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ROYAL GOVERNMENT OF BHUTAN
Agriculture Research and Development Centre
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ANNUAL REPORT 2021-2022

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ROYAL GOVERNMENT OF BHUTAN

FOREWORD

It is an immense pleasure to publish the 36^{7h} Annual Technical Report of Agriculture Research and Development Centre (ARDC), Bajo, coinciding with the financial year 2021-22. It is a synthesis of the research and development activities carried out in the fields of field crops, horticulture, technical support services, and engineering services by the Centre and its Sub-Centre at Menchhuna, Tsirang.

ARDC-Bajo implements activities focusing on its national mandate for coordination of field crops research and development, the regional mandate for horticulture research and development, and commodity mandates for rice, citrus and water management research and development. It carries out the activities in close collaboration and consultation with the Ministry of Agriculture and Forests, the Department of Agriculture and its central agencies, projects, Local Government agencies, and most importantly with the farmers and other beneficiaries.

The Centre initiated and implemented numerous activities such as rice varietal evaluations, the establishment of horticulture germplasm blocks, quinoa evaluations, citrus management trials and demonstrations, the establishment of demonstration orchards, National Citrus Canopy Management, vegetable evaluations and top working of fruit trees. The Centre carried out research, social studies and impact studies. However, regular monitoring and evaluations have remained weak and wanting. The Centre has now ventured into hydroponic farming research, smart irrigation and automation.

Amidst the COVID-19 pandemic, ARDC- Bajo could complete all the planned activities for the financial year (FY) 2021-22. The successes and achievements made were possible because of tremendous support from the central agencies and the projects in general. All staff of ARDC-Bajo, ARDSC-Menchhuna, and Chimipang Royal Project made big efforts to contribute towards achieving planned activity targets as well as ad-hoc activities. While firmly remaining determined to make whatever positive differences to farming communities and grateful to all those who contributed towards achieving the planned targets of the Centre for 2021-22, I would like to entreat all seniors, colleagues, supporters, and stakeholders to continue to provide full cooperation, support and best wishes.

This report is intended not only to serve as an account of activities implemented in the last year but also possibly as technical reference and guidelines to all stakeholders involved in agricultural research and rural development to achieve national food and nutrition self-sufficiency, economic self-reliance and eventually the overarching national goal of Gross National Happiness in Bhutan.

Tashi Delek La!

Pema Chofil
Program Director

GLOSSARY OF ACRONYMS

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

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

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Executive Summary

This report presents the outcome of the research and development activities of RDC Bajo for the financial year 2021-2022. The progress is reported Program wise.

Field Crops Research and Development Program

The main objective of implementing the Field Crops research is to increase the productivity of different cereals, oilseeds and pulses. Research and Development works were equally emphasized both on station and on farm. The centre continued to evaluate elite lines and commercial varieties received through international research institutes. The 12 lines were screened from Initial Evaluation Trials and will be taken to Advance evaluation. From six lines under Advance evaluation, three are selected as potential cultivars for release for cultivation. The Sector also participated in Evolutionary Plant Breeding with national and International agencies. Different inputs, techniques and technologies for rice production such as alternate wetting and drying (AWD), and Azolla were also assessed. Demonstration on production capacities of released rice varieties were also carried out. The centre over the years played a crucial role in germplasm maintenance program through promotion of improved varieties, characterization of local cultivars, and seed production.

Similar to rice, evaluation of high yielding varieties of wheat from CIMMYT are under process. Evaluation of Biofortified wheat lines are also carried out. Seed production of promising varieties of wheat was taken, as a parallel activity to the evaluation trial of various materials, which will further be up-scaled in the ensuing season. Assessment of potential of differen cultvars of maize, quinoa, grain legumes and oil seeds are also some of the important activities carried ount by this program. Seed production of released varieties of maize has been carried out on-station to maintain quality seeds.

Horticulture Research and Development Program

The core objective of horticulture crops research is to improve rural livelihood and to achieve vegetable and fruit self-sufficiency in the region and at the national level. The research activities of the horticulture sector include crop management technology, post-harvest practices, improved seeds, plant propagation techniques and maintenance of mother plants and breeder seeds of released crops besides varietal evaluation. The sector also focused on broadening the genetic base of the prioritized horticultural crops through either introduction or selection from local diversity such as of Inchi, Colocasia, cole crops, eggplants, winter chillies, and sweet potato.

The horticulture sector also gave equal importance to outreach programs wherein demonstration of superior varieties over the existing ones and alternative cash crops options were implemented based on location specific farming systems in collaboration with extension officials. Furthermore, the sector provided technical support to the farmers and also carried out capacity development of farmers and extension agents.

The sector participated and facilated coordination of important national programs on Million Fruit Tree Project, Desuung Skilling Progam, and Plantation of Saplings with National, Regional and Local government agencies.

Support Service Research and Development Program

Plant Protection and Integrated Pest Management
The unit participated in evaluation of pest management inputs, assessment of pest damages, recoding of pests occurrences, and demonstrated sustainable plant protection techniques through use of integrated pest management methods and organic inputs. The unit also provided pest dianistic services and technical recommendations on pest management under outbreak conditions with technical assitances in spray of pesticides.

Soil and Land management
The unit established regional soil and plant analytical laboratory, Bhutan Agri-Microbial Solution Plants, and Vermicomposting Units with supports of relevant agencies and sectors. Also, evaluation and generation of inputs for soil fertility management under organic agriculture and sustainable agriculture has been strived for. The unit participated in research on Hydroponics and provided technical assistance on estalblishement of Hydroponic Systems in the region.

Research and Communication
Documentation and development of different strategies, manuals, social studies, and technology generation were facilitated. A number of important stratetegies, books, brochures and reports were published.

A number of visitors consisting of enthusiastic farmers, extension workers, and officials from various ministries including diplomats visited the centre and the sector mainly coordinated and documented the visit.

FIELD CROP RESEARCH AND DEVELOPMENT PROGRAM

1) Rice

i. Initial Evaluation trial (IET)

The 12 lines were advanced from the observation nursery including check. This trial is conducted to screen and advance promising lines for further testing based on selection criteria. It was a Randomized Complete Block Design (RCBD) with three replications. The plot size was 5m x 2m with a spacing of 20cm x 20cm. A recommended fertilizer dose of 70:40:40 NPK kg/ha application was applied. Butachlor 1.5 kg a.i/ha is used for controlling the weed. The agronomic performance is recorded in Annexure 1. All obligatory data were collected timely and analysed.

