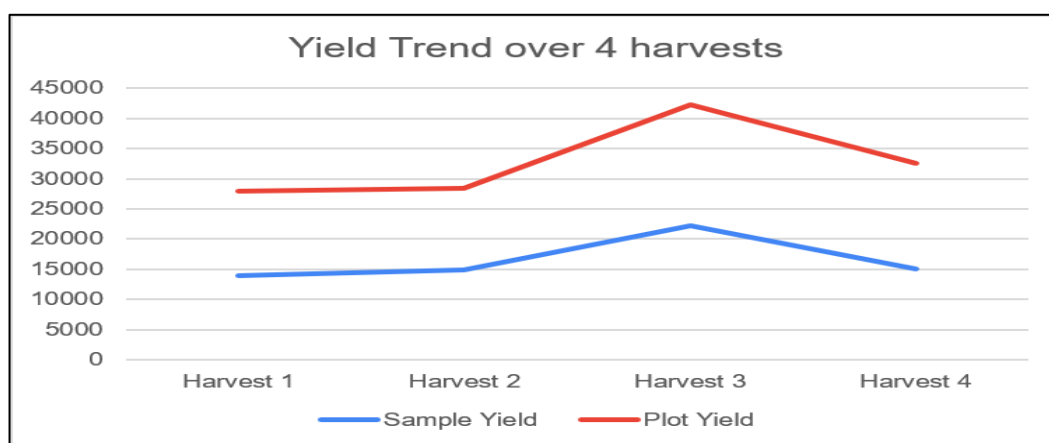


Figure 8. Yield Trend over 4 Harvests in sweet basil

2.1.15. Evaluation of Cape Gooseberry

Cape gooseberry (*Physalis peruviana* L.) is a nutrient-rich fruit crop valued for its high nutritional content and potential for processing into products such as jams and dried fruits. Despite its commercial potential and adaptability, the crop remains underutilized due to limited research and development efforts. Strengthening research, promotion, and farmer outreach can enhance its production, create market opportunities, and provide an additional source of income for farmers.

Materials and methods

The cape gooseberry was cultivated to study its feasibility and performance, evaluating different planting distances. The research was conducted on-station in NCOA, Yusipang. The study design followed was RCBD with three planting distance treatments T1-1m plant-to-plant T2-1.2m plant-to-plant and T3-1.5m plant-to-plant with a row-to-row spacing of 1.5 m and 4 replications. The planting distance was used to evaluate the yield and to find an optimum spacing for most efficient plant population in a given area.

Results and Discussion

The performance of cape gooseberry in Yusipang climatic conditions is promising with an average fruit weight of 10.76 g and overall yield of 111.02 kg from an area of approximately 171.7 m² land. The total yield was recorded highest in T3 with 3442.43 kg of fruit, followed by T2 (3088.6 kg) and lowest in T1 (2947.14 kg). This shows that higher the planting distance, higher the yield is because of lesser competition for nutrition and water among the plants, but it is important to note that higher spacing may not give the higher total yield per unit area. Generally, a single plant has a potential to yield 300 fruits, and carefully tended plants can provide 20 to 33 Mt per hectare. But the cape gooseberries grown in Yusipang recorded an average number of 190 fruits per plant, compared to 300 fruits (Global yield) the average fruit number is short by 37%. The average fruit weight was recorded highest in T2 with 11.03 g and lowest with 10.52 g in T1. The yield of cape goose berry showed a progressive increase from the first harvest and reached its maximum at the 3rd harvest (38.41 kg) and slightly declined at 4th harvest (32.305 kg). This showed a mid-season

peak production pattern where productivity increases after establishment of the crop and declines later due to physiological aging or nutrient depletion.

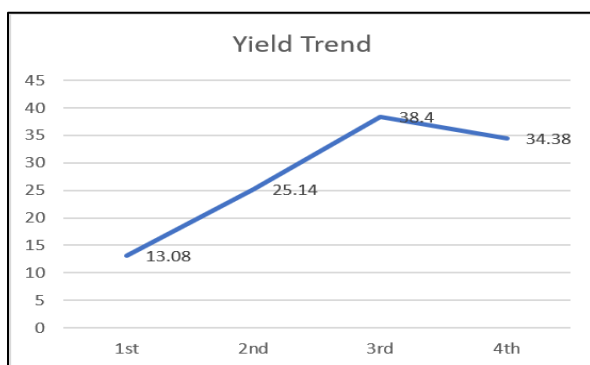


Figure 9. Yield trend over four harvests



Figure 10. Cape gooseberry fruits

2.2 Development Activities under Horticulture Program

2.2.1. Enhancement of germplasm and Production of Temperate Fruit Seedlings

Efforts were made to source and introduce new genetic resources to enhance the existing germplasm collection. Two cultivated grape varieties, ‘Perlette’ and ‘Stuben’, were obtained from the Bajo Research and Development Centre, while three wild kiwi accessions were collected from Yusipang (Thimphu), Ketokha (Chhukha), and Namling (Mongar). In addition, two varieties of grape i.e., Seto Giants and Fujiminori, five varieties of blueberry i.e., Duke, EarliBlue, Bluecrop, Chandler, Northland and two varieties of apple i.e., Benito and Umajiro were introduced from Japan through the support of iNTECROP to further strengthen the genetic diversity of the germplasm collection and support future evaluation and breeding activities. These are currently maintained and further multiplication and evaluation will be conducted.

During the reporting year, efforts were made to produce 1,000 temperate fruit seedlings as part of orchard development programs aimed at strengthening fruit-based agriculture through the supply of quality planting materials. The activity involved a systematic nursery process, including scion wood collection from healthy and high-performing mother plants during the dormant season, preparation of rootstocks through both seed (local and wild) and vegetative propagation methods, and grafting using standard techniques to ensure proper cambial alignment and high success rates.

Following grafting, intensive nursery management practices were implemented, including regular irrigation, shade regulation, weed control, pest and disease management, and scheduled fertilizer application. These practices supported successful graft union formation, healthy vegetative growth, and strong root development. Overall, a substantial number of healthy and true-to-type seedlings were successfully produced, meeting the objective of generating quality planting materials for field establishment programs.

2.2.2. SHEP In-Field Training under the JICA- iTEC Crop Project

As part of the Integrated Temperate Fruit Crops Promotion Project (iTEC Crop)-JICA, the fruits unit under NCOA, Yusipang conducted a series of SHEP (Smallholder Horticulture Empowerment and Promotion) In-Field Trainings in early January 2026 across nine gewogs in Haa, Paro, and Thimphu Dzongkhags. The training programme, implemented following the Technical Training of Trainers (ToT) held in December 2025, reached nearly 200 farmers and focused on translating technical knowledge into practical skills through field-based learning in farmers' orchards.

The training adopted a participatory and hands-on approach to strengthen farmers' capacity in key orchard management practices essential for improving fruit productivity and quality. Major topics covered included appropriate pruning intensity, grafting techniques and rejuvenation of old apple trees, young tree management, orchard layout and planting methods, basin preparation, and basic pest and disease management. Practical demonstrations were also provided on pruning, training, and trellis management techniques for kiwi, peach, and plum orchards.

A key focus of the intervention was the optimization of pruning intensity to achieve a balance between vegetative growth and fruit production. Field observations indicated that excessive pruning practices commonly adopted by farmers had resulted in vigorous vegetative growth at the expense of fruiting, thereby affecting orchard productivity. Through guided practical sessions, farmers were trained on proper branch selection, canopy management, and pruning techniques to enhance future yields and fruit quality.

The training further identified gaps in farmers' knowledge regarding plant protection practices. Inadequate understanding of pesticide application schedules and techniques had led to the omission of critical sprays and increased incidence of early-season pest outbreaks in some orchards. Accordingly, the programme emphasized the importance of timely technical interventions and proper crop protection measures to ensure effective pest management and stable production. Overall, the SHEP In-Field Training significantly enhanced farmers' practical skills and confidence in orchard management.



Figure 11. Participants during practical session of SHEP Training of Trainers (ToT) and on farm demonstrations

2.2.3. Rehabilitation of Million Fruit Tree Plantations in Chhukha and Paro Dzongkhag

The activity aimed to rehabilitate existing fruit tree plantations established under the Million Fruit Tree Program (MFTP) and to strengthen farmers' knowledge and skills in orchard management practices to improve productivity and fruit quality.

Practical orchard rehabilitation activities were conducted in farmers' fields with active participation from the beneficiaries. Demonstrations on pruning were carried out to remove dead, diseased, and overcrowded branches and to improve sunlight penetration, air circulation, and the development of productive shoots. Farmers were also trained on proper training techniques to establish a desirable tree framework, which is essential for maintaining an efficient canopy structure, improving fruit quality, and facilitating orchard operations and harvesting. A total of 2340 trees were pruned benefitting 144 beneficiaries in Chapcha gewog and Naja Gewog of Chhukha and Paro respectively.

In addition, top working was carried out on existing rootstocks where the original scion portions had been damaged or had failed. Improved cultivars were grafted onto the healthy rootstocks to restore the productivity of the trees without the need for replanting. This practice offers an efficient and cost-effective means of converting unproductive plants into high-yielding and superior varieties while reducing the time required for orchard establishment.

The field assessment revealed that many orchards established under the Million Fruit Tree Program had received little or no follow-up management after planting. As a result, trees had developed dense and overcrowded canopies, adversely affecting tree health, fruit quality, and productivity. In several cases, farmers lacked knowledge of grafted plant management and had inadvertently maintained only the rootstocks after the graft unions were damaged.

Farmers actively participated in the demonstrations and expressed strong interest in adopting the recommended practices. The rehabilitation activities are expected to improve tree vigor, restore productivity, and enhance fruit quality in the coming years. It is recommended that similar rehabilitation programs be extended to other Million Fruit Tree plantations and that regular follow-up visits, training, and technical guidance be provided to strengthen farmers' capacity.



Figure 12. Training of a three-year-old MFTP supplied apple seedling (Left), Grafting of Scion on Apple Rootstock (Right)

2.2.4. Citrus Canopy Management Training

In order to enhance citrus productivity and promote sustainable orchard management practices, a series of Citrus Canopy Management Training programs were conducted in Phuentsholing and Lokchina Gewogs of Chhukha Dzongkhag and Gakidling Gewog of Haa Dzongkhag with financial support from the World Bank- RNR Job Project under the Citrus Commodity initiative. A total of 122 farmers, 92 males and 30 females, participated in the program, demonstrating strong stakeholder engagement and demand for improved orchard management technologies.

The training adopted a participatory approach with approximately 10% theory and 90% practical demonstrations and hands-on exercises. Technical sessions focused on canopy architecture, pruning techniques, light interception, air circulation, integrated pest and disease management, nutrient management and water management through trenching methods, and the preparation and application of Bordeaux paste for the prevention of fungal and bacterial infections. Participants were also provided with practical exposure on pruning operations, Bordeaux paste preparation, top-working techniques, and orchard nutrient management practices.

The intervention addressed one of the key constraints affecting citrus productivity in Bhutan, namely the prevalence of traditional orchard management practices. Improved canopy management is expected to enhance light penetration, air circulation, spray efficiency, and overall tree vigor, thereby contributing to better fruit quality, higher yields, reduced pest and disease incidence, and improved resource-use efficiency.

The training strengthened farmers' technical knowledge and practical skills, thereby promoting the adoption of improved orchard rehabilitation and management practices. In the long term, the intervention is expected to contribute to increased orchard productivity, enhanced fruit quality, reduced production losses, and improved profitability and livelihoods of citrus-growing communities. The program further strengthened the extension support mechanism for sustainable citrus development in western Bhutan and demonstrated the effectiveness of targeted capacity-building interventions in addressing production constraints within the citrus sector.



Figure 13. Participants with pruning materials (left), Explaining to farmers on importance of maintaining right number of branches in citrus (Right)

2.2.5. Community Citrus Fruit Fly Management Training and Awareness

During this financial year of 2025-2026, a series of community-based Citrus Fruit Fly Management Training and awareness campaigns were conducted in Baeyul Kuenza and Meritsemo under Bongo Gewog, Chhukha Dzongkhag, and in Ngatsena-Putsena and Dorithasa villages under Gakidling Gewog, Haa Dzongkhag. Around 158 farmers have participated in this activity. The activities were implemented with financial support from the World Bank-funded RNR-JOB Project (Citrus Commodity) in close collaboration with the Agriculture Sector of Chhukha and Haa Dzongkhags. The intervention was designed to address one of the most critical production constraints affecting Bhutan's citrus industry, namely the Chinese Citrus Fruit Fly (*Bactrocera minax*), which is responsible for severe fruit damage and substantial yield losses in major citrus-growing areas. The programme focused on enhancing farmers' knowledge and technical skills on the biology, life cycle, economic significance, and integrated management of the pest. Particular emphasis was placed on the importance of synchronized and community-wide implementation of management measures to effectively suppress fruit fly populations. Farmers were trained on key components of integrated pest management, including orchard sanitation through regular collection and deep burial of infested fruits, winter soil cultivation to expose overwintering pupae, preparation and application of protein bait sprays, and timely chemical control measures based on the pest's life cycle. In addition, awareness was created on the safe and judicious use of pesticides, emphasizing adherence to recommended dosages, use of appropriate personal protective equipment (PPE), and environmentally responsible handling and disposal practices to minimize risks to human health and the environment.



Figure 14. Presentation on Citrus Fruit Fly Management (left), locally made bait trap explained (right)

The participatory nature of the programme facilitated active engagement and experience sharing among farmers, thereby fostering collective action and strengthening community ownership of pest management interventions. Overall, the intervention significantly strengthened farmers' capacity for sustainable citrus production and promoted area-wide pest management approaches. The adoption of these practices is expected to contribute to reduced fruit fly incidence, lower production losses, improved fruit quality, enhanced orchard productivity, and increased income opportunities for citrus-growing households, thereby supporting the long-term sustainability and competitiveness of Bhutan's citrus sector.

2.2.6. Development of a Field Gene-bank on Native Horticultural Crops

The Field Gene-bank on Native Horticultural Crops was established with support from the Bhutan Trust Fund for Environmental Conservation (BT FEC). The initiative aims to conserve Bhutan's rich diversity of indigenous and locally adapted horticultural genetic resources. It addressed emerging threats to native germplasm, including land-use change, climate. The project focused on the establishment of an ex-situ Field Gene-bank for the collection, conservation, characterization, and sustainable utilization of diverse horticultural genetic resources from different agro-ecological zones of the country.

Extensive germplasm collection was conducted across Dagana, Thimphu, Chhukha, Paro, and Mongar districts. Priority was given to valuable wild and local fruit species such as wild walnut, wild kiwi, crab apple, wild cherry, local peach, plum, pear, apricot, and weeping peach. Propagation activities were initiated in March 2026 using collected scion materials and cuttings, and an approximate graft success rate of 95% was achieved. All propagated plants were maintained under nursery conditions for proper monitoring, care, and hardening prior to field establishment.

Significant progress was made in the development of the Field Gene-bank site, including land preparation, pit digging, pit filling, and plantation establishment. In addition, irrigation infrastructure development was initiated through the construction of a water reservoir, with plans for the installation of a drip irrigation system to enhance water-use efficiency and plant survival. Overall, NCOA successfully accomplished key milestones in germplasm collection, propagation, field establishment, and infrastructure development, thereby laying a strong foundation for the long-term conservation and sustainable use of Bhutan's native horticultural genetic resources.

2.2.7. Floriculture enhancement

A cherry garden covering an area of 0.050 acre was established on-station as part of floricultural activities to enhance the aesthetic value of the centre and promote on-farm biodiversity. The plantation was developed following proper land preparation and orchard establishment practices to ensure healthy growth and long-term sustainability. Beyond its visual appeal, especially during the flowering season, the garden is expected to create a pleasant environment for researchers, farmers, trainees, students, and visitors. In addition, the cherry blossoms will provide nectar and pollen resources for bees, butterflies, and other pollinators, thereby enhancing pollinator activity and supporting improved pollination and productivity of nearby temperate fruit and vegetable crops. The increased presence of flowering plants is also expected to contribute to a more balanced ecosystem by supporting beneficial insects, birds, and other fauna, which is an important component of sustainable and organic farming systems.

In addition to on-station establishment, the Centre also supported beautification efforts in Haa and Chhukha Dzongkhags through the supply of ornamental planting materials, including rose plants and cherry saplings. These plants were provided for landscaping public spaces, contributing to improved scenic beauty and greener surroundings. The initiative also promotes biodiversity conservation beyond the station by providing food sources for pollinators and raising awareness

on the importance of integrating ornamental plants into landscape development. Overall, these combined efforts contribute to environmental stewardship, biodiversity enhancement, and the development of more attractive, resilient, and sustainable ecosystems in both on-station and community landscapes.

2.2.8. Prefabricated greenhouse support to growers

A total of 10 greenhouses sized 20 m x 5 m were supported to the growers and progressive farmers during the period on cost-sharing mechanism to enhance tomato and chilli production capacity.

Table 32. List of growers who received greenhouse support

Sl.No.	Name	Village/ Gewog/Dzongkhag	Quantity in numbers
1	Chencho	Zhungkharna, Shaba, Paro	2
2	Dawala	Nichu, Tshento, Paro	2
3	Dorji	Lingshi, Naja, Paro	1
4	Nima Dema	Wanakha, Naja, Paro	1
5	Chencho Pem	Singo (Bitekha), Naja, Paro	1
6	Bokum	Zhanglaykha, Genekha, Thimphu	2
7	Tibinda Powdel	Lamoizingkha, Lhamoizingkha, Dagana	1
Total			10

2.2.9. Training on nursery and seed production and breeding

The center conducted three days of comprehensive training on Vegetable Production Technology and Participatory Breeding. Funded by the Asian Food & Agriculture Cooperation Initiative (AFACI), 36 participants comprising 20 farmers (16 males, 20 females) and 14 extension staff of 13 Gewogs from the four Dzongkhags and two from the National Seed Centre benefited from the training. Farmers, extension staff and seed producers of the four western Dzongkhags of Thimphu, Paro, Chhukha and Haa actively attended the training from 16th to 18th September 2025.



Figure 15. Participants actively participating in the training

2.2.10. Early tomato production in Bunagu, Chhukha

Tomato is identified as a priority crop under the 13th Five-Year Plan (FYP). Through collaboration between Chhukha Dzongkhag Office and NCOA, Yusipang, 13 farmers/households were supported for early tomato production in 20 greenhouses of Bunagu village, Chapcha gewog, Chhukha Dzongkhag. The tomato growers were provided with technical support as well as seedling support.

Demonstrations on transplanting, crop and pest management were taught to the participants. Tomato seedlings were distributed to the farmers, and proper planting techniques were demonstrated. A spacing of 50 cm between plants and 50 cm between rows was maintained to ensure optimal growth. Additionally, two bundles of mulching plastic were provided for shared use among the beneficiaries. At the time of this report, the plants are at fruit development stage.



Figure 16. Demonstration of tomato bed preparation, mulching, irrigation and planting at Bunagu

2.2.11. Winter vegetable production

The farm is situated at an altitude of 2700 masl where winter vegetable production in greenhouses has become an important agricultural practice. In high-altitude areas, harsh climatic conditions limit open-field cultivation during the winter season. Low temperature, frost, snowfall, and short daylight hours greatly affect the growth and productivity of vegetables in these areas. As a result, farmers often face shortages of fresh vegetables during winter and largely depend on supplies from lower regions or imports from India. In order to address this challenge, the sector utilized seven greenhouses for winter vegetable cultivation after the harvest of tomato and chilli in October 2025. Crops cultivated successfully during the cold season include radish, carrot, cabbage, Chinese cabbage, mustard greens, spinach, pakchoi, and coriander.

Table 33. Quantity of vegetable produced and sold at the sale counter

Crop	Nursery raising	Transplanting time	Harvesting time	Production
Radish	August-September	Direct	November -December	144 kg
Carrot	September-October	Direct	February- April.	55 kg
Cabbage	January	February	April	141 kg
Chinese cabbage	First week of October	Last week of October	December- January	103 kg
Mustard green	October-February	Direct	November-April	122 bundles
Spinach	October-February	Direct	November-April	32 bundles

Pakchoi	October-February	Direct	November-April	266 bundles
Coriander	October-February	Direct	November-April	87 bundles
Spring onion	September	October	December	40 bundles
Lettuce	October-February	Direct	November-April	20 bundles
Coloured cabbage	December	January	March	23 kg



Figure 17. Vegetables growing healthily in greenhouses in peak winter

2.2.12. Seedling and technical support for high altitude medicinal and aromatic plant and culinary herbs

The MAP unit has 80 species of plants including both high altitude medicinal and aromatic plants and culinary herbs. The unit provided technical support and seedlings to high end hotels, students, interested clients and 3 farms (Samtenling Royal farm, Kamichu Royal Orchard and Hongtsho peri urban organic farm) with the different types of culinary herbs and medicinal herbs and technical guidance. The table below shows the types and quantity of herbs supported in the fiscal year 2025-2026.

Table 34. MAPs and culinary herbs supported

Herbs	Potted plant (No.)	Seedling (No.)	Seeds (g)	Cuttings (No.)
Apple mint	2	-	-	-
Arugula rocket	-	-	36	-
Cape gooseberry	7	45	2	-
Celery	-	80	26	-
Celery root	-	10	-	-
Chamomile (Bodegold)	-	-	10	-
Chamomile (Goral)	5	20	-	-
Chives	-	180	10	-
Chocolate mint	3	-	-	-
Fennel	-	-	35	-
Goji berry	-	-	-	500
Italian giant parsley	-	30	5	-
Lavender	36	-	-	-
Lemon verbena	1	-	-	-
Oregano	37	-	15	-
Parpata	-	30	-	-
Rosemary	28	-	5	-
Sage	24	-	-	-

Sichuan pepper	5	-	250	-
Sweet basil	1	100	25	-
Thyme	31	-	-	-
Triple curled parsley	-	80	36	-
Yusi dill	-	-	25	-
Grand Total	180	575	480	500



Figure 18. Input support to Folk Heritage

2.2.13. Germplasm Maintenance of Medicinal Herbs and Culinary Herbs

The MAP unit has maintained a germplasm block for both the culinary and MAPs herbs which contains around 30 different of culinary herbs and 54 species of MAPs. Annual maintenance is important to ensure germplasm is preserved for educational and research uses.

Table 34. Some of the herbs multiplied this year

Sl. No.	Herb	No. of herbs multiplied
1	Rosemary	120
2	Lavender	120
3	Sage	120
4	Thyme	100
5	Pepper mint	100
6	Tiyangku	120
7	Ruta	100
8	Manu	100
Total		880



Figure 19. Propagating common herbs

The mother block serves as a display block for students of College of Natural Resources, farmer groups and other visitors. Maintenance of greenhouses, core area and shade house where MAPs and herbs are kept are also carried out.

Wasabi

The third lot of wasabis was harvested on 7th November, 2025 as per the advice of wasabi counterparts which was planted in September, 2023. There were 381 plants making up to 7610 grams. The average weight of the rhizome was 19.9g. The size of the rhizome was very small because the plantlets were planted so closely without maintaining the standard planting space. The new lot of wasabi was planted on 2nd March, 2026.



Figure 20. Wasabi trial harvest and data collection

3. NATIONAL POTATO PROGRAM

3.1. Research Activities under National Potato Program

3.1.1. Strengthening Potato Seed Systems through Quality Seed Multiplication

As part of a seed replacement initiative, the National Potato Program acquired in-vitro plantlets of four released potato varieties; Desiree, Khangma Kewa Kaap, Yusi-Maap, and Yusi Maap 2 along with 12 new clones from the International Potato Centre (CIP) in Lima in March 2024. These disease-free, genetically pure materials are expected to reduce disease pressure, enhance crop performance, and increase yields.

Production of disease-free pre-basic seed (G0) for the four released varieties and the 12 new clones was carried out at NCOA, Yusipang. Last year, a total of 2,394 micro-tubers for the released varieties and 4,374 mini-tubers were multiplied at NCOA. In April 2026, both the resulting micro-tubers and mini-tubers of the four released varieties are being multiplied. By 2027, the resulting pre-basic seeds will be planted at the National Seed Center (NSC) and Regional Seed Growers (RSG) fields for basic seed multiplication. Certified seed production is targeted by 2029. In parallel, 12 new clones are undergoing multiplication for evaluation at four sites, with one promising clone anticipated for release. Additionally, Apical Rooted Cutting (ARC) technology has been introduced to accelerate seed multiplication. Collectively, these interventions aim to improve seed quality and sustainably revitalize potato production nationwide. Details on the

number of micro-tubers and mini-tubers produced at the tissue culture laboratory and greenhouses at NCOA are presented in table below.

Table 35. Details of Micro and Mini tuber Production at NCOA

Sl.No.	Variety/Clones	No. of microtuber	No. of mini-tuber
1	Desiree	751	497
2	Yusi maap 2	717	441
3	Yusi maap	479	198
4	Khangma kaap	447	246
5	312887.075	-	406
6	312908.092	-	176
7	312890.040	-	265
8	312914.053	-	176
9	312908.138	-	309
10	312903.013	-	265
11	312914.020	-	420
12	312888.048	-	271
13	312725.047	-	210
14	396026.101	-	135
15	391034.103	-	271
16	312721.245	-	88
Total		2394	4374



Figure 21. Multiplication of mini tubers and true to type of 4 released varieties and rooted apical cutting

3.1.2. Effect of seed tuber size on growth and yield performance of potato varieties under field conditions

In Bhutan, the availability of high-quality seed tubers remains a constraint for farmers, with many relying on farm-saved seeds of variable sizes. The current recommended seed size for potato production by National Potato Program is 35-60 g. However, the choice of potato varieties, each with distinct growth habits and yield potential, adds another layer of complexity to determining optimal seed tuber sizes. Despite the critical role of these factors, limited research has been

conducted to explore their combined effects under Bhutan's agro-climatic conditions. This study aims to evaluate the effects of seed tuber size on the growth and yield performance of Yusi Maap variety. By identifying the optimal seed tuber sizes for different varieties, the findings are expected to provide practical recommendations for farmers and contribute to sustainable potato production in the country. The trial was carried out from March – September, 2025 at NCOA. A RCBD design was employed with 6 treatments [T1 (15-30 g), T2-(31-45 g), T3-(46-60 g), T4-(61-75 g), T5-(76-90 g), T6 – (> 90 g)] with 3 replications.

The treatment-wise analysis of tuber size categories revealed clear variation in tuber distribution across size classes. Treatment T1 (15–30 g) recorded a mean table tuber number of 20.67 with a corresponding table tuber weight of 4.66 kg, indicating moderate production of smaller-sized marketable tubers. T2 (31–45 g) showed a lower mean table tuber weight (2.21 kg) despite a relatively higher seed tuber number (48.67), suggesting a shift towards medium-sized seed-grade production. T3 (46–60 g) was characterized by the highest mean non-commercial tuber weight (1.04 kg), reflecting a greater proportion of oversized or undersized tubers falling outside market standards within this size class.

Table 36. Result from first year trial showing tuber seed size affected by number of tubers and tuber weight

Treatment	Tuber Number			Tuber weight (kg)		
	Table Size	Seed Size	Non-commercial	Table Size	Seed Size	Non-commercial
T1 (15-30 g)	20.67	35.33	18.00	4.66	2.28	0.30
T2-(31-45 g)	12.67	48.67	20.67	2.21	3.01	0.21
T3-(46-60 g)	12.00	29.67	25.00	2.31	1.74	1.04
T4-(61-75 g)	15.33	67.33	22.33	3.38	4.61	0.36
T5-(76-90 g)	12.33	56.67	31.00	2.53	3.09	0.53
T6 –(> 90 g)	10.33	54.00	21.00	2.18	3.26	0.38

Larger tuber size classes demonstrated superior performance in terms of seed and table tuber weight. T4 (61–75 g) recorded the highest mean seed tuber weight (4.61 kg) along with a substantial table tuber yield (3.38 kg), indicating optimal partitioning between seed and marketable tubers. T5 (76–90 g) produced the highest mean non-commercial tuber number (31.00), suggesting an increase in oversized tubers at higher size grades. T6 (>90 g) exhibited a moderate table tuber weight (2.18 kg) but relatively higher seed tuber weight (3.26 kg), indicating that very large tubers favored seed-grade yield over table-grade production. Overall, intermediate to larger size classes (T4–T6) were more productive in terms of total tuber biomass compared to smaller size classes.

The study demonstrated that tuber size classes significantly influenced the distribution of table, seed, and non-commercial tubers. Intermediate to larger size treatments, particularly T4 (61–75 g) and T6 (>90 g), showed superior performance in terms of seed and total tuber weight, while smaller size classes contributed relatively lower marketable yield. Overall, selecting appropriately sized seed tubers in the medium to large range is crucial for optimizing both marketable and seed-grade potato production under the given experimental conditions. The second-year trial has been successfully established in April 2026 and will be harvested by September 2026.

3.1.3. Optimizing Fertilizer Application for tuber quality

Potato (*Solanum tuberosum*) holds significant importance as a primary food and cash crop in Bhutan, cultivated across all districts. Over the past few years, the National Potato Program has released several promising and high-yielding potato varieties. However, an issue arose with the Yusi Maap variety, concerning the occurrence of oversized tubers. While the precise factors contributing to this oversized tuber phenomenon remain unclear, certain studies have suggested the importance of nitrogen (N) in tuber protein synthesis and growth (Westermann, 2005; Kavvadias et al., 2012). Moreover, it has been noted that excessive nitrogen supply during later stages of growth can continue crop growth and potentially lead to an abundance of oversized potatoes.

In Bhutan, Suphala (15:15:15 NPK) stands out as the most commonly used fertilizer for potato cultivation. Despite the widespread use of Suphala fertilizer, limited scientific evidence exists regarding its specific effects on potato tuber size in Bhutanese agricultural conditions. Given this context, understanding the response of potato tuber size to Suphala fertilizer application is essential for optimizing fertilizer management practices and improving potato yield (tuber size) and quality.

A field study was conducted over two consecutive years. In the first year, a three-factorial split-plot design with three replications was used to evaluate the effects of variety, fertilizer rate, and fertilizer application timing on tuber size. The three potato cultivars (Desiree, Yusi Maap, and Yusi Maap 2) were assigned to the main plots. The sub-plot treatments consisted of all factorial combinations of fertilizer rate and application timing, as detailed in Table XXX. Based on the first-year results, which indicated that 'Yusi Maap' as the most responsive variety in terms of tuber size enlargement, a follow-up experiment was conducted in the second year 2024-2025. This experiment used RCBD with four replications specifically to validate the response of fertilizer rate and application timing on the tuber size of Yusi Maap.

The same fertilizer rates and application timings from the first year were maintained. Both trials were planted in mid-March. Data such as yield parameters including marketable tuber, non-marketable tuber and tuber diameter were collected. The geometric mean diameter (Dg) was computed using the cube root of the product of L, W, and T.

$$Dg = (L \times W \times T)^{(1/3)} \text{ or } Dg = (LWT)^{0.333}$$

- **Dg:** Geometric Mean Diameter
- **L:** Maximum Length (longest dimension)
- **W:** Maximum Width (dimension perpendicular to length)
- **T:** Maximum Thickness (dimension perpendicular to both length and width)

Treatment effects on tuber yield and yield components were not significant for any parameter ($p > 0.01$). Marketable tuber yield averaged 27.0 Mt/ha (range: 23.3–29.4 Mt/ha), while non-marketable yield averaged 4.0 Mt/ha (range: 3.3–4.5 Mt/ha). Marketable tuber number averaged 63 per plot (range: 58–65), and non-commercial tuber number averaged 40 per plot (range: 36–45). Overall, the observed numerical differences among treatments were not statistically meaningful, suggesting negligible treatment effects under the tested conditions.

Table 37. Details of yield parameter for Yusi Maap variety under different fertilizer regime

Treatment	Marketable tuber yield Mt/ha	Non marketable tuber yield Mt/ha	Marketable tuber No.	NC tuber No.
248_0	27.0	3.3	61	39
124_124	26.0	4.5	58	41
267_0	27.7	3.7	63	37
133_133	29.2	4.5	64	36
200_0	29.4	3.6	65	41
0_0	23.3	4.5	65	45
Sig (p value)	ns	ns	ns	ns

All evaluated treatments produced seed tubers well within the acceptable 28–55 mm commercial grade, with mean diameters ranging from 49.1 mm (0_0) to 54.1 mm (200_0). Although treatments 200_0 and 267_0 yielded the largest seed tubers, their means approached the upper threshold of the target class, which may not be desirable if strict adherence to the mid-range is preferred. In contrast, treatments 248_0 (51.5 mm) and 124_124 (51.3 mm) produced seed tubers that were statistically comparable to the largest-yielding treatments (200_0 and 267_0), while remaining closer to the mid-point of the recommended tuber size for seed potato (28–55 mm). These treatments offer a balanced compromise achieving competitive seed tuber size without risk of exceeding the upper grade limit. Treatment 133_133 (49.9 mm) and the control (0_0, 49.1 mm) produced the smallest seed tubers, though still within the acceptable range. Overall, 248_0 and 124_124 are recommended for optimal seed tuber production when the goal is to consistently hit the 28–55 mm class without approaching oversized grades.

Table 38. Detail diameter of Yusi Maap variety under different fertilizer regime

Treatment	Table tuber dia. (mm)	Seed tuber dia. (mm)	NC tuber dia. (mm)	Average tuber dia. (mm)
248_0	70.5	51.5 ^{ab}	38.1	53.4 ^a
124_124	74.8	51.3 ^{ab}	37.6	54.6 ^a
267_0	70.6	53.7 ^a	37.3	53.9 ^a
133_133	68.6	49.9 ^b	37.2	51.9 ^{ab}
200_0	70.3	54.1 ^a	40.2	54.9 ^a
0_0	63.4	49.1 ^b	35.6	49.4 ^b
Sig (p value)	ns	***	ns	***



Figure 22. Measuring length, width and height of potato tuber (left) and Fertilizer trial in the field (right)

3.1.4. Conduct Field Assessment on Potato Wart in Bhutan to Study the Feasibility of Exporting Seed Potatoes

Potatoes are a vital crop in Bhutan, with 22% of farming households (over 33,000) depending on them for their livelihoods, mainly through exports to India. Potato industry offers numerous opportunities for revenue generation, with seed potatoes being a major area of interest. Currently, Bhutan exports its potatoes to India as table potatoes, which Indian growers use as seed potatoes. The wart disease issue in 1977 to early 1980s has posed a significant threat to Bhutan's seed potato market. However, after more than three decades and with the introduction of new varieties, wart disease appears to have diminished and has not been reported recently. To confirm the current status of potato wart and strengthen the seed potato market, the National Potato Program under the National Centre for Organic Agriculture, in collaboration with the National Plant Protection Centre, carried out an assessment in the country. The study started in May 2025. For this activity, a sum of Nu. 2.550 million has been approved under RNR-JoB project.

The assessment covered nine major potato-growing dzongkhags and 21 gewogs, engaging 438 farmers across their fields. The preliminary survey phase comprising household interviews, visual field examinations, tuber inspection and soil sampling has been completed through this project. Subsequently, five plant protection officials—three from the NCOA and two from the National Plant Protection Centre—received training on soil-based potato wart analysis in West Bengal from April 19 to May 2, 2026. To facilitate the confirmation of wart pathogen presence in soil, laboratory equipment and reagents totaling Nu. 0.889 million were procured. The analysis scheduled to commence in July 2026, with Nu. 0.600 million allocated as a carry-over fund for the next fiscal year to cover report publication and other related follow-up activities. The result from this assessment will be instrumental in reinforcing the confidence of both domestic and international stakeholders in Bhutan's seed potatoes. By verifying the elimination or absence of wart disease, Bhutan can re-establish itself as a dependable and high-quality source of seed potatoes, potentially opening up new markets and enhancing revenue sources.