Table 1 ANOVA on yields of IET rice lines

Source	DF	SS	MS	F-value	Pr(>F)
Rep	2	337340.22	168670.11	2.26	0.128
Trt	11	12548420.31	1140765.48	15.30	0.0000
Error	22	1639935.11	74542.51		
Total	35	14525695.64			
CV (%) = 10.50		Mean = 2599.81 kg/ac			

There is a significant difference in the yields of different treatments with the highest yield in lines SVIN357, SVIN319, SVIN329, SVIN356, and SVIN031 from all other treatments. All the treatments are performing better than the check Bajo Kaap 1.

Table 2 Post-hoc summary on yields of different rice lines under IET

Treatment	Mean Yields (kg/ac)	N	Groups
BK1	1111.67	3	d
SVIN022	2800.00	3	ab
SVIN031	3020.67	3	a
SVIN047	2482.67	3	abc
SVIN304	2708.33	3	abc
SVIN319	3087.67	3	a
SVIN329	3040.67	3	a
SVIN344	2708.33	3	abc
SVIN356	3080.67	3	a
SVIN357	3157.33	3	a
SVIN360	1901.33	3	cd
SVIN372	2098.33	3	bc

Note: Means with the same letter are not significantly different at α= 0.5 as indicated by Tuckey's HSD

ii. Advance evaluation trial (AET)

In the AET, 6 lines were evaluated under AET including checks during the FY 2021-22. This trial was advanced from IET based on the performance of lines. The plot size was 5m x 2m with a spacing of 20cm x 20cm. A recommended fertilizer dose of 70:40:40 NPK kg/h was applied. Butachlor 1.5 kg a.i/ha is used for controlling the weed. The aim was to identify suitable varieties with high yield potential, medium height, optimum maturity and resistance to pests and diseases. The agronomic performance of AET is recorded in Annexure 2.

Table 3 ANOVA for yields of AET Rice lines

Source	DF	SS	MS	F-value	Pr(>F)
Rep	2	26875.44	13437.72	0.84	0.4593
Lines	5	3536186.94	707237.39	44.31	0.000
Error	10	159607.22	15960.72		
Total	17	3722669.61			
CV(%) = 7.57		Mean yield = 1669.72 kg/ac			

The yields of different treatments are significantly different with the highest in IRRI179 followed by IR12N110 and IR14D155. The least mean yield was in IRRI11A306 and Bajo Kaap 2 (check) with a CV (%) of 7.57. Overall, the mean is 1669.72 kg/ac.

Table 4 Post-hoc summary on yields of different AET Rice lines

Lines	Mean Yields (kg/ac)	N	Groups
BK2	1123.33	3	c
IR12N110	2058.67	3	a
IR14D155	2044.00	3	a
IRRI11A306	1119.67	3	c
IRRI179	2176.00	3	a
IRRI248	1496.67	3	b

Note: Means with the same letter are not significantly different at $\alpha = 0.5$ as indicated by Tuckey's HSD

iii. Participatory technical assessment of evolutionary plant breeding

The Research Centre in collaboration with National Biodiversity Centre (NBC) and Dzongkhag Agriculture Sector has been conducting "Participatory technical assessment of evolutionary plant breeding (EPB)" trials on mid-altitude rice in Punakha and Tsirang. The EPB trials are introduced in Bhutan for the first time through the EPB project which is funded by International Fund for Agricultural Development (IFAD) through Biodiversity International. In Bhutan, the EPB project is nationally executed by NBC in collaboration with ARDCs (Yusipang, Bajo and Samtenling) and Dzongkhags. EPB trials in Bhutan have been initiated on rice and beans. The EPB trials on rice are ongoing in Punakha and Tsirang representing the mid-altitude rice-growing areas. The evolutionary populations for the crops were prepared by mixing the most popular traditional and improved varieties collected and contributed by farmers and ARDCs from specific locations.

Table 5 Table of Means for EPB Rice lines at Punakha

Treatments	Mean Yield (kg/ac)
BM1	2346.16
Bonday	2223.51
Dawa local	2267.06
IR64	2295.38
Mixture2-6	2114.62
Ngabja local	2280.13
Tan Tshering local	2332.40

The treatments used (Annexure 3) at Punakha were IR 64 (V1), Bajo Maap 1 (V2), Dawa local (V3), Ngabja local (V4), Tan Tshering (V5), Bonday (V6) and mixture 2-6 (V7). Whereas in

Tsirang the treatments were For Tsirang the treatments were Attey (V1), Chottey (V2), Gawri Masino(V3), WR-II (V4), IR64 (V5) & mixture (Annexure 4). The trials were conducted as per NBC's protocol. Timely data were collected like the date for germination, flowering & maturing, blast score and other parameters like crop height, the number of tillers, panicle height, yield, were along with the crop cut. The trials will be carried out for four years for coming up with a new variety with appropriate traits. During the harvesting time, a field day was organized where nearby farmers from the gewog attended were briefed on the EPB project activities and the importance of the trials conducted. Crop-cut of 10m2 is taken randomly from five samples. There is no significant difference in the yields of different treatments (α= 0.5). The mean yields of the different treatments are presented in the table below.

Table 6 Table of means for EPB Rice lines at Tsirang

Treatments	Mean Yield (kg/ac)
Attey	1451.67
Chottey Masino	1488.67
Gawri Masino	1486.67
IR64	1563.67
Mix	1440.67
WRK2	1462.67

iv. The effect of Azolla on the growth and yield components of rice variety IR64

Rice yield is strongly influenced by Nitrogen fertilizer. Nitrogen sourced from organic amendment is better than those from inorganic fertilizers due to its beneficial effect on soil and the environment. Known as nature's 'green gold mine,' Azolla is utilized as a water purifier and a source of nutrients for rice plants. A study was conducted from June to December 2021 to investigate the effect of Azolla on the yield and growth parameters of paddy IR64 and its influence on soil properties. The RCBD experiment comprised four treatments; T_1- Azolla 15t/ha applied 20 DBT (days before transplantation), T_2-Azolla 15t/ha applied 15 DAT, T_3-NPK @80-50-20 kg/ha, and T_4-Control (without any inputs). The effect of treatments on the plant height, number of grain/panicles, panicle length, and yield/acre was observed in NPK outperforming the other treatments. Azolla had a significant influence on the parameters as compared to the control. Grain size ratio and 1000 grain weight were not influenced by the Azolla application. The study suggests Azolla as a nitrogen fertilizer is an effective way to increase the rice yield. The summary of the yield parameters is tabulated in Table 7.