Figure 23. Tuber inspection in the store and field

3.1.5. In-country training of researchers and extensions on advanced potato production technologies

While potato cultivation represents a vital component of rural livelihoods and household income in Bhutan, average yields remain substantially below their genetic potential. This productivity gap can be attributed to several interrelated factors, including suboptimal crop management practices in seed production, the widespread use of low-quality seed potatoes, and the progressive accumulation of seed-borne pathogens over successive generations. Given that the utilization of quality seed can contribute to 20-30 percent of total production, targeted training interventions in quality seed production are essential for addressing this fundamental constraint. Extension agents and researchers are the main bridge connecting new technologies to farming communities, yet they often lack practical, in-depth expertise in advanced seed physiology, seed multiplication methods, and integrated pest and disease management tailored to seed crops.

Moreover, given the limited technical specialists in seed potato production within the country, a training on advance potato production was carried out with technical assistance from the International Potato Center (CIP). The four days training was organized by National Potato Program under National Centre for Organic Agriculture and funded by RNR-JOBS Project (World Bank). The training aimed at providing extension agents and researchers with the advanced technical knowledge and hands-on skills necessary to advance the national potato industry.

Moving beyond basic production, the curriculum also looked into the principles of quality seed production, emphasizing its critical role in overcoming challenges like seed degeneration and low yields. Participants were made aware of the entire seed system; from the biology of the seed tuber and multiplication schemes to integrated crop management, disease control and post-harvest handling. Further the training also aims to build a cohort of master trainers who can effectively disseminate best practices, strengthen the linkage between formal seed producers and farming communities, and ultimately enhance the productivity, sustainability, and profitability of potato farming across all major growing regions of Bhutan.



Figure 24. Practical session in the field during the training

A total of 45 participants including extension agents of major potato growing sites across the country, officials from the regional centers of National seed Centre, researchers from ARDC, plant

quarantine officials from three districts and researchers from NCOA attended the training. The four-day potato training in Bumthang covered essential topics across the entire seed potato value chain, from agro-ecological requirements and seed system structures to tuber physiology, seed degeneration caused by viruses like PVY and PLRV, and the importance of certification with systematic rouging. A practical field session at Thangbi village allowed participants to diagnose germination issues, viral infections, and late blight firsthand, while reinforcing storage practices, dormancy management, and hilling techniques. The training also introduced rapid multiplication using rooted apical cuttings and post-harvest storage strategies to minimize losses. Interactive group discussions facilitated peer learning, clarified field-level challenges, and led to the development of a roadmap for future seed potato production.



Figure 25. Group photo and theory session during the training on advanced potato production

3.1.6. Germplasm Collection and Maintenance of other Root and Tuber Crops

Under this activity, on-station germplasm establishment of the newly released sweet potato variety, Yusi Kewa Ngam, was undertaken at three locations: Royal Farm, Ramthangkha (Paro), Drametse (Mongar), ARDC Wengkhari, and ARDSC Khangma. Released by the National Centre for Organic Agriculture (NCOA), Yusipang, following the 27th Variety Release Committee (VRC) meeting, the variety has been successfully established at ARDC Wengkhari and ARDSC Khangma. The maintained germplasm will function as a valuable genetic resource for conservation, agronomic evaluation, and future dissemination activities in the eastern region.



Figure 26. Slip cuttings of Yusi Kewa Ngam for planting (left) and demonstration of sweet potato plantation using slip cutting

Concurrently, slip cutting and plantation demonstrations were carried out at all sites to enable rapid multiplication and propagate planting material.

3.1.7. Germplasm maintenance of climate resilient, biofortified and nutrient dense potato clones

Germplasm maintenance of 74 biofortified and climate-resilient CIP (International Potato Center) clones were carried out in three different locations of Phobjikha Bumthang and NCOA, Yusipang from 2024. The maintenance was carried out mainly to evaluate the performance of the CIP clones under the different agro-climatic conditions to identify the good-performing varieties that will be suitable for cultivation in the future. However, considering the performance, all the germplasm has been discarded.

Table 39. Details of potato germplasm of biofortified and heat and drought tolerant maintained in NCOA Yusipang, NSC Bumthang and NSC Phobjikha

Sl.No.	Clone No.	Sl.No.	Clone No.	Sl.No.	Clone No.	Sl.No.	Clone No.
1	30957.31	19	309103.85	37	312725.036	56	312782.011
2	301028.56	20	309121.6	38	312725.047	57	312827
3	302476.19	21	312535.062	39	312725.048	58	314079.1
4	302533.3	22	312545.053	40	312725.052	59	389087.2
5	302595.3	23	312609.525	41	312725.055	60	393062.199
6	302935.3	24	312621.097	42	312725.057	61	395436.8
7	303513.57	25	312637.024	43	312725.067	62	397196.3
8	304357.31	26	312637.069	44	312725.128	63	398098.203
9	306135.75	27	312680.01	45	312725.163	64	398098.209
10	306143.65	28	312682.005	46	312725.376	65	398180.289
11	306155.73	29	312682.042	47	312731.004	66	398180.292
12	306412.1	30	312721.029	48	312735.051	67	398190.605
13	308208.219	31	312721.038	49	312735.114	68	398192.213
14	309017.101	32	312721.169	50	312747.056	69	398192.592
15	309041.1	33	312721.241	51	312751.021	70	398208.219
16	309074.129	34	312721.245	52	312751.025	71	399004.19
17	309077.116	35	312721.286	53	312763.44	72	399073.18
18	309087.23	36	312725.001	54	312764.013	73	399078.11
				55	312767.014	74	598192.553

3.1.8. On-station production and maintenance of basic seed potatoes

Basic seed production and maintenance is an important aspect in agricultural research as it ensures the preservation of genetic diversity, ensure seed quality, maintain existing varieties, and contribute to the availability and distribution of improved seeds to the farmers. For that, the basic seed of six released varieties under organic and conventional practice are produced and maintained in the Centre.

Table 40. Details of basic seed production at NCOA

Sl.No.	Practice	Variety	Total quantity (Mt)
1	Conventional	Yusi Maap 2	0.9
		Yusi Maap	0.4
		Desiree	0.2
		Nkk	0.5
		KK.Kaap	0.3
		Khumal Rato	0.4
		Yusi chip-1	0.2
		TOTAL	2.8
2	Organic	Yusimap	0.2
		Yusmap 2	0.1
		Nkk	0.1
		Yusi chip 1	0
		Desiree	0
		Total	0.4
Grand Total			3.2

3.2. Developmental Activities under National Potato Program

3.2.1. Dissemination of Improved Potato Varieties Through Targeted Research Outreach in High-Potential Areas

Outreach programs under the RNR Jobs project were implemented across five districts—Thimphu, Paro, Punakha, Wangdue, and Chhukha covering a total area of 53 acres. The core objective of this initiative is to demonstrate enhanced potato production practices to local growers. This includes training including land preparation, optimal nutrient management, weed control, pest and disease management, and post-harvest techniques. Through these demonstrations, the program aims to enhance potato productivity by equipping farmers with the latest, improved cultivation practices. Besides, specifically, for the nutrient management component, the program carried out demonstration of validated fertilization practices across. A total of 53 metric tons of potato seeds (43 MT of Yusi Maap and 10 MT of Desiree), valued at Nu. 1.34 million (with a project contribution of 90%), were procured from the National Seed Centre (NSC) and distributed to the farmers.

The distribution adhered to the Ministry's Cost Sharing Mechanism (CSM) 2025, which follows a 90:10 ratio. Additionally, fertilizer worth Nu. 0.526 million was procured for the ROP sites, where optimal nutrient management practices along with other agronomic interventions were demonstrated to enhance potato productivity. Furthermore, demonstrations of Yusi Chip and Yusi Maap 2 were conducted at research sites in Paro (Pangbisa) and Mongar (Drametse). Following best practices, the potato cultivation demonstrations was carried out during the planting season at each site. At harvest, yield measurements will be taken. The results from these ROP sites will then be compared with non-ROP sites.

Table 41. Details of Research-Outreach program carried out under RNR-JOBS Project

Sl.No.	Dzongkhag	Gewog	Village	Area (Acres)	Seed qty. (MT)	Variety
1	Thimphu	Chang	Hontsho	7	7	Yusi maap
2	Paro	Tsento	Ramthangka organic	2	2	Yusi maap
3	Punakha	Chubu	Organic village	2	2	Yusi maap
4	Chukha	Chapcha	Gu Gonpa	5	5	Yusi maap
			Shaemagangkha	6	6	Yusi maap
			Tshamdro	3	3	Yusi maap
			Bongo	10	10	Desiree
5	Wangdue	Khotokha	9	9	Yusi maap	
		Saephu	9	9	Yusi maap	
Total				53	53	



Figure 27. Demonstration in the field during planting season (left) and potato plant in the field (right)

3.2.2. Potato seed replacement initiative under RNR-JOB project

Potato (*Solanum tuberosum*) serves as a cornerstone of Bhutan's agricultural economy, supporting the livelihoods of approximately 28,645 rural households as of 2024. Despite its commercial significance, national productivity has stagnated, largely due to the use of inferior seed quality and minimal seed replacement. Currently, the seed replacement rate (SRR) stands at just 4.1%, with an estimated 98% of farmers relying on informal seed systems, such as self-saved seeds or neighbor exchanges (ICIMOD & MoAF, 2018). Given that high-quality seeds can enhance yields by 15–20% and up to 50% with improved management (Singh, 2013; Natrajan et al., 2009) systematic seed replacement is essential to reverse declining productivity. Within this context, the RNR-JoBs project aims to address these gaps through component 1, activity titled support evaluation and promotion of climate resilient varieties of potato to enhance productivity.

Under this activity, a total of Nu. 5.270 million was allocated for procurement and supply of improved or climate resilient varieties of potato to enhance potato production. A total of 199.95 metric tons of Yusi Maap potato seeds were procured from the National Seed Centre and distributed to four gewogs; Khamed, Chhokhor, Drametse, and Kanglung across four dzongkhags. The seeds covered approximately 200 acres and benefited 463 potato farmers. The seeds procured at Nu. 28 per kilogram from the NSC, the seeds were supplied in accordance with the Ministry's cost-sharing mechanism (CSM 2025), which follows an 80:20 ratio. The total project contribution amounted to Nu. 4.48 million. The remaining balance of Nu. 0.79 million was utilized for

monitoring, procurement of vermiculate for multiplication of pre-basic seeds for to expediate seed replacement, crop cuts for yield measurement, and research activities related to seed replacement including studies on seed quality from different sources. Yield measurement is being carried out in some sites such as Drametse and Kanglung and an estimated production of 120 Mt is expected from the four sites.

Table 42. Details of seed replacement carried out

Dzongkhag	Gewog	Qty supplied (MT)	Area covered (acres)	Total household	Male	Female
Gasa	Khamed	11.95	11.95	119	28	91
Bumthang	Chhokhor	60	60	88	7	81
Mongar	Dremetse	60	60	136	44	92
Trashigang	Kanglung	68	68	120	12	108
Total		199.95	199.95	463	91	372

3.2.3. Capacity Development of Informal Seed Potato Growers to Strengthen Seed Replacement

Under the Asian Development Bank's project, Enhancing Food Security through Smallholders' Climate Adaptive Potato Project, a total of three capacity development of informal potato seed growers was carried out in Yangneer gewog under Trashigang and Domkhar Chiwog and Zungye Chiwog under Chummey gewog in Bumthang. A total of 95 farmers including 21 male and 74 female attended the training. The primary objective of the training was to enhance the knowledge and skills of informal potato growers in key technical areas including production management practices, pest and disease management, soil fertility and nutrient management, post-production handling, and the importance of seed quality. A closely related objective was to demonstrate how, even within an informal system, growers can adopt simple yet effective interventions to slow seed degeneration and achieve a higher seed replacement rate over time.



Figure 28. Capacity development of informal potato seed growers in Chumey and Yangneer

The training employed a participatory approach combining lectures, demonstrations, and group discussions to address seed quality and production gaps among informal potato growers in Bhutan. The training covered four technical modules: (i) crop production management, (ii) nutrient management, (iii) pest and disease management and (iv) climate change impacts. The participatory approach, which encouraged farmers to share local challenges and experiences, ensured that technical recommendations were contextualized and actionable.

The event also fostered closer collaboration between the National Potato Program, Dzongkhag Agriculture Sector, and local farming communities, laying a strong foundation for sustained support and knowledge exchange.

3.2.4. Develop and promote model potato production community with improved production technologies

Under RNR-JoBs Project for Potato Value Chain, four model potato villages were initiated, namely Toktogom (Bongo Gewog), Chongaykha and Delling (Phuntsholing Gewog) in Chhukha, and Dramphel (Chhokhor Gewog) in Bumthang. A consultation meeting and training programme on the development of Model Potato Production Communities was successfully conducted in all the four villages. The programme brought together selected farmers, local leaders, and agriculture officials to introduce the project's objectives, implementation strategy, and five-year phased support plan. Farmers were informed that the initiative would provide technical assistance, quality inputs, capacity-building programmes, and continuous follow-up interventions to gradually strengthen their skills and transform the selected villages into sustainable and commercially viable potato production communities. The programme included technical sessions on improved potato production and agronomic management practices, covering land preparation, quality seed selection and handling, planting techniques, nutrient management, irrigation, integrated pest and disease management, and proper harvesting and post-harvest handling. Farmers were also introduced to climate-resilient production practices and sustainable soil fertility management. Specialized sessions were conducted for model village farmers interested in transitioning to organic production, covering organic soil nutrient management to enhance soil health and reduce synthetic fertilizer dependence, alongside ecological plant protection methods such as biopesticides, cultural practices, and habitat manipulation to minimize chemical inputs.

In addition, awareness on the principles and requirements of organic certification, including certification procedures, documentation, internal control systems, and the long-term environmental and economic benefits of transitioning to organic potato production was also carried out. Further, a hands-on training on the preparation and field application of organic biofertilizers and biopesticides was also conducted. For Toktogom village under Bongo, 10 Mt, Desiree potato variety was supplied.

Table 43. Seed supplied for model potato production site

Sl.No.	Dzongkhag	Gewog	Village	Area (Acres)	Seed qty. (MT)	Variety
1	Chhukha	Bongo	Toktogom	10	10	Desiree

Table 44. Fertilizer supplied under Model Potato Production Sites

Fertilizer	Qty per bag(kg)	Price/bag (Nu)	No. of Bags	Total amt (Nu. MT)
Suphala	50	3016	8	0.024128
Urea	45	1524	10	0.015240
SSP	50	3335	5	0.016675
Total Amount (Nu. M)				0.056043



Figure 29. Model potato production awareness and training under Bumthang and Chhukha dzongkhags

4. POLICY REGULATION AND COORDINATION PROGRAM

4.1. Development Activities under Policy Regulation and Coordination Program

4.1.1. Organic Registration, Field Inspection, Certification, and Renewal of Organic Farms

The Policy Regulation and Coordination Program (PRCP) is one of the key programs under the National Centre for Organic Agriculture (NCOA). It plays a vital role in regulating and guiding organic production across Bhutan. PRCP works closely with key stakeholders, including Dzongkhag Agriculture Offices, organic farmers' groups, certification bodies, and relevant agencies, to ensure that organic farming practices are implemented in accordance with the Bhutan Organic Standard (BOS).

During the fiscal year 2025–2026, PRCP registered new farms, conducted field inspections, and issued organic certificates to newly registered farmers. In addition, the program renewed certificates for existing individual and group organic farmers in Punakha, Tsirang, Bumthang, Zhemgang, Samdrup Jongkhar, and Chhukha Dzongkhags.

Table 45. Summary of Newly Registered and Certified Households.

Dzongkhag	Registered HH	Registered Area (ac)	Households Certified	Certified area (ac)
Bumthang	1	10	0	0
Tsirang	1	1.37	0	0
Dagana	1	1.24	0	0
Thimphu	29	11.8	1	0.50
Total	32	24.41	1	0.50

Table 46. Status of Renewal of LOAS Certificates

Dzongkhag	HH Renewed	Total Area Renewed and Certified (ac)
Punakha	1	9
Zhemgang	2	12.733
Chhukha	2	148.45
Thimphu	1	0.5
Samdrup Jongkhar	1	10.099
Total	7	180.782

Table 47. Overview of Registered and Certified Organic Aggregators and Processors

Dzongkhag	HH registered	HH Certified	Aggregators	Processors
Samtse	8	8	8	0
Paro	1	1	1	0
Chhukha	6	6	6	0
Thimphu	2	2		2
Total	17	17	15	2

In addition, we registered and issued registration certificates to organic aggregators and processors based on registration forms received from interested individuals.

4.1.2. eLOAS: Organic Registration, Certification, Renewal and Data Management System

The Policy Regulation and Coordination Program (PRCP) has collaborated closely with GovTech and system developers to design and implement the electronic-Local Organic Assurance System (eLOAS). This system development is in continuation to the Business Requirement Document (BRD) developed in the previous fiscal year i.e., FY 2024-2025.

This digital platform is engineered to streamline online registration, certification, and renewal processes, while also providing a marketplace for organic producers and enterprises to connect. Scheduled for deployment at the commencement of the upcoming fiscal year, eLOAS will enable organic farmers to secure certification digitally, thereby eliminating administrative burdens and the need for redundant document submissions.

4.1.3. Initiate Accreditation of Bhutan Organic Guarantee Systems

The activity to initiate accreditation of the Bhutan Organic Guarantee System (BOGS) to international standards was implemented under FY 2025-2026 by the National Centre for Organic Agriculture (NCOA) and the Department of Agriculture, with technical assistance from Earth Net Foundation, Bangkok.