Table 7 Effects of Azolla on yield parameters of rice

Treatments	**No. of grains/ panicle (No)**	**1000 grain weight (Gram)**	**Yield /Acre (kg)**	**50% flowering (days)**	**Maturity (days)**
Azolla_20DBT	109.76^{b}	27.61^{a}	1956.60^{b}	71.66^{b}	99.66^{a}
Azolla_15DAT	106.30^{b}	27.62^{a}	2332.20^{ab}	72.66^{a}	99.33^{a}
NPK	117.26^{a}	28.05^{a}	2561.79^{a}	65.66^{c}	92.33^{b}
Control	97.63^{c}	26.92^{a}	1821.18^{b}	65.33^{c}	94.66^{b}
CV (%)	7.05	2.15	11.43	5.14	3.47

CV= Coefficient of variation. α= 05. Mean followed by the same superscript letter in the same column are not significantly different

v. Demonstration of released rice varieties

As the Centre receives different groups of visitors with different learning objectives farmers showed interest in seeing new crop varieties which yield more; extension personnel were keen on new technologies; and trainees, guests and visitors had specific objectives to visit the Centre. In general, many were interested in technologies available or adopted in the Centre. To showcase and disseminate technology to farmers, students and extension staff, a demonstration plot consisting of eight released rice varieties was established at the research station. The following rice varieties were demonstrated on-station. Necessary agronomic practices such as irrigation and weeding were done based on the requirement.

Table 8 Yields of released rice varieties at demonstration plots

Designation	Plant height (cm)	Tillers/hill	Maturity days	Grain yield (kg/ac)
Bajo Kaap1	105	13	145	2350
Bajo Kaap 2	110	6	150	2320
IR 20913	120	14	125	1510
Bajo Maap 2	110	13	153	1982
IR 64	108	21	143	1990
Bajo Maap 1	115	16	140	1598
Black rice (local)	130	10	160	989
Vietnam rice	125	11	160	898

vi. Evaluation of local rice varieties under alternative wetting and drying (AWD)

Based on the availability of resources, feasibility and considering the present scenario of the pandemic, in consultation with the field crop sector head ARDC-Bajo on-farm evaluation of local rice varieties under Alternative Wetting and Drying (AWD) technology, was proposed and incorporated into our work plan for the fiscal year 2021-22 and the trial was conducted with the objectives to evaluate the performance of selected mid-altitude local rice varieties with alternative wetting and drying (AWD) technology

The trial was initiated in 2021 at ARDSC-Menchhuna, Tsirang. Six locally available rice varieties (Sigsima, Ray Kaam, Thakmaro. Kali Ray Map, Gawri Masino and Sukimey) were used for assessment for performance evaluation with the AWD technology, following the principles of Participatory varietal selection. The nursery was raised in dry bed method on 14th may 2021 and to avoid birds' damage during the pre-germination stage pine needles were used as mulching. Enough quantity of seedling was raised for Treatments (Local Accessions with AWD technology + another Check) with full irrigation/flooded. The AWD trial was established or transplanted on 21st June 2021 in a randomized complete block design with three replications of plot size. These trials were transplanted with a spacing of 20 cm between the lines and 20 cm between the hills. Punch (10% G) at the rate of 10 kilograms per acre was applied two days after transplantation to control weed pressure. Moreover, the basal dosage of required organic fertilizer was applied. To ensure enough nutrient supplement chemical fertilizer at the rate of 70:40:20 (N-P-K) kg per hector was also applied. Applied whole P and K and 40%N as a basal dose and executed 1st top dressing with urea on 30th July 2021 approximately 39 days after transplantation.

After fifteen days of paddy transplantation, the following alternative wetting and drying schedule as tabulated below maintain the gap of ten days intervals in between. However, after some intervals, there were continuous rainfall and the irrigation levels remained at saturation points although proper drainage was made at ground level to facilitate proper field drying.

Table 9 Schedule for Alternative Wetting and Drying

Date	Schedule	Water level	Remarks
5th July 2021	Drying	2cm	Partial rainfall
15th July 2021	Wetting		
25th July 2021	Drying	3cm	Partial rainfall
4th August 2021	Wetting		
14th August 2021	Drying	saturated	10-23 continuous rainfall.
24th August 2021	Wetting		
3rd September 2021	Drying	saturated	
13th September 2021	Wetting		
23rd September 2021	Drying	3cm below the ground level	Heavy rainfall on 28/09/21 only
3rd October 2021	Wetting		
13th October 2021	Drying	<15 cm	Sunny days
23rd October 2021	Wetting		
29/9/2021	Harvested	G.masino< 15 cm	

The first weeding was carried out using a rotor weeder machine after 35 days from transplantation followed by manual weeding along with bund cleaning. Huge variation in flowering and maturity was observed and the early maturing varieties were found very prone to bird damage during the milky stages. Accordingly, to evade birds' damage, the entire trial site of AWD was covered with bird nets.

Table 10 Effects of AWD on rice cultivars

Entry	Sigsima	Ray Kaap	Thakmaro	Kali Ray Maap	Gawri masino	Sukimey
50% flowering days	134	124	124	129	135	135
Plant height (Cm)	114	110	111	102	113	112
Tiller Nos	9	10	10	12	9	11
Nos of panicle/hill	9	10	10	12	9	11
Days to maturity	165	145	145	165	175	165
Disease score	Nil	Nil	Nil	Nil	Leaf blast	brown sport
MC%	23.5	22.7	23.6	22.5	23.8	16.3
Yield kg/plot	1.92	1.79	1..87	2.075	1.785	1.545
Yield kg/ac	1534	1447	1494	1682	1422	1352

The performance of the crop was recorded both in AWD plots, as well as in fully irrigated check plot of area of plot 2x3m =6M^2. The different parameters of different varieties are presented in Table 10 and Table 11. Among the six test varieties, Kali Ray Maap (collected from Dagana) was found very promising for the AWD technology in terms of yield and regards to the agronomic

character such as medium plant height, resistance for logging and grain quality. In addition, a field day on participatory varietal selection for the varieties adaptable/evaluation for AWD technology was conducted and most of the participants suggested better crop stand and expect better yield considering the physical appearances of the Kali Ray Maap.

Table 11 Effects of full flooding on different rice varieties

Entry	Sigsima	Ray Kaap	Thakmaro	Kali Ray Maap	Gawri masino	Sukimey
50% flowering day	134	124	124	129	135	135
Plant height (cm)	109	107	104	133	114	113
Tiller Nos	12	10	8	9	9	11
Nos of panicle/hill	12	10	8	9	9	11
Days to maturity	162	162	162	183	183	177
Disease score	Nil	Nil	Nil	Nil	Leaf blast	Brown sport
MC%	23.5	26.3	22.6	23.1	22.4	18.2
Yield kg/plot	2.64	2.82	2.63	2.86	2.875	2.24
Yield (kg/ac)	1583	1326	1596	1724	1749	1437

From on-farm evaluation results of local rice varieties under alternative wetting and drying technology and based on farmer's feedback and taking into account the yield potential of those varieties, the Kali Ray Maap was found a suitable variety for the AWD technology and anticipated better performance in areas where there is the limitation on irrigation water. The normal irrigated field showed a higher yield.

vii. Production Evaluation Trial of YP/K-Y/B-20

ARDSC-Menchhuna carried out an on-station production evaluation trial of the YP/K-Y/B-20 line of rice variety which was distributed by NCOA, Yusipang. The trial was carried out following the research protocol with the following treatment following all the research protocols. The agronomic performance result is computed in Annexure 5.

Table 12 Mean yields of production evaluation of YP/K-Y/B-20

Treatment	Yield (kg/ac)
YP/K-Y/B-20	1376.00
WRKIII	1116.67

There is a significant difference in yield as computed in the AVONA table whereby the YP/K-Y/B-20 yield is 1376.00 compared to the control yield at 1116.67.

viii. Local rice varieties characterization

ARDSC-Menchhuna has carried out an on-station trial of the local rice characterization of local varieties. Seven promising varieties are selected for the study to document the local rice characterization. All the Agronomic traits data are recorded. Upon maturating the crop cut was

carried out with a 3mX2m area taking six samples each and the result was computed on average as recorded in Table 13.

Table 13 Agronomic performance of local rice characterization

Treatment	Plant height (cm)	Tiller/hill (nos)	Panicle length (cm)	Panicle shattering	Panicle thresh-ability	Yield/AC (KG)
Sigsima	109	12	24	low	easy	1583
Ray Kaap	107	10	24	low	easy	1326
Thakmaro	104	8	23	low	easy	1596
Kali ray map	133	9	25.6	low	int	1724
Gawri masino	114	9	24	low	easy	1749
Drujegang red	112	9	24	int	easy	1120
Sukimey	113	11	23	high	easy	1437
Bathram (Teza)	109	10	22	low	easy	1080
Kamshing	90	12	25	low	easy	1209
Bogarmo	92	12	22	low	easy	1087
Ray naab	89	7	24	low	easy	1034
Attey	103	10	24	low	easy	1444
Chaskarpa	93	8	23	low	easy	1508
Bondey	104	10	24	low	easy	1421
Sasanishiki	severely affected by brown spot in vegetive stage					
Chenghey bonday	106	9	24	int	easy	1370
YP/k-Y/B-20	122	11	24	moderate	easy	1593
Black rice	104	11	23	high	easy	887
Thangji ray maap	91	9	23	moderate	easy	1118

ix. Effect of Azolla on rice yield performance

With the introduction of Azolla for research purposes, the Field Crop sector has initiated research on the "Effect of Azolla on the growth parameter and yield components of rice" to quantify the effect of Azolla on the growth and yield of rice variety Wengkar Ray Kaap 2 under the wet sub-tropical environment at ARDSC Menchhuna. RCBD with three replication design trials were set in each plot of 5mX4m.

Table 14 ANOVA for yields of rice with Azolla

Source	DF	Sum of Square	Mean Square	F Value	Pr(> F)
Replication	2	0.0233	0.0117	1.00	0.5000
Variety	1	0.0017	0.0017	0.14	0.7418
Error	2	0.0233	0.0117		
Total	5	0.0483			

There is no significant difference in the yields of different treatments. The mean yield of WRK without Azolla was 2.77 t/ac while with Azolla was 2.80 t/ac.

x. Improving local rice varieties through cross-breeding

The introduction of modern rice varieties was begun in 1982. Many introduced rice varieties often fail due to the uniqueness and distinctiveness of local growing conditions. To overcome such

problems, a cross-breeding program was started in 1995 in Bhutan to understand desired genes in Bhutanese local varieties. Improved varieties account for about 42% of the national rice area.

IR 64 was the first modern rice variety released in 1988 in Bhutan. In 1999, four varieties were released of which only one (BR 153) was intended for the low altitude zone. BW 293 was released in 1990 for the low altitude zone. However, this variety did not gain popularity due to its short plant stature. In 2002, *Yusiray Kaap 1* and *Yusiray maap 1* which incorporated blast resistance genes in the native varieties were released. In 2010, two drought-tolerant varieties (Bhur Kambja 1 and 2) were released for low altitude. Released rice varieties have good yield potential and diverse genetic backgrounds.

Objectives of breeding/crossing rice:

i. Yield: Rice is a crop with high yield potential. Yet, the average yield of existing rice varieties in Bhutan is one of the lowest in the world. Yield is a complex character which may be influenced by many physiological processes within the plant. it is necessary to include genes for resistance to those conditions in the environment which unfavourably affect the yield, such as lodging, disease resistance, and others. In the Bhutanese breeding context, yield improvement of the local varieties is a priority.

ii. Quality in rice: Quality in rice, as with other cereals processed for human food, is a combination of many characteristics. The grower is concerned with those characteristics that affect the drying of the rice, its market quality, and its germination. If rice is used for home consumption, plumpness of grain, freedom from diseased kernels and cooking quality are also important. All those quality characteristics of rice are affected by the variety; but they are also affected by soil, climate, disease, and procedures in harvesting, drying, and processing. Therefore, it's important to consider genetic improvement in the grain characters and the milling and cooking characteristics of the rice.

iii. Reduce plant height and growth duration of local varieties: shorter plant height and sturdier culms are preferred as plants respond better to fertilization and do not lodge. The local rice varieties are exceptionally tall and lodging is a serious problem. Thus, the incorporation of genes for shortness in local cultivars is a breeding priority.

Parents: Females parent- Bonday, Tan-Tshering and Ngabja; Male parent: IR 64, BK3. In total 50 samples were taken and, as the result, we could do a total of 5 crosses made between the varieties. The half-naked seeds were harvested except the cross between Tan Tshering and IR64, Ngabja and BK3.