The objective was to review and strengthen BOGS in line with international organic certification systems (IFOAM, EU, COR, NOP) and develop a roadmap for international accreditation. Stakeholder consultations, farm visits in Tsirang and Thimphu, and market surveillance at Kaja Throm were conducted to assess certification, compliance, traceability, and implementation at all levels.



Figure 30. Stakeholder meeting



Figure 31. Exit meeting

The assignment concluded with an exit meeting and submission of a final situational analysis report, providing key recommendations and a strategic roadmap for strengthening BOGS and advancing Bhutan's organic certification towards international recognition.

4.1.4. Awareness Program and Capacity Building on the Organic Regulation and Certification System in Bhutan

The Bhutan Organic Standard (BOS) version 02: 2022 is a document officially listed under the International Federation of Organic Agriculture Movement (IFOAM) Family of Standards to strengthen the overall organic regulation and certification system in Bhutan. The main objectives of the Bhutan Organic Standard are to ensure a healthy population in a healthy environment in compliance with the four principles of organic agriculture and to provide a basis for the labelling of organic products with a clear landscape for organic production in Bhutan. The organic farmers must undergo training on BOS 02:2022, as it is a prerequisite for organic certification.

4.1.5. Capacity Building of Organic Operators/Farmers on BOS 02:2022 Organic Management and Practices

In FY 2025-2026, the National Centre for Organic Agriculture (NCOA) has conducted capacity-building training for farmers of Jhomolhari Ngomen Tshogpa in Soe Gewog, Go Organic in Chang Gewog, Thimphu Dzongkhag, Rangthaling ginger group under Tsirang Dzongkhag, and farmers of Samar Gewog under Haa Dzongkhag.

A total of 151 organic operators participated in the training; the details are provided in the table below.

Table 48. Organic Operators Trained (FY 2025-2026)

Dzongkhag	Gewog	Village	No. of Participants
Thimphu	Chang	Yusipang & Hongtsho	24
	Soe	Soe	19
Tsirang	Rangthaling	Charingma	24
Haa	Samar	Langpa-Nupgang	10
Dagana	Kana	Pungzhi	40
Zhemgang	Trong	Subrang	18
Chhukha	Bongo	Toktogom	16
Total			151

The NCOA also provided capacity building and organic awareness to the farmers of identified villages for MOV development. Pungzhi farmers in of Kana Gewog in Dagana and farmers of Subrang village of Trong Gewog in Zhemgang Dzongkhags were trained on organic regulation and certification systems, including BOS 02:2022 and farm diary maintenance. The Thakorling village under Rangthaling Gewog in Tsirang, was also identified as the MOV. However, the capacity building on organic regulation and certification was not conducted as these groups were already trained and certified under the LOAS.



Figure 32. Capacity Building of Farmers on BOS, ICS, and Farm diary

The training covered key aspects of Bhutan Organic Standard (BOS 02:2022), Internal Control System (ICS), farm diary maintenance, and the organic certification system. The sessions aimed to enhance farmers' understanding of organic production requirements, record-keeping practices, group certification procedures, and compliance with national organic standards. The training was conducted based on the farmers expressed interest in adopting organic farming practices and obtaining organic certification. Through the programme, participants gained knowledge and practical skills necessary for implementing organic agriculture and maintaining compliance with organic standards, thereby contributing to the promotion of sustainable and environmentally friendly farming practices in the respective gewogs.

4.1.6. Capacity Building on Organic Regulation and Certification

A five-day capacity building on Organic Regulation and Certification, mainly for the private sector and farmers, was held in Tsirang by the National Centre for Organic Agriculture (NCOA) with the funding support from the EU Technical Assistance for Agrifood Systems (EU-TAAS) project implemented by FAO Bhutan.

The overall capacity-building program aimed to strengthen organic agriculture and certification systems in Bhutan. Other specific objectives were to:

- i) Provide a comprehensive understanding of the organic regulation through the Bhutan Organic Guarantee System (BOGS), which includes Bhutan Organic Standards (BOS). Also, provide the information on the Local Organic Assurance System (LOAS) scheme operated by NCOA.
- ii) Educate participants on how to maintain a farm diary and institute an Internal Control System (ICS).
- iii) Understand the Bhutan Food and Drug Authority (BFDA's) third-party organic certification system.
- iv) Spread awareness and build capacity on soil fertility and plant protection technologies under organic management.

This initiative is in line with MoAL's 13th Five-Year Plan, which aims to develop high-value organic exports and transform the agrifood industry. The program addresses recurring problems in the organic industry, including inadequate understanding of certification procedures, disease and

pest problems, a lack of bio-inputs, and limited market options. To improve their knowledge and abilities in organic standards and certification, 50 participants, including farmers, farmer groups, processors, aggregators, and *Sanam Japchorpas*, came together for the training session. Such a gathering is also expected to enhance the linkage between the farmers, aggregators, processors, and others and enhance organic marketing and value-chain.



Figure 33. With the participant (Private enterprises, farmers, and Sonam Japchorpa)

4.1.7. Development of Model Organic Villages in Dzongkhags Near Gelephu Mindfulness City (GMC)

As the apex body for organic agriculture in the country, the National Centre for Organic Agriculture (NCOA) has the mandate to promote and upscale organic farming nationwide. The Model Organic Village (MOV) programme is a special initiative of NCOA aimed at identifying villages with the potential to be registered and certified as organic villages. Through this approach, NCOA seeks to increase awareness of the importance of organic agriculture in an era dominated by conventional farming practices, while also expanding the area under organic farming and creating greater opportunities for organic farmers. Identification of villages as MOVs is expected to enhance sustainable farming practices based on the principles of organic agriculture. It will also provide an opportunity to adopt various organic technologies that improve long-term sustainability and deliver ecological benefits to local communities. Moreover, the establishment of the Gelephu



Figure 34. During the Dzongkhag-Level Stakeholder Consultation Meeting with the DAO's and Organic Focals

Mindfulness City (GMC) as a fully organic city provides a unique opportunity to create synergies between urban development and surrounding rural communities. Therefore, to kick-start the MOV initiative in the prioritized landscapes, the NCOA has initiated the initial discussions with the Dagana, Tsirang, and Zhemgang Dzongkhags in late November 2025. The Dzongkhag-level consultation contributed to understanding the concept of MOV, the finalization of the concept notes, and the recommendation of the potential landscapes by the Dzongkhag Agriculture Officers and Dzongkhag Organic Focal.

After initial Dzongkhag-level consultation, the NCOA moved to the grassroots level, holding village consultations across Dagana, Tsirang, and Zhemgang from January 21–27, 2026. The focus of these meetings was to decide on the development of Model Organic Villages (MOV). Crucially, these decisions were driven by the farmers' own interest and willingness to participate.



Figure 34. Subrang villagers of Zhemgang Dzongkhag during the Village-Level Stakeholder Consultation on MOV Development.



Figure 35. Thakhorling organic group, Tsirang Dzongkhag (left) and Pungzhi chiwog Dagana Dzongkhag (right) during the Village-Level Stakeholder Consultation

The selected villages of Subrang, Thakhorling, and Pungzhi of Zhemgang, Tsirang, and Dagana Dzongkhags, respectively, agreed and expressed interest in converting their village into a model organic village, in the presence of the Dzongkhag Organic Focal (ADAO), Gewog Representatives, Gewog Agriculture EA, Chiwog Tsogpa, and the NCOA.

Upon the farmers' willingness and interest, the NCOA team deliberated on what model organic village should look like, and the planned activities the Centre plans to implement in collaboration with the Dzongkhag, Gewog, and other stakeholders.

With the completion village-level consultation meeting, the NCOA has rolled out a comprehensive support plan as per the concept note developed. The PRCP sector in close collaboration with the Technical Support Service program has completed the initial base-line survey and capacity building of farmers on organic agriculture, certification systems, BOS 02:2022, and farm diary maintenance.

4.2. Research Activities of Policy Regulation and Coordination Program

4.2.1. Nationally Coordinated Trial on Evaluation of Different Organic Substrates for Oyster Mushroom (*Pleurotus spp.*) Production

Background

Oyster mushrooms are saprophytic fungus, which can grow on all types of agricultural waste, forestry residues, grasses and woody materials throughout the year, provided proper shed and climatic conditions. Oyster mushrooms well adapt in dark environment (Kong, 2014) and ligno-cellulosic substrates are good source of growing oyster mushrooms (Sanchez, 2010). *Pleurotus sp.* belonging to family *Pleurotacea* is locally called as 'Naaky Shamung' in western part of Bhutan. Currently, Oyster mushroom is commonly cultivated in our country using paddy straw as substrate. However, it is limited in its scope for expansion since farmers use rice straw as fodder for cattle and are expensive for non-paddy growers (Gyeltshen & Dorji, 2019). Hence, exploring inexpensive alternatives becomes imperative to minimize production cost. Various researchers have experimented with different alternatives substrates for oyster mushroom production (Menon, et al., 2021; Hoa, et al., 2015; Nasiruddin, et al., 2008; Kumari & Achal, 2008) but no study has been conducted using locally available grasses and oak leaves as substrates. Studies have shown that grass substrates are high in cellulose and hemicellulose, they emerge as promising alternatives for mushroom cultivation (Siddhant, et al., 2024). Therefore, study aims to investigate the locally available grass and oak leaves as substrate in Oyster mushroom production besides paddy straw and to find best alternative substrates in order to enhanced Oyster mushroom production in the country.

The study aims to

- Assess the feasibility of using dried grass and oak (*Quercus griffithii*) leaves for Oyster mushroom production
- Determine the growth performance and yield of the researched substrates
- Compare the yield of the organic substrates with paddy straw, most commonly used substrate.

Materials and methods

The experiment was conducted from last week of April till last week of June, 2024 and 2025 in National Center for Organic Agriculture (NCOA), Yusipang in collaboration with National Mushroom Center (NMC), Wangchutaba. The three treatments are as follows (Replicated 15 times).

T1: Dried tall fescue grass

T2: Dried oak (*Quercus griffithii*) leaves

T3: Paddy straw (Control)

The spawn was prepared by NMC. In both years, the same procedures were followed for substrate preparation. The different substrates were chopped into 2–5 cm lengths and filled into net sacks. The filled net sacks were completely immersed in water for 30 minutes, and the excess water was drained overnight. Steam sterilization was carried out in a petroleum drum after ballooning of the plastic sheet covering the mouth of the drum; the substrates were sterilized for 2 hours in 2024, and the duration was increased to 3 hours in 2025. The sterilized substrates were then immediately packed into clean plastic bags and allowed to cool overnight.

Sample size of 2 kg was prepared in clean transparent plastic bag with spawn rate of 60 g/bag (3% on wet weight of substrate) for each substrate in both years. The inoculated bags were labelled as per treatment and date of inoculation. Inoculated bags were transferred to incubation room. Small holes were made after five days of inoculation for air circulation. In 2025, the window glasses were all covered with black plastics to make growing room warmer.

The experiment was laid out in RCBD. Mycelium initiation, days required to complete substrate colonization, days of pin head formation, number of fruits, and yield data were recorded in MS Excel sheet. Yield was measured with digital weighing balance. Recorded data were analyzed by Kruskal-Wallis's test and treatment means were compared through Dunn's post hoc test using JASP software.

Results

The yield and growth parameters such as mycelium run initiation, days to full colonization, and pin head initiation were analyzed. The substrate used in this study showed variation in spawn run, days to colonization, pin head initiation, and mean yield in both years. Moreover, significant difference in both growth parameters yield was observed in two years.

Effect of Substrate on Growth Parameters

The time (days) required for mycelium initiation, colonization, and pinhead initiation differed significantly among substrates and between years. In 2024, mycelium initiation was significantly faster in dry oak leaves (9 days) compared to paddy straw (31 days) and dry grasses (35 days) ($p < .001$). In 2025, initiation time marked to be earlier across substrates ($p < 0.001$), with paddy straw and dry oak leaves requiring 9 days and dry grasses 12 days. Colonization period also varied significantly (2024: $p = 0.004$; 2025: $p < 0.001$). In 2024, paddy straw (37 days) and dry grasses

(39 days) were statistically similar, whereas in 2025 colonization was faster, particularly in dry grasses (11 days) compared to paddy straw (24 days). No colonization and pin head were observed in dry oak leaves in either year, since the substrate was fully affected by green mould bacteria and was discarded after mycelium run. Pinhead initiation did not differ significantly between substrates in 2024 ($p = 0.324$), both paddy straw and dry grasses requiring 7 days; however, significant differences were observed in 2025 ($p < 0.001$), with dry grasses (6 days) forming pinheads earlier than paddy straw (11 days). Overall, the production phases were substantially accelerated in 2025 compared to 2024, which may be associated with the longer steam sterilization period (3 hours) and the warmer incubation and growing room conditions achieved by covering glass windows with black plastic. *Table 49. The effect of different substrate treatments on growth parameters of Oyster mushroom*

Treatment	Time (days)					
	Mycelium initiation		Colonization		Pinhead initiation	
	2024	2025	2024	2025	2024	2025
Paddy straw	31 ^a	9 ^b	37 ^a	24 ^b	7 ^a	11 ^b
Dry grasses	35 ^a	12 ^c	39 ^a	11 ^d	7 ^a	6 ^a
Dry oak leave	9 ^b	9 ^b	-	-	-	-
Mean	25	10	38	17.5	7	8.5
p-Value	<0.001	<0.001	0.004	<0.001	0.324	<0.001

Effect of Substrate on Yield Parameters

The graph indicates that yield consistently declined from Flush 1 to Flush 3 in both 2024 and 2025 regardless of substrate, confirming that the first flush contributed the highest production. Paddy straw generally recorded higher yields than dry grasses across most flushes in both years. In 2024, paddy straw yielded 365.9 g, 200.3 g, and 152 g compared to 253.7 g, 189.4 g, and 122 g from dry grasses across the three flushes.

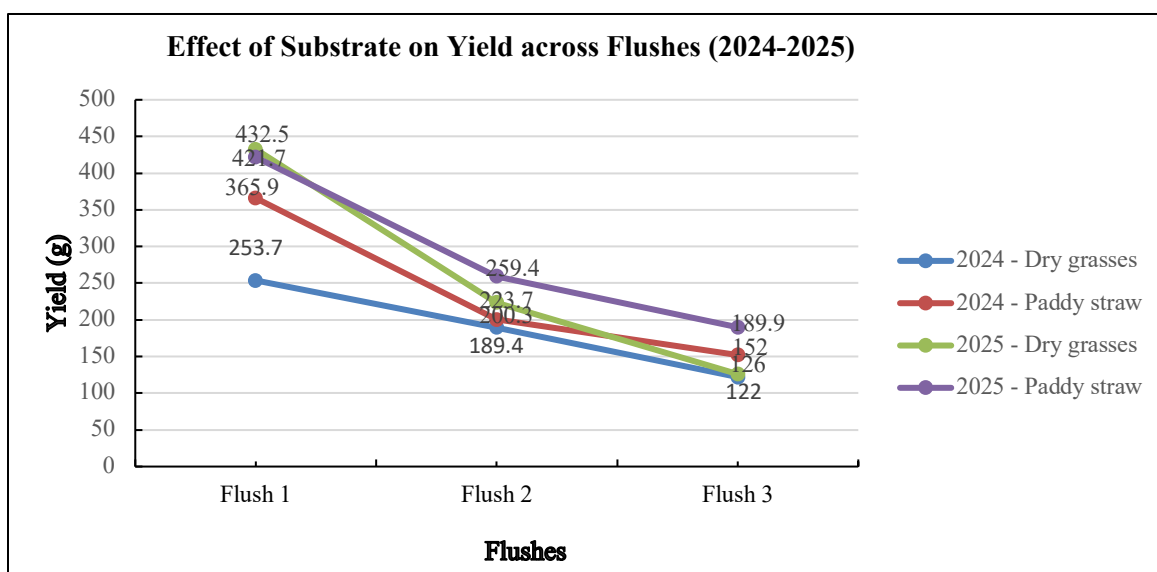


Figure 35. Effect of substrate on yield across years

In 2025, paddy straw produced 421.7 g, 259.4 g, and 189.9 g, while dry grasses yielded 432.5 g, 223.7 g, and 126 g, respectively. Although paddy straw showed slightly higher yields in most cases, the overall observation and trend across flushes in both years indicate that dry grasses performed at par with paddy straw (control treatment), particularly considering the similar declining pattern and comparable yields. This suggests that dry grasses can be used as an alternative substrate for Oyster mushroom cultivation in place of paddy straw.

The figure below depicts the ‘effect of substrate on the number of fruits of Oyster mushroom’ shows a consistent decline from Flush 1 to Flush 3 in both 2024 and 2025, irrespective of the substrate used. In 2024, Paddy straw (control) produced a higher number of fruits in the first flush compared to Dry grasses; however, in the second and third flushes, Dry grasses performed similarly or slightly better than Paddy straw.

In 2025, a similar pattern was observed where Paddy straw recorded higher fruit numbers in the first flush, while Dry grasses showed comparable performance in the subsequent flushes. Overall, the trend across flushes in both years indicates that although the control treatment performed slightly better in the initial flush, Dry grasses-maintained fruit production at levels comparable to Paddy straw. The error bars across treatments within the same flush appear to overlap, suggesting that the differences in fruit number between substrates are not statistically distinct and that variability among replicates is within a similar range. Therefore, based on the overall trend and variability indicated by the error bars, Dry grasses can be considered at par with Paddy straw and may serve as a suitable alternative substrate for Oyster mushroom cultivation.