Table 15 Results of Rice cross-breeding

Female parent	Male parent	Remarks
Ngabja	IR64	1 panicle harvested
Tan-Tshering	IR64	No panicle harvested
Tan-Tshering	BK3	2 panicles harvested
Bonday	BK3	2 panicles harvested
Ngabja	BK3	No panicle harvested

Conclusion: The domestic rice production in Bhutan meets only about half of the national requirement despite the Royal Government of Bhutan wishing to raise the level of rice self-sufficiency in the country. One of the ways to increase production has been the use of high-yielding modern varieties. Rice research and development started in 1982 in Bhutan. The national rice research program is aimed at developing new varieties coupled with better crop management practices. Three local varieties (Ngabja, Tan 11ap11ring and Bonday) are used as female parents and have been crossed with IR 64, and BK3. The harvested half-naked seeds are sown in the pot for further evaluation and selection.

xi. The increased area under spring and upland rice in the region

Spring and upland rice cultivation play a vital role in achieving the objective of 12FYP to achieve 60 % of rice self-sufficiency. ARDC Bajo mandated for National Rice, the Centre has a target set of 1200 ac of area to be brought under upland and spring rice in 12FYP. To achieve the target, the Centre has set a target of 100 ac in the FY 2021-22 for spring and upland rice. During this season, the Centre achieved 119.67ac of the area in promotion of upland in the West-Central region. This is through seed supply and technical support. Unlike the previous years, farmers did not cultivate spring rice in the region due to certain circumstances like the COVID-19 National lockdown during the peak season (February). Rinchengang is the main area practices spring rice every year but this year they could not cultivate spring rice due to irrigation problems. Instead, they have cultivated wheat crops. The Centre could facilitate seven acres of spring rice at Chimipang Royal Project (CRP), Punakha.

Table 16 Promotion of spring and upland rice cultivation in FY 2021-2022

Dzongkhag	Gewog	Support	Qty (kg)	Area (ac)	Remarks
Punakha	CRP, Baarp	Seed & technical	175.00	7.00	Spring rice
Wangdue	Nahi	Seed &Technical	1000.00	166.70	Upland rice
Wangdue	Phangyul	Seed & technical	60.00	4.00	Upland rice
Dagana	Tshangkha	Seed & technical	330.00	22.00	Upland rice
Dagana	Kana	Seed & technical	75.00	5.00	Upland rice
Tsirang	Patshaling	Seed & technical	150.00	10.00	Upland rice
Tsirang	Sergithang	Seed & technical	75.00	5.00	Upland rice
Total			**1865.00**	**119.67**	

xii. Promoted improved high-yielding rice seeds

Rice is the main stable food crop of the country while there is a rice deficit of more than 50% which is met through imports from India. 12FYP aims to rice self-sufficiency from 47% to 60 %. ARDC Bajo has National Mandate for Rice, we need to initiate achieving this to contribute to the Government's goal of achieving a higher level of rice self-sufficiency, through increased rice productivity and production we have to go for improved high-yielding varieties. During the FY 2021-22, the Centre has supported 5MT of rice seed to the rice-growing farmers and Centre. The support was through procurement of improved high-yielding rice seeds and from the stock maintained at the Centre. The seed supply was on promotional basics and for those households whose nursery has been affected by armyworm, especially in Nahi Gewog, Wangdue Phodrang as recorded in the table below.

Table 17 Promotion of rice seeds in FY 2021-2022

Dzongkhag	Gewog	No. of HHs	Qty (kg)	Area (ac)	Rice Varieties
Dagana	Kana		206	8.24	Bajo Kaap3, Bajo Maap1, Bonday
Dagana	Drujegang		200	8	
Dagana	Karmaling		200	8	Bajo Kaap3
Dagana	Lhamoizingkha		77	3.08	Bajo Kaap3
Dagana	Tashithang	06	120	4.8	Khangma 12ap
Dagana	Tshangkha		530	21.2	Khangma Maap
Tsirang	Patshaling	10	161	6.44	Khangma Maap
Tsirang	Sergithang	4	120	4.8	Khangma Maap
Tsirang	Kilkorthang	16	500	20	Wengkhar Raykap2, Bajo kap2, IR 28. Bonday, Bulk 20
Tsirang	Rangthaling		200	8	Wengkhar Raykap 2, Bajo Kap3
Tsirang	Barshong		180	7.2	Wengkhar Raykap2, Bajo kap2, IR 28. Bonday, Bulk 20
Wangdue	Tshetsho		192	7.68	IR 64
Wangdue	Nahi	88	2153	86.1	Assorted
Wangdue	Phangyul		60	2.4	Khangma maap
Mongar	Wengkhar		102	4.08	Bajo Kaap 3
Total			5001	200.	

xiii. Seed production and maintenance of varieties

The Centre produce and maintain paddy seeds of promising varieties every year basically to maintain the seed for research to meet unforeseen circumstances and support the Dzongkhags during their time of need. The seed is from the trial plots, seed production and demonstration blocks. In the FY 2021-22, the Field Crop Sector produced **6.26** MT paddy seed was produced (Table 18) from ARDC Bajo, ARDSC Menchunna & CRP Chimpipang. Paddy seeds of the released varieties such as Bajo Kaap1 and 2; Bajo Maap1 and 2 Bajo Kaap3; IR-64; IR20913; Wengkhar Raykaap2 were produced to support promotional programs in the Dzongkhags. Bajo also produced some seeds of unreleased varieties like IR28, Ceres, and TME 80518 Vietnam Rice for seed multiplication.

Table 18 Paddy seed produced from released and potential varieties

SN	Variety	Qty (kg)	Centre	Remarks
1	IR 64	450.00	ARDC Bajo	Released variety
2	IR20913	150.00	ARDC Bajo	Released variety
3	Bajo Kaap 1	350.00	ARDC Bajo	Released variety
4	Bajo Kaap2	350.00	ARDC Bajo	Released variety
5	Bajo Maap 1	350.00	ARDC Bajo	Released variety
6	Bajo Maap 2	320.00	ARDC Bajo	Released variety
7	TMES 0518	450.00	ARDC Bajo	Released variety
8	Wengkhar Raykaap 2	560.00	ARDSC Menchhuna	Released variety
9	IR 28	680.00	ARDSC Menchhuna	Not released
10	Assorted	100.00	ARDSC Menchhuna	Local varieties
12	Assorted	1500.00	CRP	Released variety and local
13	Mixture	1000.00	ARDC Bajo	
	Total	**6260.00**		

2) Wheat

i. Observation and selection of 10th HPYT CIMMYT lines

The Centre received a set of bread wheat lines in the 2020-2021 season from CIMMYT with nursery name 10th HPYT (Harvest Plus Yield Trial) and trial ID 47756. Out of 98 different lines, only 38 lines were selected based on plot uniformity, lodging incidence, agronomic score and spike observation. These selected lines were sown in December 2021 along with the released variety Bumthangkaadruckhu as a local check. The observation nursery was set up based on protocol and trial design shared by the parent organization. And from 38 lines, a total of 16 lines were selected based purely on grain yield and previous parameters; plot uniformity, lodging incidence, agronomic score and spike observation. These selected lines will be further evaluated in a replicated IET in 2022-23 seasons to ascertain their performance. The measured agronomic traits in these lines were also found to be acceptable.