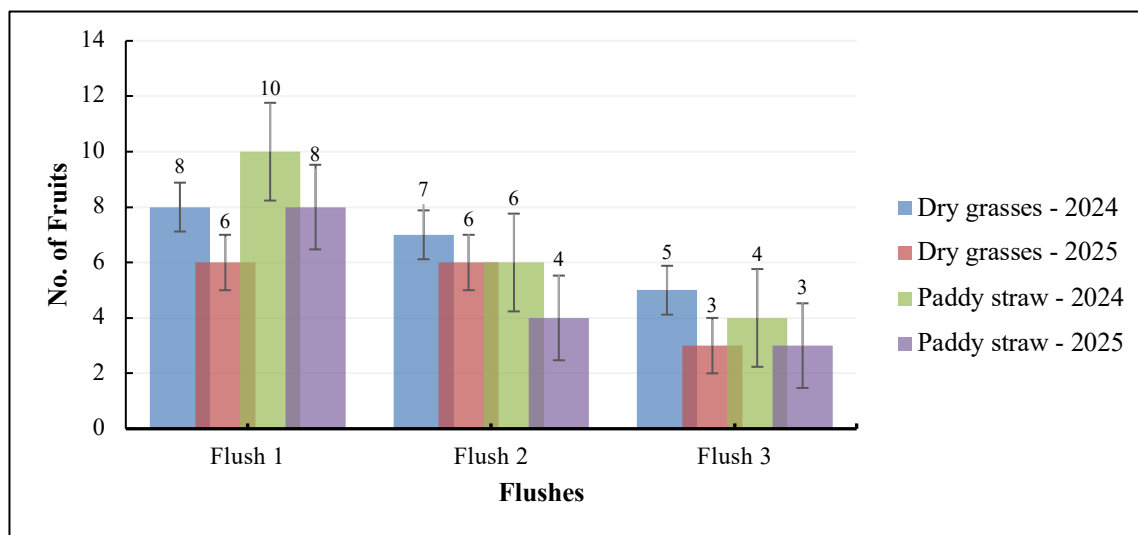


Figure 36. Effect of substrate on no. of fruits

Conclusion

In conclusion, the growth and yield parameters of oyster mushroom were higher in 2025 compared to 2024. This indicates that warmer growing and incubation room conditions are more favorable for the growth and productivity of oyster mushroom. Mycelial initiation was observed to be faster in dry oak leaves (T2); however, the substrate was gradually infected with green mold, rendering

it unsuitable for oyster mushroom cultivation. In contrast, the mean growth parameters, number of fruiting bodies, and yield obtained from dry grasses were comparable to those of paddy straw (control treatment). Therefore, in situations where paddy straw is unavailable, long dry grasses can be considered a suitable alternative substrate for oyster mushroom cultivation.

5. TECHNICAL SUPPORT SERVICE PROGRAM

5.1. Research Activities under Technical Support Service Program

5.1.1. Conduct second year research trial on the efficacy of different bio-pesticides in controlling cutworms in cole crops

Cutworms (*Agrotis* spp.) are among the most significant pests affecting cole crops (*Brassica* spp.) such as cabbage, cauliflower, and broccoli in Bhutan. The larvae of the cutworms are known for their destructive feeding habits, particularly in the seedling and early growth stages of the cole crops, causing significant yield loss. Inorganic pesticides having environmental impact and gradual development of resistance by pests is becoming a concern. Moreover, consumers are getting highly concerned of their health consuming chemically treated vegetables, switching their preference to chemical free vegetables. Environmentalists are encouraging farmers to adopt environmentally sustainable cultivation practices. This has led to increased interest in the use of bio-pesticides, which are generally considered safer and more sustainable alternatives. Bio-pesticides are derived from natural materials such as animals, plants, bacteria, or minerals.

In recent years, several bio-pesticides have shown promise in controlling various agricultural pests, including cutworms. In addition to that, ginger and garlic extract has also shown to be effective in controlling insect pests due to its pungent aroma.



Figure 37. Nursery raising



Figure 38. Trial Layout and Trial Establishment



Therefore, the research is conducted to evaluate the effectiveness of five bio-pesticides (*Beauveria bassiana*, Azadirachtin, *Metarhizium anisopliae*, *Bacillus thuringiensis*, Rangzhing Bupmen) and one local bio-extract (ginger and garlic) in controlling cutworm infestations in cole crops. The study was conducted at the field of NCOA. Golden cross variety was used for the study purpose where the nursery was raised on 14/04/2026. Following the germination, transplantation was done

on 05/05/2026 in the RCBD with 7 treatments having 3 replications each. The total plots are 21 in number with each measuring 2m². The first treatment application was administered on 08/05/2026, and is being systematically administered every week with the data collection on presence of cutworms is ongoing.

5.1.2. Rearing of Beneficial Insects in the Lab (Lady beetle)

In order to reduce reliance on synthetic chemical inputs and strengthen the centre's biological pest management capabilities, an initiative was launched to establish a laboratory rearing protocol for beneficial predatory insects. The primary objective was to build a self-sustaining laboratory colony of lady beetles to evaluate their efficacy as a biological control agent against aphid infestations and other soft-bodied pests within greenhouse environments especially in the winter.

The laboratory set up was configured using cost effective and practical materials, utilizing modified plastic containers equipped with fine mesh lids to ensure ventilation and containment. By April and May 2026, parental stock was field collected to successfully seed the initial breeding colonies.

Currently, in the lab two different species of lady beetle are being reared in separate isolate containers to maintain genetic integrity and track species specific behaviour. The colonies are sustained on a dietary regime consisting of honey, sugar and yeast as supplementary nutrients, alongside live aphids. Simultaneously a parallel rearing system has been established where live aphid populations are actively cultivated on potted broccoli plants. To maintain a healthy environment within the breeding units, biochar is systematically utilized at the base of the containers as a natural substrate to absorb excess moisture and prevent mold outbreaks.



Figure 39. Aphid rearing on broccoli potted plant



Figure 40. Ladybeetle feeding on aphids (left); hatch tray (right)

A key strategic advantage of this innovative setup is its simplicity; by utilizing readily available modified plastic containers, the rearing system is designed to be highly replicable, ensuring that farmers can easily adopt and scale this low-cost biological control technique on their own farms upon the successful completion of ongoing trial. This marks a critical transition toward scalable, farmer-friendly, and organic pest management alternatives

5.1.3. Report on Evaluation of the Impact of Different Organic Nutrients (Liquid Fertilizers) on Growth and Yield of Broccoli

Introduction

Broccoli (*Brassica oleracea* var. *italica*) is a nutrient-rich vegetable valued for its vitamins, minerals, and antioxidants, with global demand increasing due to its health benefits (Octo Frost, 2017). Its growth and yield depend on soil fertility, and rising concerns about pesticide residues have driven interest in organic vegetable production (Warman & Harvard, 1997; Panday et al., 2024). While synthetic fertilizers can degrade soil productivity over time (Dorji et al., 2022), organic liquid fertilizers derived from plant or animal sources provide essential nutrients that support vegetative growth and yield (Jigme et al., 2015; Alkobaisy et al., 2021; Dimovska et al., 2019). Locally prepared biofertilizers, such as Jolmal, have improved soil fertility and vegetable yields in Bhutan and Nepal (Tashi et al., 2022; ICIMOD, 2020). Despite their potential, research on the effects of organic liquid fertilizers on broccoli in Bhutan remains limited, highlighting the need to evaluate their effectiveness in enhancing production.

Materials and methods

The experiment was conducted at the National Centre for Organic Agriculture (NCOA), Yusipang, Bhutan (altitude 2700 m) using a Randomized Complete Block Design (RCBD) with seven treatments: Rangzhin Luechu (Jeevamrut, T1), K-Booster (T2), Jholmol 1 (T3), Jholmol 2 (T4), Vermiwash (T5), a 50:50 mixture of Jholmol 1 and 2 (T6), and an untreated control (T7), each replicated three times (21 plots).

A one-month-old broccoli seedlings (desico variety) were transplanted in double rows at 40 × 50 cm spacing in raised beds of 1 × 2 m (2m²) with 50 cm buffer zones, 10 plants per plot. Treatments T1–T4, and T6 were diluted 1:1 and T5 at 1:5 with water and applied to the base of plants 30 days after transplanting at 15-day intervals for three applications (Wangchuk, Lepcha & Ghimiray, 2022). Seedlings were hardened for one week prior to transplanting, and the field was ploughed and rotavated to fine tilth. Irrigation, weeding, and hoeing were performed as needed, and cutworms (*Agrotis* spp.) were managed with *Azadaractin* when necessary. Composite soil samples were collected at 0–20 cm depth before transplanting and after harvest, sieved (<2 mm), and submitted to NCOA laboratory for analysis of pH, organic matter, nitrogen, phosphorus, potassium, and electrical conductivity (Saquee et al., 2023).

Growth parameters, including plant height, stem diameter, leaf number, canopy size, and leaf area, were recorded from five tagged plants per plot every 15 days. Yield parameters measured at harvest included fresh weights of curd. Curds were harvested manually when firm, before the flower buds

spread, and total yield per plot was computed. Pest and disease incidence was recorded and expressed as percent infection (Baidoo & Adam, 2012). Data were analysed using JASP 0.94.4 (Intel). Treatment effects were tested by one-way ANOVA at 95% confidence, and significant differences between treatments were compared using Games-Howell and Tukey post-hoc test.

Results and discussions

Plant height

The plant height was recorded at 15, 30, 45 and 60 days after transplanting (DAT). The result showed that treatments had no statistically significant effect on plant height at 15, 30, and 60 DAT ($p > 0.05$). However, a significant effect of treatment was observed at 45 DAT ($p = 0.008$). Even though the overall treatment was significant at 45 DAT, Tukey's post hoc test revealed no statistically significant differences between individual treatments ($p > 0.05$). Based on the mean values, the highest plant height was recorded in Jeevamrut (58.69), followed by combined Jholmol treatment (Jholmol 1+ Jholmol 2); (58.51), Vermiwash (55.54), Jholmol 2 (54.62), K-booster (51.70), Jholmol 1 (51.45) and minimum was recorded in control (50.75). Although differences among treatments were not statistically significant according to Tukey's post hoc test, the numerical variation indicates a positive influence of organic nutrient sources on vegetative growth. The observed variation in plant height among treatments may be attributed to differences in nutrient availability and stimulation of soil microbial activity, which influence vegetative growth and plant development. However, the presence of clubroot infection throughout the crop growth period likely affected root function and nutrient uptake, contributing to variability among treatments and limiting the full expression of treatment effects on plant height.

Table 50. Effect of treatments on plant height

Plant height after transplanting (cm)				
Treatments	15 DAT	30 DAT	45 DAT	60 DAT
Jeevamrut	17.19 ^a	35.95 ^a	58.69 ^a	60.64 ^a
K-booster	14.03 ^a	30.59 ^a	51.70 ^a	54.88 ^a
Jholmol 1	16.44 ^a	33.01 ^a	51.45 ^a	57.68 ^a
Jholmol 2	16.03 ^a	32.13 ^a	54.62 ^a	56.11 ^a
Vermiwash	16.37 ^a	34.64 ^a	55.54 ^a	59.81 ^a
Jholmol 1+Jholmol 2	16.87 ^a	36.16 ^a	58.51 ^a	61.12 ^a
Control	17.06 ^a	32.81 ^a	50.75 ^a	55.78 ^a
<i>p-value</i>	Ns	Ns	Ns	Ns
CV (%)	22.71	16.03	13.45	13.04

Plant Canopy

The result revealed a significant difference in plant canopy among treatments at 15 days after transplanting ($p < 0.008$) among treatments, (Table 2). At 15 DAT, the plant canopy was recorded highest in control (18.19), followed by Jeevamrut (17.68), Combined treatment (Jholmol 1 and Jholmol 2); (16.44), Vermiwash (16.22), Jholmol 1 (15.37), Jholmol 2 (14.91), and the smallest was plant canopy was recorded in k-booster (12.29).

However, since fertilizer treatments had not been applied at this stage, the observed differences reflect initial field variability rather than treatment effects. At 30, 45, and 60 days after transplanting, no significant differences were observed among treatments ($p > 0.05$), indicating that the different organic nutrient sources did not significantly influence plant canopy development during the growth period. However, different treatment resulted in different canopy size of the plant at different DAT.

The highest canopy size was recorded in plants treated with Jeevamrut at 60 DAT (66.30), followed closely by Jholmol 2 (64.38) at 45 DAT, Jholmol 1 and 2 combined Treatment (61.82), vermiwash (59.74), K-booster (58.88) at 60 DAT, Jholmol 1 at 45 DAT (58.14) and comparatively, the lowest canopy size was recorded in Control (55.09) at 60 DAT.

Table 51. Effect of treatments on plant canopy

Plant canopy after transplanting (cm)				
Treatments	15 DAT	30 DAT	45 DAT	60 DAT
Jeevamrut	17.68 ^b	40.68 ^a	65.55 ^a	66.30 ^a
K-booster	12.29 ^a	31.50 ^a	55.72 ^a	58.88 ^a
Jholmol 1	15.37 ^{ab}	34.11 ^a	58.14 ^a	56.64 ^a
Jholmol 2	14.91 ^{ab}	33.49 ^a	64.38 ^a	62.73 ^a
Vermiwash	16.22 ^{ab}	37.67 ^a	56.67 ^a	59.74 ^a
Jholmol1+Jholmol 2	16.44 ^{ab}	35.67 ^a	61.56 ^a	61.82 ^a
Control	18.19 ^b	38.29 ^a	53.48 ^a	55.09 ^a
<i>p-value</i>	**	Ns	Ns	Ns
CV (%)	42.13	36.11	27.88	27.85

Stem Girth

The result revealed a significant difference in stem girth among treatments at 15 days after transplanting ($p < 0.046$). At 15 DAT, the stem girth was recorded highest in vermiwash (0.327 cm), followed by Jeevamrut (0.313 cm) and control (0.313 cm), combined treatment Jholmol 1 and Jholmol 2 (0.293 cm), Jholmol 1 (0.280 cm), Jholmol 2 (0.273 cm), and the smallest stem girth was recorded in k-booster (0.233 cm). However, since the liquid organic fertilizer treatments had not been applied at this stage, the observed differences reflect initial field variability rather than treatment effects.

At 30, 45, and 60 days after transplanting, no significant differences were observed among treatments ($p > 0.05$), indicating that the different organic nutrient sources did not significantly influence stem development during the growth period. However, different treatment resulted in different stem diameter of the plant at different DAT.

The highest stem diameter was recorded in plants treated with combined treatment Jholmol 1 and Jholmol 2 (1.993 cm) at 60 DAT followed closely by Jeevamrut (1.987 cm), Vermiwash (1.900 cm), Jholmol 2 (1.833 cm), Jholmol 1 (1.713 cm), K-booster (1.693 cm) and, the lowest stem girth was recorded in Control (1.640 cm) at 60 DAT.

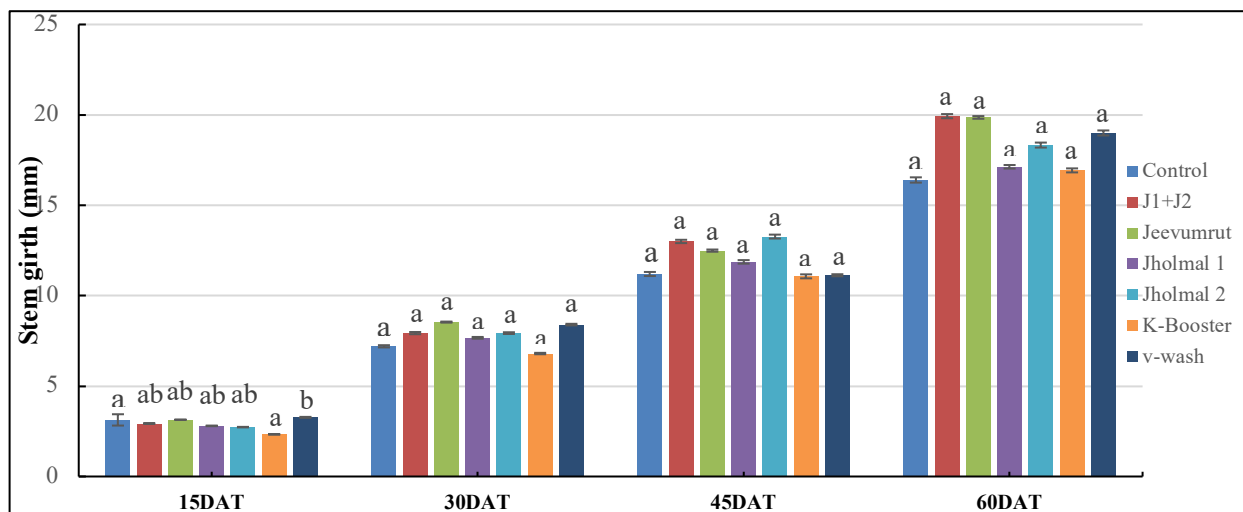


Figure 41. Effect of different treatments on the stem girth.

Number of Leaves

The number of leaves of broccoli did not differ significantly ($p > .05$) among treatments up to 45 DAT. However, slightly significant difference ($p = 0.046$) was observed only at 60 DAT. The plots treated with Jeevamrut had maximum number of leaves (18) per plant followed closely by Vermiwash treated plots (15.40), Combined treatment Jholmol 1 and Jholmol 2 (15.33), Jholmol 2 (14.93), K-booster (13.40), Control (13.27), and the lowest was found in Jholmol 1 (13.20). However, the post hoc test did not show significance difference among the treatments.

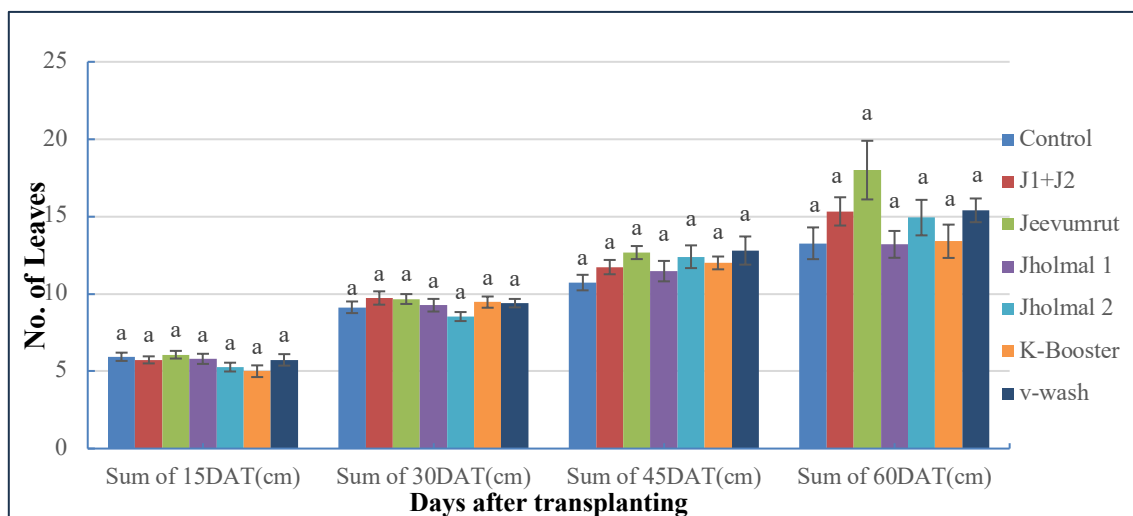


Figure 42. Effect of different treatments on the stem girth.

Effect of treatments on yield parameters Fresh head weight

The treatment effect on broccoli head weight was not statistically significant ($p > .05$) among the treatments. However, the descriptive statistics showed variation in mean head weight across

treatments. The highest mean head weight was recorded in the plots treated with Jeevamrut (66.95g), followed by Jholmol 2 (64.76g), Vermiwash (64.63g), combined treatment of Jholmol 1 and Jholmol 2 (63.66g), Jholmol 1 (56.83g), while the lowest mean was observed in K-booster (36.05g). The control plot recorded a mean head weight of 57.02g. The high variability in head weight could be due to severe incidence of clubroot, which affected a considerable number of plants across treatments. Some plants failed to produce heads and eventually died. The treatment differences were difficult to observe due to variability from clubroot infection.

Table 51. Effect of different treatments on fresh curd weight of broccoli

Treatments	Head weight (g/head)	Coefficient of variation
Jeevamrut	66.95 ^a	0.360
K-booster	36.05 ^a	0.941
Jholmol 1	56.83 ^a	0.796
Jholmol 2	64.76 ^a	0.725
Vermiwash	64.63 ^a	0.628
Jholmol1+Jholmol2	63.66 ^a	0.472
Control	57.02 ^a	0.736
<i>P-value</i>	ns	

Yield at harvest

The analysis of variance showed that the yield of broccoli was not statistically significantly ($p>0.05$) among the treatments. However, by comparing the means, the plants from combined treatment of Jholmol 1 and Jholmol 2 showed the highest yield (675 g/plot), followed by jeevamrut (669 g/plot) and then by Jholmol 2 (668 g/plot), Vermiwash (646 g/plot), Control (570 g/plot), Jholmol 1 (568 g/plot). The lowest yield at harvest was found in the K-booster plots (360 g/plot).

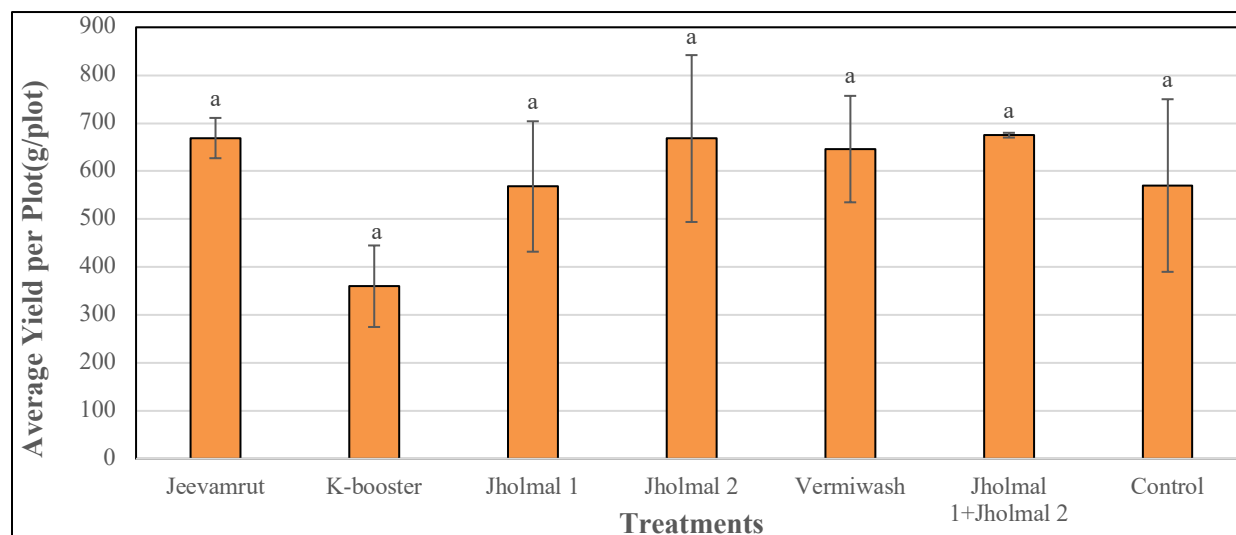


Figure 43. Effect of different treatments on yield

Disease incidence Percentage

Clubroot disease incidence was assessed across all treatments in the organic liquid bio-fertilizer trial. Disease incidence ranged from 53.3% to 93.3% among the treatments. The lowest disease incidence (53.3%) was recorded in the Jholmal 1 treatment, while the highest incidence (93.3%) was observed in the K-Booster treatment.

The control, Jeevamrut, Jholmal 1 + Jholmal 2, and Jholmal 2 treatments each recorded a disease incidence of 80.0%, whereas Vermiwash recorded 73.3% incidence. The high incidence of clubroot disease across treatments may have influenced crop performance and yield, highlighting the need for further investigation into integrated disease management approaches under organic production systems.

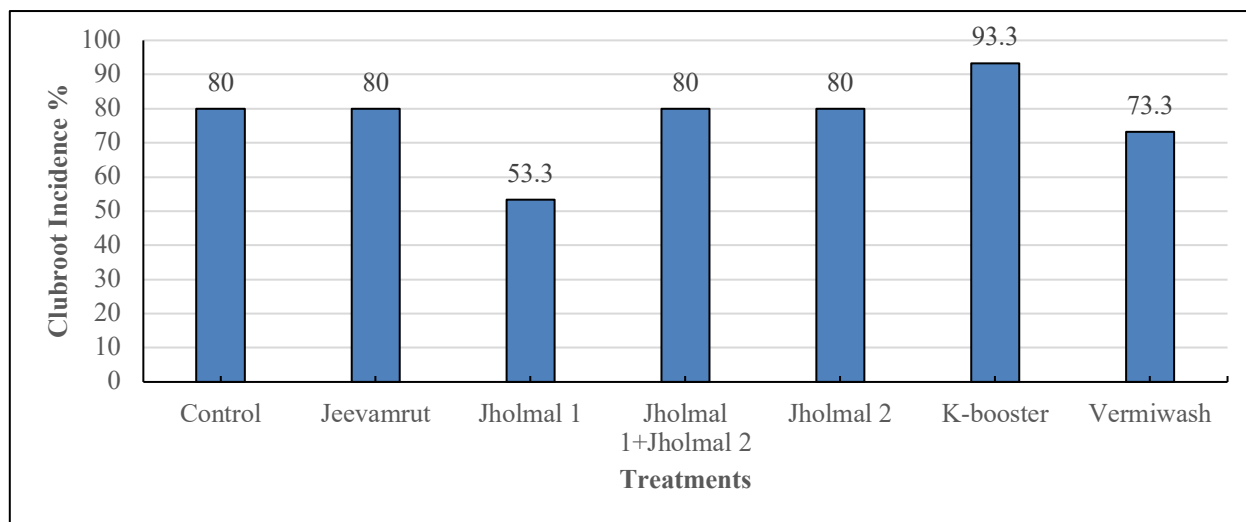


Figure 44. Effect of different treatments on clubroot incidence

Conclusion

The experimental findings showed that the use of the combined treatment of Jholmol 1 and 2 was better for broccoli yield as compared to other organic liquid fertilizers. The highest head weight was recorded under combined treatment of Jholmol 1 and 2 treated plots. The highest plant height, number of leaves, and plant canopy size were recorded under jeevamrut treated plots. The Stem girth was also highest in plots treated with combined treatments jholmol 1 and jholmol 2 followed by jeevamrut.

However, statistical analysis using JASP revealed that the differences among treatments were not statistically significant, indicating that the observed variations cannot be conclusively attributed to the treatments alone. It is also important to note that the experimental results may have been influenced by the incidence of clubroot in the experimental field, which could have affected plant growth and yield performance across the treatments. Therefore, while combined treatment of Jholmol 1 and 2 appears promising, further studies under controlled conditions and with proper disease management are recommended to validate these findings.

5.1.4. Effect of Different Composting Materials on the Decomposition Rate

Background

Compost is the product of the controlled biological decomposition of organic materials. More specifically, compost is the stable, humus-like product resulting from the biological decomposition of organic matter under controlled conditions (Chen et al., 2009).

Increasing concerns over land degradation, excessive use of inorganic fertilizers, environmental pollution, declining soil health, and loss of soil biodiversity have renewed global interest in organic waste recycling, particularly composting. Composting is a biological process that converts organic wastes into stable, value-added soil amendments, improving soil fertility, soil health, agricultural productivity, and environmental quality (Misra et al., 2003). Chemical fertilizers are associated with greenhouse gas emissions, environmental pollution, degradation of soil organisms, and human health risks, prompting a renewed shift toward composting for sustainable waste management and soil fertility restoration (Ayilara et al., 2020).

Objective: To evaluate the thermal performance and decomposition efficiency of cattle manure when supplemented with carbon-rich (Oak leaf) and microbial-rich (Takakura) additives.

Materials and methods

The observation trial was established on August 7, 2025, within the greenhouse facilities of the National Center for Organic Agriculture (NCOA). The experiment utilized a randomized design consisting of four distinct composting treatments formulated from cattle manure, oak leaf litter, and Takakura seed compost.

Experimental Treatments: The composting piles were formulated based on the following specific feedstock ratios and initial bulk densities:

Table 52. Treatments

Treatment ID	Composition	Initial Density
T1 (Control)	100kg Cattle Manure	3.35
T2	100kg Cattle Manure + 13kg Oak Leaf	2.10
T3	100kg Cattle Manure + 26kg Takakura Seed Compost	3.46
T4	100 kg Cattle Manure + 5 kg Oak Leaf + 5 kg Takakura Seed Compost	2.50



Figure 45. Treatments used in the experiment

Monitoring

To ensure standardized conditions across all treatments, the following protocols were strictly implemented:

- Thermal Monitoring: Internal pile temperatures were recorded at 24-hour intervals to track microbial activity and decomposition phases.
- Moisture Management: Compost moisture content was consistently monitored and maintained at optimal levels throughout the composting period.
- Aeration and Turning: To facilitate oxygen exchange and ensure material homogenization, each compost pile was mechanically turned every 14 days.

Results and discussions

Temperature data collected from August to November 2025 were analyzed by comparing compost pile temperatures with ambient greenhouse temperatures. This comparative approach enabled the separation of biologically driven self-heating within the compost piles from external environmental fluctuations. The analysis focused on identifying differences in thermal behavior among treatments.

During the initial phase of composting, particularly on August 13, a sharp decline in ambient greenhouse temperature (down to 13 °C) was observed. However, this decrease did not translate into a corresponding drop in compost pile temperatures. All treatments maintained internal temperatures between 25 °C and 31 °C, indicating strong early-stage microbial activity and effective self-heating.

Among the treatments, Treatment 2 (cattle manure + oak leaf) recorded the highest peak temperature (31 °C). This suggests that the incorporation of oak leaf litter enhanced aeration and supported more active aerobic decomposition compared to the control treatment (Treatment 1: manure only). The presence of leaf material likely created pore spaces within the pile, facilitating oxygen diffusion and stimulating microbial metabolism.

A clear relationship was observed between initial bulk density and thermal behavior. Treatments with lower bulk density (Treatments 2 and 4) exhibited higher initial temperature increases, likely due to improved oxygen availability for aerobic microorganisms. In contrast, treatments with relatively higher density (Treatments 1 and 3) showed greater thermal stability, maintaining more consistent temperatures over time. This suggests that higher density may contribute to better insulation and reduced sensitivity to ambient temperature changes.

Differences among treatments were most pronounced during the first two weeks of composting, after which temperature profiles became similar across all piles. Treatment 2 (manure + oak leaf) consistently showed the highest temperatures, followed by Treatment 3 (manure + Takakura seed compost), Treatment 4 (manure + oak leaf + seed compost), and finally the control (Treatment 1). The relatively small size of the compost piles may have reduced the visibility of treatment differences, particularly during later stages. The strong performance of Treatment 2 indicates that

the simple practice of mixing manure with leaf material (Oak leaf) effectively enhances composting by improving aeration and passive ventilation.

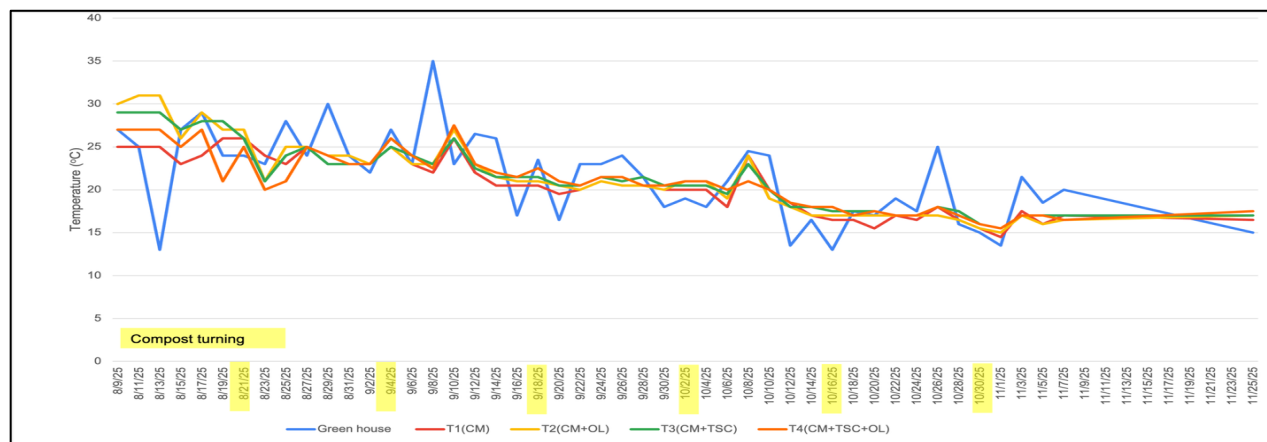


Figure 46. Comparison of Treatments Across Four Groups

Table 53. Comparison of Treatments Across Four Groups

	Temperature			
	T1	T2	T3	T4
Valid	47	47	47	47
Missing	0	0	0	0
Mean	20.57	21.37	21.41	21.06
Std. Deviation	3.367	4.319	3.825	3.389
Minimum	14.50	15.00	15.50	15.50
Maximum	26.00	31.00	29.00	27.50

Conclusion

Overall, the results highlight the positive effect of incorporating leaf material into manure compost. With periodic turning at two-week intervals and appropriate moisture management, compost maturity was achieved within approximately 2.5 months across all treatments. The combination of manure and leaves proved to be a simple and effective approach for promoting composting efficiency.

5.1.5. Evaluation of the Effect of Different Green Manuring Crop Varieties on the Soil

Background

Soil degradation due prolonged fallowing and wind erosion has significantly reduced agricultural productivity under organic production system. The loss of organic matter and nutrients due to wind erosion exacerbates the problem, making soil unsuitable for cultivation. Soil erosion by wind is a

serious problem that threatens ecological security and damages the ecological environment, thereby hindering the sustainable development of agriculture (Wu et al. 2021).

Most soils in tropical region including Ethiopia are highly weathered and infertile due to lower organic matter content and open nutrient cycling systems. The low soil fertility status has been aggravated by improper and inappropriate soil conservation and management practices (Aleminey & Alemayehu, 2020)

Organic farming relies on maintaining and improving soil fertility through natural means. A component of organic farming is green manuring (Singh et al., 2023). Green manure crops offer a sustainable solution to restore soil fertility by incorporating leguminous and non-leguminous crops into the soil before they reach maturity (Panday et al., 2024). “Fertility of a soil is defined by its ability to provide all essential nutrients in adequate quantities and in proper balance for the growth of plant” (Research Institute of Organic Agriculture FiBL, n.d.). Green Manure refers to plant material that is grown as a cover crop, specifically to churn it into the soil and improve its nutritional value or texture (Jeanroy, 2023).

According to Vaghela et al. (2024), the green manures, incorporated into the soil, helps in nitrogen fixation and organic matter enhancement. The organic matter in the soil is recognized as being one of its most valuable constituents for real soil fertility (Meena et al., 2024). By incorporating organic material into the soil, it can help sustain soil fertility, improve water retention capacity, reduce the need for chemical fertilizers, reduce soil erosion and can reduce the impacts of climate change. Green manuring can improve the availability of nutrients in the soil specifically through biological nitrogen fixation, resulting in increased yields and improved crop quality (Patra et al., 2023). Incorporating green manures can improve the soil's physicochemical properties and ensure sustainable crop yields (Hlaing et al., 2024). The study done by Nilza et al. (2015) states that the use of different legume species, as green manure, may affect differently on soil biological and chemical properties.