Table 19 Agronomic traits of 10th HPYT of bread wheat lines in 2021-2022

Entry	Days to Heading	Days to Maturity	Plant height (cm)	Spike length (cm)	Grain yield (t/ac)
30	97	145	81	10	2.02
85	92	145	79	9	1.74
54	92	145	79	10	1.62
42	102	145	82	10	1.34
21	92	145	77	9	1.70
10	102	145	82	10	1.62
37	102	145	79	10	1.62
32	102	145	78	9	1.70
86	97	145	80	10	1.62
15	102	145	75	9	1.62
75	97	145	74	8	1.62
23	92	145	76	9	1.50
79	97	145	75	8	1.50
82	92	145	83	10	1.50
49	102	145	80	10	1.50
6	102	145	85	8	1.42

ii. Introduction and selection of 11th HPYT CIMMYT lines

The International Wheat and Maize Improvement Centre (CIMMYT) based in Mexico distributes wheat germplasm to institutions, National Research Centres and interested individuals for evaluation and selection of their lines under different ecological and environmental conditions. In the 2021-2022 season, the Centre received a set of bread wheat lines originating from CIMMYT with the nursery name 11th HPYT (harvest plus yield trial) and trial ID 48397 for evaluation and varietal development under our condition. The nursery was established at ARDSC, Menchhuna on the 1st of October 2021 and harvested in April 2022. The introduction nursery was set up based on protocol and trial design shared by the parent organization. There were 50 lines or accessions in a set. Out of 50 lines, only eighteen lines were selected based on yield, lodging incidence and agronomic score. These selected lines will further be evaluated in the coming season to ascertain their performance under our condition.

Table 20 Agronomic traits of 11th HPYT of bread wheat lines in 2021-2022

Entry	Days to Heading	Plant height (cm)	Grain yield (g/plot)	1000 Grain weight (g)	Agronomic score (5=Best)
404	103	90.5	736	51	4
406	94	83	862	48	5
409	100	83	541	48	3.5
411	110	86.5	443	49	4.5
412	83	76.5	556	48	3
413	94	85	567	50	4
414	91	84.5	888	48	4.5
417	92	87	605	46	4.5
418	94	78.5	515	44	2.5
419	99	85.5	518	52	4
430	92	91	525	44	4.5
433	93	82.5	513	56	4.5
434	94	83.5	538	46	4
435	106	90.5	605	59	4.5
438	74	76.5	595	45	3.5
443	75	85.5	510	52	4
426	91	87	518	48	3
446	82	85.5	642	51	4

iii. Participatory Evaluation Trials (PET) of Biofortified wheat lines

Biofortification is a strategy to increase the level of minerals and vitamins in crops by applying genomic, biotechnology and breeding techniques (Bouis and Saltzman 2017; Garg et al. 2018). It addresses the serious health problem of mineral and vitamin deficiencies. Biofortification is a sustainable and long-term approach to overcoming micronutrient deficiency compared with fortification or dietary supplements that require ongoing investment (de Valença et al. 2017).

International Centre for Wheat and Maize (CIMMYT) initiated biofortification in wheat breeding in 2006. Since then, several biofortified lines have been developed to increase people's intake of Zinc and Iron. Participatory Evaluation trials (PETs) on biofortified have been carried out in major wheat-growing areas around the globe. For adaptability and performance observation, the lines were distributed in wheat-growing countries. Bhutan being part of CIMMYT activity and global wheat network received 50 biofortified entries during the 2014-15 seasons.

Table 21 Agronomic traits of Biofortified wheat lines in 2021-2022

Entry	Days to Heading	Days to Maturity	Plant height (cm)	Spike length (cm)	1000grain weight (gm)	Grain yield (t /ac)
BF450	97	145	80	7	1.6	1.74
BF447	92	145	76	9	1.5	1.90
BF415	92	145	80	8	1.6	1.62
BF422	102	145	71	7	1.5	2.11
BF412	92	145	72	9	1.4	2.15
BF411	102	145	72	8	1.4	1.62
Check (Bumthangkaadrukchu)	102	145	87	8	1.7	1.82

From these lines, 6 best performing lines were evaluated under PET in 2020- 2021 and further scrutinized in a replicated trial in the 2021-2022 seasons. Multi-location production trials will be carried out in the 2022-23 season.

iv. Wheat production, maintenance and promotion

Wheat seeds of released varieties such as Bajosokha, Gumasokha and Bumtangkaadrukchu were produced and maintained to support promotional programs in the Dzongkhags in the coming season. In addition to the released varieties, a promising wheat line NL-1073 was also produced for seed multiplication and supply to the farmers for on-farm trials. Following quantities of seed of released and promising wheat lines were produced in the 2021-2022 season (Table 22).

Table 22 Quantity of wheat seed produced

Sl.no	Varieties /Lines	Qty produced (Kg)	Centre	Remarks
1.	Bajosokha kaa	270.00	ARDC, Bajo	Released variety
2.	Gumasokha kaa	190.00	ARDC, Bajo	Released variety
3.	Bumthangkaadrukchu	390.00	ARDC, Bajo	
4.	NL-1073	60.00	ARDC, Bajo	Promising line
5.	Mixture (trial borders)	349.00	ARDC, Bajo	
6	Assorted (NL-1073, Bajosokha)	300.00	ARDSC, Menchhuna	
7	Bumthangkaadrukchu	1000.00	CRP, Chimipang	Released variety
Total		**2559.00**		

During the FY 2021-22 the Centre has distributed the 1220.00 kg of wheat seed through procurement and the Centre. More than 1500 kg of seed is balanced in the stock which will be distributed to farmers on a promotional basis after maintaining seed for the next coming season.

Table 23 Wheat seed distribution in 2021-2022

Dzongkhag	Gewog	No. of HHs	Qty (kg)	Remarks
Tsirang	Sergithang	06	100.00	
Tsirang	Rangthaling & Mendrelgang	06	110.00	
Wangdue	Phangyuel gewog	09	180.00	
Tsirang	Goseling	02	40.00	
Trongsa	Tangsibji	02	20.00	
Tsirang	ARDSC, Menchunna		10.00	For trial purpose
Punakha	Chimipang Royal Project		50.00	For seed purpose
Wangdue	National Seed Centre (NSC)		710.00	
Total			**1220.00**	

3) Maize

Maize is a major food crop of the country and is cultivated by more than 70% of the rural households for subsistence. It is cultivated across the country and it ranks first in terms of the area and production of food crops. Although the extent of cultivation varies widely, maize is cultivated in all the 20 Dzongkhags, farmers cultivate only the popular varieties The RNR Statistics 2000 show that out of the 202 Gewog a total of 189 Geogs produce maize. Most of the maize is cultivated in the drylands, followed by *Tseri* and to a small extent in wetlands, especially in the south. The cultivation ranges from less than 300 m up to 3000 m owing to its versatile capacity to adapt to different environments. Maize is also cultivated as a second crop in the lower altitudes and is estimated to cover about 15% of the total area under maize normal maize.