Depleting soil fertility is a major constraint in organic farming systems, leading to reduced crop productivity. The use of synthetic fertilizers is prohibited in organic farming, making it essential to explore natural soil fertility enhancement techniques. Green manuring is a promising solution, but limited research has been conducted to determine the most effective green manure crops for improving soil nutrient status in Bhutan. Therefore, this research aims to evaluate the impact of various green manure crops on soil nutrient status under organic farming system. The study will evaluate on soil pH, soil nutrient levels (NPK), organic matter content and soil moisture content before and after green manure application.

Research Objectives

- To assess the initial soil status (pH, organic matter, nutrient levels) before applying green manure.
- To evaluate the changes in soil properties after applying different green manure crops.

- To compare the effectiveness of six different green manure crops in improving soil pH, organic matter, nutrient levels.

Materials and methods

Study area: The research was carried out at NCOA, Yusipang which is located at an altitude of 2700 m above sea level. The area for the study was selected based on its suitability for conducting field trial.

Research Design: The experiment was conducted using a RCBD to evaluate and compare the effectiveness of different green manure crops in enhancing soil nutrient status after incorporation into the soil. The experiment was conducted to determine the effectiveness of six green manure crops and a control without green manure crop where the natural weed population was allowed to establish and was incorporated into the soil. To ensure adequate moisture availability for crop growth, the study field was managed under sprinkler irrigation, which was applied as needed based on soil condition, particularly during dry periods. The experiment has seven treatments including control with three replications resulting in total of 21 experimental plots. Each plot size measures 2 m x 4 m (i.e. 8 m²). Treatments were randomly assigned to each plot through line sowing. All the treatments were plough back into the soil during its initial flowering stage (Hlaing et al., 2024).

Experimental Treatments: The study include seven treatments which are **T1:** Rajma beans; **T2:** Peas; **T3:** Soyabean; **T4:** Lupine; **T5:** Adzuki beans; **T6:** Peanut; **T7:** Control

Soil sample collection

The soil samples were collected to determine the nutrient status of the experimental site before sowing green manure crops. A composite soil sample was obtained by thoroughly mixing subsamples collected from each plot at a depth of 0–20 cm using a soil auger. Three soil samples were collected from each plot following a zig-zag pattern (Saquee et al., 2023). There was a total of twenty-one samples for analysis. Similarly, soil samples were collected again using same technique to assess changes in soil nutrient status after 30 days and 90 days from the incorporation. Each soil sample was sieved to (< 2 mm) for analysis (Nilza et al., 2015b). The soil sample were taken to NCOA soil laboratory to analyze soil nutrient status.

Assessment of Nodulation Parameters

In order to evaluate the nitrogen-fixing efficiency of the different green manure crops, root nodulation assessments were conducted before incorporating into the soil. Each treatment plot was divided into equal sections to ensure representative sampling. From each section, plants were randomly selected using zigzag pattern and simple random selection method (selecting at regular intervals), until a total of 20 plants per treatment is obtained. Selected plants were carefully uprooted and washed to observe root nodulation characteristics. Nodules were scored visually using a 0-5 scale adapted from Corbin et al. (1977), considering the number and distribution of nodules in the crown-root zone (approximately 5 cm below the first lateral roots) and elsewhere on the root system.

Nodules were also classified based on color: pink or red nodules were regarded as active (effective) due to the presence of nitrogen-fixing bacteroid tissue, while white or green nodules will be considered inactive. This method allowed both quantitative and qualitative assessment of nodulation across the green manure treatments (Peoples et al., 1989).

Nodule Assessment report for different treatments

Nodulation in leguminous crops is a critical indicator of biological nitrogen fixation potential. This study evaluated the mean nodule score of different crop treatments to estimate their capacity for nitrogen fixation. Nodules were scored based on their color and activity, with red/pink nodules indicating active nitrogen-fixing sites. The mean nodule scores were interpreted using the following scale.

Table 54. Mean nodule score interpretation

Mean nodule score	Interpretation
4 - 5	Represents excellent nodulation; excellent potential for N ₂ fixation.
3 - 4	Represents good nodulation; good potential for N ₂ fixation.
2 - 3	Represents fair nodulation; N ₂ fixation may not be sufficient to supply the N demand of the crop.
0 - 2	Represents poor nodulation, little or no N ₂ fixation

(Peoples et al., 1989).

The plots where rajma beans were grown showed poor nodulation, indicating little or no nitrogen fixation. In contrast, the plots planted with peas exhibited excellent nodulation, suggesting a high potential for N₂ fixation. Similarly, soybean-grown plots showed poor nodulation with minimal nitrogen fixation. Lupin plots demonstrated fair nodulation, indicating that N₂ fixation may not be sufficient to meet the crop's nitrogen demand. The adzuki bean plots recorded excellent nodulation, reflecting strong potential for N₂ fixation. Groundnut (peanut) plots showed fair nodulation, which may not adequately supply the nitrogen requirement of the crop. No nodulation data were recorded in the control plots, as no crop was grown.

Table 55. Mean nodule score for different treatments and its interpretation

Treatments	Mean Nodule Score	Interpretation
(T1) Rajma Beans	0.1	Poor nodulation, little or no N ₂ fixation
(T2) Peas	4.75	Excellent nodulation; excellent potential for N ₂ fixation
(T3) Soyabean	1.0	Poor nodulation, little or no N ₂ fixation
(T4) Lupins	2.6	Fair nodulation; N ₂ fixation may not be sufficient to supply the N demand of the crop.
(T5) Adzuki beans	4.7	Excellent nodulation; excellent potential for N ₂ fixation
(T6) Pea nut	2.4	Fair nodulation; N ₂ fixation may not be sufficient to supply the N demand of the crop.
(T7) Control, No crop	NA	NA

Overall, the highest mean nodule score was observed in plots treated with peas, followed by adzuki beans, lupins, peanut, soyabean while the lowest mean score was recorded in rajma bean plots. Peas

and adzuki beans demonstrated excellent nodulation, suggesting a strong ability to fix nitrogen and potentially reduce the need for synthetic nitrogen fertilizers. Lupins and pea nuts showed fair nodulation, which might contribute some nitrogen but may not fully meet crop demand. Rajma bean and soyabean had poor nodulation, indicating minimal contribution to soil nitrogen and possibly requiring additional nitrogen inputs. Since, in control, no crop was grown, so nodulation was not applicable.

5.1.6. Assessment on Application of Dolomite on Change in pH of acidic Soils, Growth and Yield Parameters of Cabbage and Broccoli

Introduction

Soil acidity is a significant constraint to agricultural productivity in Bhutan. However, there has been limited research on effective remedial measures. Previous studies have highlighted the urgent need to develop appropriate soil amendment technologies to neutralize the soil and create a favourable environment for optimum plant growth and development. Dolomite, a natural mineral found abundantly in Bhutan, is rich in magnesium and calcium, elements that are typically deficient in Bhutanese soils. It is also documented to be widely used in Japan as a soil amendment to stabilize acidic soil and supplement essential nutrients. Therefore, it is imperative to explore the potential of dolomite as a soil amendment technology in Bhutan to enhance crop productivity, improve crop quality, and protect crops from pests and diseases. This study aims to evaluate the effect of various rates of dolomite application on changes in soil pH, crop production and productivity.

Objectives

- To investigate the effectiveness of dolomite application in neutralizing acidic soils in different ecological zones of Bhutan.
- To assess the impact of dolomite application on soil properties such as pH, nutrient content (NPK), cation exchange capacity (CEC), electrical conductivity (EC), organic matter (OM), and base saturation (BS).
- To evaluate the influence of dolomite application on crop growth and yield parameters, including plant height, width, circumference, weight (fresh & dry), number of leaves, leaf length, and leaf color index (SPAD).

Material and methods

Location of the experiment: To ensure effective coordination and leadership of the research, NCOA Yusipang, NSC Paro, and NSSC Semtokha will jointly oversee the research. The study will be conducted in two phases. In the first year (2023), the research will take place at NSC farms (Paro), NCOA Yusipang, ARDC Samtenling, and ARDC Bajo. These locations will serve as the experimental sites for the on-station trials. In the second year, the study will expand to include farmers' fields in addition to the on-station trials. This will allow for a more comprehensive assessment of the effectiveness of dolomite application on acidic soils in various ecological zones.

Experimental design: The experimental design would be a Split plot design with two crop varieties (cabbage and broccoli), four treatments and four replications (blocks). The total experimental field of 100 sq. m with acidic soil shall be identified and subdivided into 16 plots, each measuring 2m x 2m. Each plot will have 8 plants.

Table 56. Details of the main treatments

Treatment	Remarks
T1: Control	No application
T2: Dolomite	6.27 kg/m ²
T3: Vermicompost	3 kg/m ²
T4: Dolomite + Vermicompost	6.27 kg/m ² + 3 kg/m ²

***Whole plot factor/main factor = Treatment and Sub-factor/sub treatment = Crop varieties.*

Soil sampling and laboratory analysis

For soil analysis, soil samples from a minimum of 5 randomly selected points within the block shall be collected at a depth of 20 cm using a soil auger. Soil samples shall be cleaned and mixed thoroughly to form one representative composite sample from each block, weighing 1000 g each.

Soil sampling shall be carried out in three batches. The first batch of soil samples shall be collected 1 week before plantation. The second batch of soil samples will be collected prior to plantation, and the third batch after the crop harvest.

These samples will be sealed in a plastic bag, and provide with proper labels indicating name, location, plot, and date of sampling, and submit to the laboratories for analysis. Soil samples shall be analyzed for soil pH, CEC, OM%, BS%, N, P, K, Ca, Mg. The soil chemical and physical properties shall be analyzed at National Centre for Organic Agriculture laboratory.

Data collection and analysis

Laboratory results will be analyzed for the change in soil properties due to dolomite treatments. In addition, data on crop growth parameters and yields, pests and diseases incidences will be also collected using standard data collection format (detailed in separate document). R statistical packages/SPSS will be used to perform statistical analysis such as analysis of variance (ANOVA), and reporting will be done jointly by the implementing agencies.

During the experimental period, soil samples will be collected regularly to monitor the changes in soil properties, such as pH, NPK, CEC, EC, OM, and BS. Plant growth parameters, including height, width, circumference, weight (fresh and dry), leaf number, leaf length, and leaf color index (SPAD), will also be measured.

Results and Discussion

At 30 days after transplanting (DAT), a Two-Way ANOVA showed a highly significant difference in plant height between the two crop types ($p < 0.001$) with broccoli demonstrating a greater baseline height compared to cabbage group, and a significant main effect for the treatments ($p < 0.032$). The interaction effect between treatment and crop type was borderline but notable ($p = 0.057$). Post-hoc

comparisons using Tukey's HSD revealed that treatments specifically altered the growth of broccoli; Vermicompost (Treatment 3) resulted in significantly higher early plant height (25.2 cm) compared to the broccoli Control Group (18.75 cm, $p = 0.014$). In contrast. No statistically significant variations in height were recorded among any of the cabbage treatments at 30 DAT. By 60 DAT, the initial variations caused by the treatment minimized resulting in a non-significant interaction effect between treatment and crop ($p = 0.358$). However, the main effect for crop type remained highly significant ($p < 0.001$), reflecting the distinct genetic growth habits of the two species. By harvest time, the initial growth variations observed at 30 DAT stabilized, yielding a non-significant main effect for the treatments ($p = 0.078$) and a non-significant interaction effect ($p = 0.314$). The highly significant main effect for crop type persisted through maturity ($p < 0.001$), with broccoli reaching final average heights between 47.61cm and 56.72cm, while the compact canopy of cabbage finished between 19.11 cm and 22.56 cm across all plots.

Table 57. Effect of Treatment on Plant Height

Crop & Treatments	Days after transplanting (cm)		
	30 DAT	60 DAT	Harvest
Broccoli			
Control	18.75 ^{ab}	41.12 ^b	47.60 ^b
Dolomite	23.63 ^{bc}	39.04 ^b	56.72 ^b
Vermicompost	25.20 ^a	38.56 ^b	50.94 ^b
Dolomite + Vermicompost	20.19 ^{abc}	34.72 ^b	49.87 ^b
Cabbage			
Control	15.93 ^a	22.18 ^a	19.11 ^a
Dolomite	15.46 ^a	21.31 ^a	21.64 ^a
Vermicompost	16.70 ^a	22.73 ^a	21.18 ^a
Dolomite + Vermicompost	16.70 ^a	22.82 ^a	22.56 ^a

At 30 DAT, the main effect of treatments on stem diameter was non-significant ($p = 0.181$), and there was no significant interaction between treatment and crop type ($p = 0.495$). However, a highly significant main effect was observed for the crop type ($p = 0.001$), reflecting the morphological differences between the crops: cabbage seedlings exhibited thicker stems. By 60 days DAT, the main effect of soil treatments remained statistically non-significant ($p = 0.098$), and no significant interaction effect was detected ($p = 0.209$), meaning the treatments continued to show uniform behavior across crops. However, a highly significant main effect for crop type persisted ($p = 0.001$). Over the 30 to 60 DAT growth window, an inversion in stem thickness occurred broccoli plants developed inherently heavier, thicker stems ranging from compared to cabbage stems. By harvest time, the differences in stem diameter across both crops minimized, resulting in a non-significant main effect for soil treatment ($p = 0.391$) and a non-significant interaction effect ($p = 0.430$). Furthermore, the highly significant main effect for crop type observed during early developmental phases leveled out by maturity ($p = 0.152$). Final broccoli stem widths ranged from 1.68 to 3.23 cm, while cabbage stem widths concluded between 1.51 to 1.93 cm across all treatment groups.

Table 58. Effect of Treatment on Plant Stem

Crop & Treatments	Days after transplanting (cm)		
	30 DAT	60 DAT	Harvest
Broccoli			
Control	0.58 ^a	1.47 ^a	1.67 ^a
Dolomite	0.66 ^a	1.40 ^a	3.23 ^a
Vermicompost	0.70 ^a	1.20 ^a	1.93 ^a
Dolomite + Vermicompost	0.58 ^a	1.09 ^a	2.0 ^a
Cabbage			
Control	0.75 ^a	1.10 ^a	1.50 ^a
Dolomite	0.76 ^a	0.89 ^a	1.66 ^a
Vermicompost	0.70 ^a	0.98 ^a	1.72 ^a
Dolomite + Vermicompost	0.76 ^a	0.99 ^a	1.90 ^a

Regarding the number of leaves at 30 DAT, a Two-Way ANOVA revealed a non-significant main effect for soil treatments ($p = 0.376$) and a non-significant interaction effect ($p = 0.797$), indicating that leaf production progressed uniformly across all treatment groups at this stage. However, a highly significant main effect was observed for crop type ($p < 0.001$), reflecting distinct leaf canopy structure. Cabbage seedlings consistently produced a higher volume of foliage, averaging between 12.87 and 14.07 leaves per plant, whereas broccoli seedlings maintained a lower leaf count, clustering tightly between 7.07 and 8.07 leaves across all groups. At 60 DAT, the leaf production across both crops remained unaffected by the treatments yielding a highly non-significant main effect for treatment ($p = 0.950$) and a non-significant interaction effect ($p = 0.146$). However, a highly significant variation persisted between the crop species ($p < 0.001$). By harvest time, a highly significant interaction effect between treatment and crop type emerged for the number of leaves ($p = 0.002$), overriding the individual main effects and demonstrating that the crops responded uniquely to the treatments at maturity. Post-hoc comparisons using Tukey's HSD interaction test revealed that Dolomite application triggered a significant vegetative burst exclusively in broccoli, resulting in a significantly higher final leaf count (23.90 leaves) compared to all other treatment combinations across both crops, which remained statistically uniform.

Table 59. Effect of Treatment on number of Leaves

Crop & Treatments	Days after transplanting (cm)		
	30 DAT	60 DAT	Harvest
Broccoli			
Control	7.06 ^a	14.40 ^a	15.64 ^a
Dolomite	7.60 ^a	15.20 ^a	23.90 ^b
Vermicompost	8.06 ^a	12.66 ^a	15.84 ^a
Dolomite + Vermicompost	7.53 ^a	12.80 ^a	16.64 ^a
Cabbage			
Control	13.13 ^a	16.66 ^a	15.21 ^a
Dolomite	12.86 ^a	16.63 ^a	12.71 ^a
Vermicompost	14.06 ^a	18.26 ^a	15.25 ^a
Dolomite + Vermicompost	14.06 ^a	18.53 ^a	15.38 ^a

For the fresh weight of leaves remaining at harvest, the Two-Way ANOVA revealed borderline significance for both the main effect of treatment ($p = 0.054$) and the interaction effect between treatment and crop type ($p = 0.053$), while the main effect for crop type was highly non-significant ($p = 0.905$). Despite the high phenotypic variance within groups, post-hoc comparisons using Tukey's HSD interaction test identified a distinct vegetative biomass split within the broccoli trial: Vermicompost produced the highest foliar mass (313.89), which was significantly greater than the broccoli Control group. In contrast, all cabbage groups and the remaining broccoli treatments demonstrated intermediate, overlapping behaviors.

The final fresh weight of stems at harvest was significantly influenced by both individual crop type ($p < 0.001$) and the applied treatments ($p = 0.005$), with a borderline interaction effect ($p = 0.055$). Post-hoc analysis using Tukey's HSD interaction test demonstrated a stark divergence in resource allocation between the two crops. Cabbage stems remained uniformly low in weight across all treatments, clustering strictly under superscript ^a (ranging from 21.10 to 37.31). Conversely, broccoli allocated substantial biomass to its central stalk, which was uniquely maximized under Vermicompost, yielding a significantly higher stem fresh weight (126.54) than the broccoli Control group. The fresh weight of roots at harvest was exclusively driven by the highly significant main effect of crop type ($p < 0.001$), while the main effect of soil treatment ($p = 0.144$) and the interaction effect ($p = 0.533$) were non-significant. Broccoli plants consistently developed a more robust root system, with final root fresh masses ranging between 36.29 g and 57.74 g across all blocks. In comparison, cabbage root weights finished significantly lower, spanning from 16.40 g to 24.76 g across treatment groups. The total weight of the plants at harvest showed clear differences between the two crops and how they responded to the treatments. Marketable head weight was vastly different between the crops ($p < 0.001$), with cabbage producing much heavier heads overall than broccoli. However, the borderline interaction ($p = 0.054$) shows that each crop had a different preference to maximize its final yield. Broccoli head weight was maximized under pure Vermicompost (148.27 g), which matches the strong growth seen in its leaves and stems. On the other hand, cabbage heads responded best to Dolomite, reaching a maximum weight of 912.57 g. In contrast to the parts above ground, root weights differed between the two crop types ($p < 0.001$) but were completely unaffected by any of the soil treatments ($p = 0.144$).

Table 60. Effect of Treatment on Plant Biomass at harvest

Biomass at Harvest				
Crop & Treatments	Leaves Weight	Stem Weight	Root Weight	Head Weight
Broccoli				
Control	108.48 ^a	59.33 ^{ab}	36.29 ^a	61.34 ^a
Dolomite	196.19 ^{ab}	98.14 ^{bc}	45.09 ^a	95.74 ^a
Vermicompost	313.89 ^b	126.54 ^c	57.74 ^a	148.27 ^{ab}
Dolomite + Vermicompost	147.78 ^{ab}	89.19 ^{bc}	48.75 ^a	59.69 ^a
Cabbage				
Control	134.42 ^{ab}	21.10 ^a	16.40 ^a	474.96 ^{bc}
Dolomite	184.03 ^{ab}	28.57 ^a	19.86 ^a	912.57 ^d
Vermicompost	173.35 ^{ab}	31.17 ^a	20.78 ^a	556.76 ^{cd}
Dolomite + Vermicompost	259.53 ^{ab}	37.31 ^a	24.76 ^a	713.20 ^{cd}

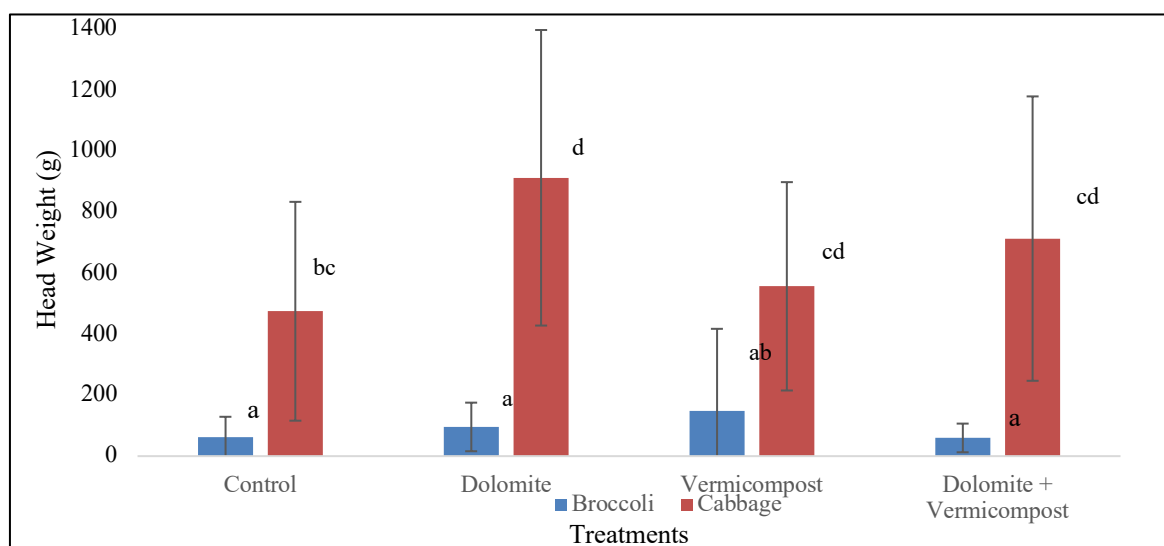


Figure 47. Effect of Treatment on Head Weight

Conclusion

The research findings showed that the use of Vermicompost was better for broccoli head yield, while pure Dolomite was vastly superior for cabbage head yield as compared to the other treatments. For broccoli, the highest head weight was recorded under the Vermicompost-treated plots. For cabbage, the highest head weight was recorded under the Dolomite-treated plots. The vegetative growth traits also followed distinct patterns; while plant height and leaf multiplication responded strongly to Dolomite and Vermicompost during the mid-season growth stages, the underground root weights showed a clear biological difference between the two crop types but remained completely unaffected by any of the treatments.

However, statistical analysis using JASP revealed that the main effect of the treatments on final head weight was right on the margin of significance ($p = 0.053$), and the Treatment $\times$ Crop interaction was similarly borderline ($p = 0.054$). Post-hoc testing using Tukey's HSD confirmed that while cabbage responded significantly to Dolomite compared to its control, the differences among the broccoli treatments were not statistically distinct from one another.

5.1.7. Isolation of *Trichoderma* spp. from Organic Soils for Biofertilizer Development

Indigenous *Trichoderma* spp. were isolated from organically managed soils in Paro and Thimphu to support the development of locally adapted biofertilizers for sustainable agriculture. A total of 18 soil samples were collected and processed using serial dilution and aseptic laboratory techniques. Colonies exhibiting *Trichoderma*-like characteristics were purified through repeated sub-culturing, resulting in the successful establishment of several healthy fungal isolates despite challenges from microbial contamination and slow initial growth.

Five purified cultures were submitted to CNR for molecular identification, providing a foundation for future characterization and biofertilizer development. The activity also strengthened laboratory

capacity in microbial isolation, culture purification, and maintenance of fungal collections. The established isolates will be further evaluated for their antagonistic activity against plant pathogens and their plant growth-promoting potential, with promising strains to be developed as locally adapted biofertilizers and biological control agents for sustainable crop production in Bhutan.

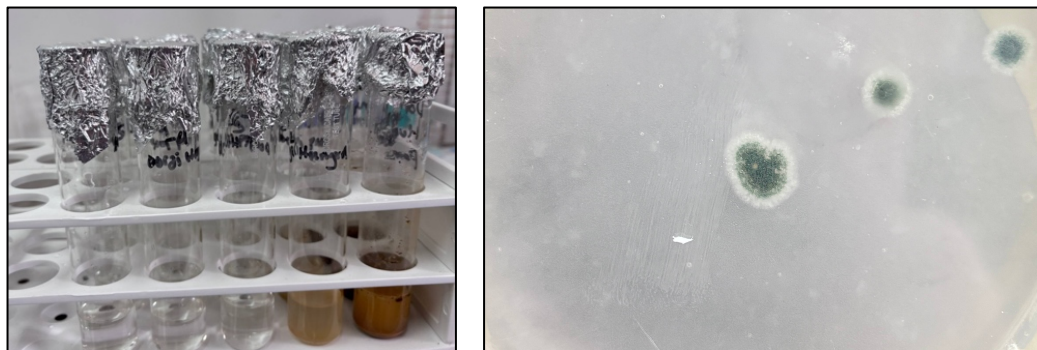


Figure 48. Serial Dilution (left) and *Trichoderma* spp. on PDA media (right)

5.1.8. Semi-Automatic Poly Bag Filling Machine

The concept and research question for the Semi-Automatic Poly Bag Filling Machine were developed by the National Centre for Organic Agriculture (NCOA), Yusipang, to address the labor-intensive and inefficient process of manual polybag filling in nursery operations. The technology was designed and fabricated in collaboration with the Agricultural Machinery Technology Centre (AMTC). The machine was developed using locally available materials to provide a simple, affordable, and practical mechanization solution for nursery development and organic farming.



Figure 49. Semi-Automatic Poly Bag Filling Machine

The performance evaluation demonstrated that the machine can fill approximately 6,000 polybags per day with three operators, compared to about 600 polybags per day through manual filling, significantly reducing labor requirements, time, and worker drudgery while improving filling uniformity. With an optimum capacity of 8.042 Mt/day and a fabrication cost of Nu. 33,709, the machine proved to be efficient, economical, and suitable for Bhutanese nursery conditions. Based on its successful performance, the technology has been approved for release for wider adoption by nurseries, cooperatives, and farmers.

5.2. Development activities under Technical Support Service Program

5.2.1. Capacity building for the Go-Organic Chang Farmers

The Go-Organic Chang Gewog Farmers Training and Study Tour was a comprehensive 10-day initiative designed to provide essential technical backstopping and capacity building for the farming community of Chang Gewog and ESPs from the Royal Chmipang Project and Royal Changaphu project. Spanning from March 2nd 2026 to March 11th 2026, the program was strategically divided into two phases: a six-day intensive technical field training followed by a four-day study tour in Tsirang Dzongkhag.

The primary objective was to facilitate the transition of current agriculture practices towards certified organic agriculture practices by equipping participants with hands on master of organic input production, soil fertility management and integrated plant protection. During the technical training phase, participants engaged in the rigorous production of solid and liquid bio-fertilizers including Bokashi, Biochar, Jeevamruth, Jholmol series, Vermicompost, Vermiwash, while also learning botanical concoctions and Sustainable Land Management (SLM) techniques. The program also included a study tour to Tsirang Dzongkhag to visit certified organic sites such as the Model Organic Fram, Ginger Powder Processing Plant and Thakorling Vegetable Group. By bridging the gap between theory and field proven success stories, the program aimed to ensure the participants feel motivated and learn more.

Participants were introduced to the fundamental concepts of organic soil nutrient management and integrated plant protection. Detailed presentations were delivered on the science behind organic inputs. Key technologies introduced included Jholmol 1, Jholmol 2, Jholmol 3, Jeevamruth, Biochar, Bokashi, Takakura compost, Vermicompost, Garlic-Ginger-Chili concoction and Neem oil. Furthermore, the session also covered essential field management practices required throughout the crop production cycle to ensure long-term farm viability.



Figure 50. Group photo of participants (left); Practical session (right)

Participants learned the basics of mitigating pest and diseases incidences through the use of organic, sustainable, non-synthetic alternatives. Participants engaged in intensive, hands-on training for the preparation and application of the Jholmol series as well as botanical pesticides like Neem oil and the Garlic-Ginger-Chili concoction. Jholmol 1 is primarily used as a bio fertilizer to enhance soil fertility and provide essential nutrients to crops. Jholmol 2 functions both as a plant growth promoter

and a preventive measure against common plant pests. Jholmol 3 is formulated as a bio pesticide, specifically designed to manage and repel insect pests through the addition of botanical ingredients such as chopped Artemisa plant. A key technical highlight of the session was the demonstration of how adding liquid soap to the Neem oil and Garlic-Ginger-Chili mixtures serves as an adjuvant. This addition acts as a surfactant, ensuring the concoction adheres better to the leaf surfaces and penetrates the protective coatings of the target pests more effectively.

5.2.2. Capacity Building of Farmers of Subrang, Trong gewog under Zhemgang

The capacity building and survey were conducted over a six-day program spanning from 23rd March, Monday till 28th March, Saturday. The program focused on the strategic development of these organic villages in Subrang, Zhemgang Dzongkhag and Thakorling, Tsirang Dzongkhag. These sites were selected for their geographical isolation from urban areas, which is required for maintaining organic integrity and positioning them as key agricultural suppliers for the Gelephu Mindfulness City. Throughout the program, the team conducted intensive capacity building sessions focusing on Bhutan Organic Guarantee Standards (BOGS), Organic Plant Protection, Soil Nutrient Management, while emphasizing the importance of Farm Diary maintenance for certification. Following the registration of farmers, a comprehensive baseline survey was carried out to assess demography, crop diversity, income levels, livestock, farm machineries and gender dynamics. Using Google Earth, a baseline map covering the total land area under organic management was developed to be used as reference.



Figure 51. Presentation on Organic Plant Protection (left) Farmers of Trong Gewog (right)

The second day was entirely focused on equipping the farmers of Subrang with the theoretical foundation required for organic certification and sustainable production. The session included organic plant protection and soil nutrient management, where the farmers were introduced to non-synthetic pest control technologies and soil fertility management practices, some of the key technologies introduced were the Jholmol Series, Jeevamruth, Bokashi, Takakura Compost, Neem Oil and Botanical Concoctions.

A session on Bhutan Organic Guarantee Standards (BOGS) was also covered to ensure that all produce meets the national standards followed by a session on the farm diary management highlighting the importance of documentation and record keeping for transparency and traceability

in organic farming. Farmers were then registered and the farm diary were distributed to them, with all the respective credentials of each farmer were filled up as required.

5.2.3. Collaboration with JiCA in Joint Technical Diagnostic Survey and Laboratory Isolation of Apple Diseases

In response to the steady decline of apple production across the region a week-long joint technical disease diagnostic survey, field sample collection and laboratory isolation was executed in August 2025, to identify the underlying pathological causes of apple orchard decline. Working under the technical guidance of international project expert Dr. Osaki, active field epidemiology and symptomatic sample collection including diseased leaves, infected bark, twigs, fruits, lichens, and macro-fungi were systematically conducted across critical apple-growing zones in Thimphu, Paro, and Haa Dzongkhags. To capture qualitative data and map orchard management practices, a detailed disease questionnaire was also filled out across the survey sites, which required providing technical translation and field facilitation to bridge communication between the expert and local growers. Field operations covered a wide geographic scope, including Genekha and Chang gewogs in Thimphu; Dopshari, Nemjo, Tsento, and the NSC Farm in Paro; and Naja, Katsho, and Kana gewogs in Haa.

Following the field phase, intensive laboratory diagnostics were conducted to isolate and culture the collected specimens. Contributions included the technical preparation of Potato Dextrose Agar (PDA) culture media, sterile sample handling, and the inoculation of infected tissues. A total of 64 distinct samples were successfully isolated, incubated, and monitored under controlled laboratory conditions. Subsequent microscopic analysis and diagnostic observations successfully identified and categorized five diseases driving orchard degradation: Valsa Canker, Apple Rust, Apple Scab, Brown Rot, and White Root Rot. The joint collaboration concluded with a collaborative presentation of the diagnostic findings and epidemiological insights to stakeholders including the Department of Agriculture (DoA), the National Plant Protection Centre (NPPC), the National Center for Organic Agriculture (NCOA), and the JICA Bhutan Office.



Figure 52. Samples collected from the farmers' apple orchards

5.2.4. Collaboration with the National Potato Program in Soil Sampling for Potato Wart Survey

Collaborated with the National Potato Program in the second phase of the National Potato Wart Survey across the Central and Eastern regions between May and September 2025. The primary objective of the two phased survey initiative was to map, monitor, and detect the presence of the high-consequence fungal pathogen *Synchytrium endobioticum*, the causative agent of potato wart disease. The activity started with a preliminary survey phase from mid-May to June 2025, utilizing a targeted, semi-structured questionnaire to interview local growers. To capture precise historical insights, the field interviews intentionally focused on experienced farmers aged 50 to 60, using pictorial identification guides of infested tubers to facilitate accurate symptom recognition. The qualitative data gathered from these initial consultations served as a critical baseline to identify high-risk households and strategically map sites for soil sample collection.

Following the preliminary phase, potato visual examinations in the field and in the storage and comprehensive soil sampling were systematically carried out during the crop harvest and post-harvest window from August to September 2025. Recognizing that *Synchytrium endobioticum* disseminates via mobile resting zoospores, soil sampling was heavily prioritized as the primary and most reliable method for diagnostic detection, strictly adhering to international USDA (2020) biosecurity guidelines. The field methodology employed a rigorous, risk-based screening design: fields displaying symptomatic vegetative plants or infected tubers underwent mandatory 100% soil sampling, while asymptomatic fields were subjected to a stratified random sampling protocol (30% to 50%) to serve as rigorous control plots. A total of 103 high-density soil samples and field verifications were successfully completed across main potato growing areas in four dzongkhags.

All collected symptomatic tuber specimens and the 103 consolidated soil samples were securely processed, documented, and submitted to the National Plant Protection Centre (NPPC) and the NCOA laboratory for definitive diagnostic and molecular analysis

Table 61. Information on the sample

Dzongkhag	Gewogs	Sample Size
Bumthang	Chummey	6
	Chokhor	16
	Tang	7
	Ura	4
Mongar	Dremetse	14
	Narang	9
Pemagatshel	Zobel	12
Trashigang	Kanglung	12
	Khaling	24
Total		103



Figure 53. Soil sample collection from potato fields

6. LIST OF PUBLICATIONS

Table 62. List of publication made during the FY 2025-2026

Title	Type	Author	Link
Organic Agriculture in Bhutan	Conference Proceedings (Regional Conference on Deep Regenerative Agriculture, Nepal, 2026)	Norden Lepcha	https://www.researchgate.net/publication/407768732_Proceedings_of_the_Regional_Conference_on_Deep_Regenerative_Agriculture
Quantifying yield gaps and agronomic drivers of potato productivity in Bhutan	Journal article-American Journal of Potato Research -Published on 22 April 2026	Passang Wangmo., Yadunath Bajgai, Yenten Namgay, Tshering Tobgay, Kailash Pradhan, Lobzang & Sangay	doi.org/10.1007/s12230-026-10052-y
A Systematic Review of Soil Health Restoration Pathways and Ecosystem Functionality in Bhutan's Mountain Agro-ecosystems	International Journal of Plant & Soil Science (Regional Conference on Deep Regenerative Agriculture, Nepal, 2026)	Yenten Namgay, Passang Wangmo, Tshering Tobgay, Tshetrim La, Kinzang Dorji	https://11nq.com/karevbq
Promotion of Regenerative Agriculture in Bhutan	SAARC Agriculture Centre (Regional Conference on Promotion of Regenerative Agriculture in SAARC Member States)	Yenten Namgay, Tshering Wangchuk, Tshering Tobgay, Tshetrim La	https://11nq.com/tir0jdu