Maize is broadly divided into eight groups based on the type of endosperm of kernels. These are dent corn, flint corn, popcorn, flour corn, sweet corn, baby corn and pod corn. Among these flint corn and dent corn are widely grown in Bhutan and are mostly yellow or white colours. There are varieties with mixed colours due to cross-pollination. Popcorn is cultivated in a small area mainly for popping. Baby corn used to be previously grown by a few farmers in peri-urban areas of Paro and Thimphu for Bhutan Agro Industry Limited. Some research Centres introduced and evaluated sweet corn but have not released any varieties.

Maize can be either Open Pollinated (OP) or Hybrid. Traditional and improved maize varieties cultivated in Bhutan are mostly Open Pollinated Varieties (OPVs) and are common maize or normal maize. Farmers can select, maintain and use the seeds of OPVs for replanting over the years without major loss of varietal characteristics and yield.

i. Baby corn and sweet corn performance evaluation trial

Since there is not much maize research done in Bhutan, two types of maize sweet corn and baby corn were evaluated at ARDC Bajo in a single large plot to evaluate performance. 50 cm row to row and 30cm plant to plant distance was maintained. The recommended dose of FYM and synthetic fertilizer was applied in time. Weeding two times 35 days after sowing; 60 days after sowing, thinning was carried out. Timely data were collected. No major pests and diseases were observed during the growth stages. Three crop cut samples were taken with a sample size of 1.5m^2 each and then computed to kg per ac.

Table 24 Agronomic traits of baby corn and sweet corn

Maize type	Plant height (m)	No. of cobs per sample	Gross weight (kg) /sample	Mean yield per sample	Yield (kg/ac)
Baby corn	1.13	9.00	7.92	0.78	2104.44
Sweet Corn	1.78	16.00	7.67	0.33	899.33

Note: *Weight right after harvest*

ii. Maize performance evaluation trial

As usual, ARDSC-Menchunna carried out maize research and development activities annually. In the FY 2020-21 the Subcentre has conducted an on-station maize performance trial of three promising varieties. Timely data were collected. No pests and diseases were observed during the growth

stages. Three crop cut samples were taken with a sample size of $7m^2$ each and then computed to kg per ac as reflected in table 13.

Table 25 Agronomic traits of promising maize varieties

Varieties	Plant height (m)	No. of cob	Cob length (cm)	Mean yield Kg/Ac
Ganesh II	2.40	17	17.20	2601.55
Yangtsipa	2.15	24	20.00	2774.99
Chaskharpa Ashom	2.04	23	18.00	3757.80

iii. Improved maize varieties seed production and promotion

As entrusted with the developmental mandate, ARDSC Tsirang produced and maintained seeds of different released maize varieties. These seeds are exclusively used in the on-farm demonstration, support to client Dzongkhags on request and other ad-hoc requests from both Department and Commodity Programs. In 2021-22, 1070 kg of maize seed is distributed to farmers on a promotional basis for Tsirang Dzongkhag which covered more than 100 acres of dryland. This is expected to make a substantial contribution to overall cereals production.

Table 26 Promotion of improved maize seed, Tsirang Dzongkhag 2021-2022

SN	Variety	Qty issued (kg)	HHs covered	Area (ac)
1	Ganesh II	465	22	46.50
2	Yangtsipa	280	20	28.00
3	Chaskharpa Ashom	325	12	32.50
Total		1070	40	107.00

4) Quinoa

i. Evaluation of Quinoa varieties

The Quinoa varietal testing was done at ARDSC Tsirang since 2016 in collaboration with parent ARDC Bajo and sister ARDCs. In the past financial year, there was a good harvest and could conduct some on-farm promotional programs. In 2021-2022 there was hardly any harvest from all the varieties of Quinoa

Table 27 Agronomic traits of quinoa varieties

Parameters	Ivory 123	DoA-PMB-2015	A. Marangoni
Date of sowing	5/10/21	5/10/21	5/10/21
Date of harvesting	10/02/22	5/02/22	10/03/22
Plant height	75.20	100 cm	120
Crop duration	4 months	4-5 month	5-6 month
Grain size	small	small	Bold grain
Panicle length	8 cm	10	12 cm
Yield/ac	.8kg	1000kg	1200kg

Multi Environmental Trial (MET) of Quinoa and Amaranth varietal trial was established at ARDSC Tsirang since 2020 to be conducted for two years in-collaborative with NCOA, Yusipang. For quinoa two years of trial were conducted and could not do the second year MET for Amaranth

due to organizational structure, and change in the Quinoa Coordinator. The data for the first and second harvest of Quinoa and the first harvest of Amaranth was taken by the Quinoa Coordinators (NCOA, Yusipang and ARDC Wengkhar).

5) Grain legumes and oil seed

i. Participatory technical assessment of evolutionary plant breeding-bean

ARDSC-Menchunna in collaboration with the National Biodiversity Centre (NBC) and has conducted "Participatory technical assessment of evolutionary plant breeding (EPB)" trials on grain beans in Tsirang and Dagana. The EPB project is for four years and the overall goal of the project is to sustainably increase rice and beans productivity and to enhance the resilience of the farming communities to climate change. The evolutionary populations for the crops were prepared by mixing the most popular traditional and improved varieties collected and contributed by farmers and ARDSC from specific locations. The study is ongoing for pole beans and dwarf beans in Tsirang and Dagana Dzongkhags. The NBC research protocol is followed for the trials and all the data were recorded as per the format. Hand weeding is carried out to control the weed and irrigation was not given because of ample rainfall.

Table 28 ANOVA table for yields of climber beans

Source	DF	SS	MS	F-value	Pr(>F)
Rep	2	59655.54	29827.77	2.61	0.1225
Treatment	5	1355348.14	271069.62	23.72	0.000
Error	10	114294.18	11429.41		
Total	17	1529297.87			

CV(%) = 13.03 Mean = 820.39 kg/ac

ANOVA for yields indicated there are significant differences at $\alpha = 0.5\%$. The pairwise mean comparison for the yield of climber beans is in Table 29.

Table 29 Tukey's Honest Significant Difference (HSD) Test Summary

Treatment	Mean	N group
Boshi Bori	930.31	3 a
Gew Bori	222.80	3 b
Kalo Gew Bori	1050.34	3 a
Mixture	927.61	3 a
Pole Bean (Gray)	954.32	3 a
Pole bean (White)	836.98	3 a

Kalo Gew Bori has the highest mean yield but was not significantly higher than other cultivars except Gew Bori. Similar to climber beans, ANOVA (Table 30) for yields indicated there are significant differences at $\alpha = 0.5\%$ for draw beans as well.

Table 30 ANOVA table for the yield of dwarf beans

Source	DF	SS	MS	F-value	Pr(>F)
Rep	2	10926.4195	5463.2097	2.99	0.1071
Treatment	4	62267.5996	15566.8999	8.53	0.0055
Error	8	14607.2509	1825.9064		
Total	14	87801.2700			
CV(%) = 29.48			Mean yield =144.95 kg/ac		

The pairwise mean comparison for the yield of climber beans is in Table 31. Adzuki bean has the highest mean yield compared to other cultivars. Gew Bori has the least mean yield.

Table 31 Least Significant Difference (LSD) Test summary

Treatment	Mean	N group
Azuki bean	256.92	3a
Gew Bori	70.81	3c
Mixture	149.70	3bc
Pink Rajma	153.61	3b
Rajma	93.73	3bc

In both treatments (pole beans & dwarf beans) varieties the flowering type was indeterminate and pest/disease attack observed was negligible. The grain yield computed was higher for pole beans compared to the yield from the dwarf varieties as indicated in Table 29 and Table 31.

ii. Soybean production and maintenance trial

The National coordination trial on the evaluation of Soybean varieties at ARDSC-Menchhuna to study the performance and adaptability in Tsirang and seed purification and maintenance was continued on-station with five soybean varieties.

Variety	Local Brown	Khangma Libi-2	TGX-1740F early	Khangma Libi-1	Japanese White
Yeld (kg/ac)	647.76	161.87	95.65	517.15	165.57

Local brown performs well with the highest yield of 647.76 kg/ac followed by Khangma Libi-1 with 517.15kg/ac compared to others.

iii. On-station beans production evaluation trial

Bush beans generally require less maintenance and are easier to grow whereas pole beans typically yield more beans and are very disease resistant. ARDSC-Menchunna set up the observation trial with four varieties namely Gue bori, brow pole bean, white pole bean and white dwarf bean for seed purification and maintenance following all the resderch protocal.

Table 32 Yield data of different bean varieties

Varieties	Production kg/m2			Average production kg/m2	Yield per acre (kg/acre)
	Plot 1	Plot 2	Plot 3		
Yellow beans	0.335	0.37	0.36	0.35	706
Gew bori	0.36	0.385	0.33	0.36	714
Brown beans	0.46	0.43	0.51	0.47	934
White beans	0.2	0.38	0.32	0.30	600

iv. On-station mustard production seed and purification trial

As regular activities, ARDSC-Menchhuna carried out the on-station mustard seed production and purification trial of three mustard varieties to evaluate the yield performance and seed purification.

Table 33 Yield data of mustard varieties

Variety	Production kg/6m2			Average yield (kg/6m2)	Yield per acre (kg/acre)
	Sample I	Sample II	Sample III		
Lumley	0.83	0.79	0.82	0.81	548.59
Bharasharisha	0.87	0.85	0.81	0.84	568.83
Pragati	0.45	0.39	0.44	0.43	288.91

The Lumley and Bharasharisha varieties performed well compared to Pragati.

v. Peanut production evaluation trial

Peanut, *Arachis hypogea*, is a herbaceous annual plant in the family Fabaceae grown for its oil and edible nuts. To achieve maximum yields, peanut fields should be kept as free as possible from competing weeds. Plants should be supplied with additional irrigation if dry conditions coincide with flowering and pod fill. Peanuts do not generally require the addition of supplemental nitrogen as their roots form symbioses bacteria which are capable of fixing atmospheric nitrogen in the soil. ARDSC-Menchhuna maintains five varieties on production and maintenance trials to evaluate the performance of different varieties.

Table 34 Yield data of different peanut varieties

SN	Crop	Yield per plot (kg/3 m2)			Average yield per plot (kg)	Yield(kg/Acre)
		Plot 1	Plot 2	Plot 3		
1	Challipa Badam	0.32	0.52	0.47	0.44	580.00
2	Bartshampa White Badam	0.35	0.24	0.28	0.29	380.00
3	Yabrangpa Red Badam	0.31	0.31	0.50	0.37	493.33
4	Yabrangpa White and Purple Badam	0.30	0.26	0.44	0.33	436.00
5	Nanungpa Badam	0.37	0.45	0.45	0.42	560.00

HORTICULTURE RESEARCH AND DEVELOPMENT PROGRAM

1) Fruits, Nuts, Spices, Flowers

i. Evaluation of subtropical and temperate fruits and nuts germplasm

ARDC-Bajo with full support from Integrated Horticulture Promotional Project (IHPP)-JICA from January 2016 to June 2021 established both warm temperate and sub-tropical fruit and nut germplasm orchards. The orchards serve as technology generation and demonstration sites for providing hands-on training for researchers, extension agents and farmers. It is also to evaluate and identify superior cultivars for diversification of fruit cultivation. At present, there is 25 cultivators' germplasm maintained at ARDC Bajo.

Table 35 Fruit crop varieties established in the germplasm block at ARDC Bajo

Crops	**Varieties**
Peach	Kurataki (3), Nonomewase (3), Floridasan (3), Beauty cream (3), Local (4)
Apple	Bajo apple (12)
Apricot	Khasha (2), New Castle (2)
Pear	Yakumo (3), Niitaka (3), Hosui (3), Kosui (3), Shinko (3), Chojuro (3), Local (4)
Kiwi	Hayward (19), Wengkhar Yellow (29), Wengkhar Green (24), Bajo Red (19), Male (8)
Grape	Steuben (15), Perlette (10), Campbell (32), Kyoho (7) Risamate (2), Nsehelena (2), Portland (7)
Dragon fruit	Gewai ringa (44)
Pomelo	R3P4 (40), R4P5 (40), Banpeiyu (25)
Lemon	Frost Eureka (28)
Loquat	Mogi (8), Tanaka (14)
Avocado	Brogdown (9), Hass (10), Bacon (7), Fuerte (10), Reed (6) Zutano (10), T1 (5), T2 (8), T3 (10), M1 (6), M2 (5)
Persimmon	Jiro (25), Fuyu (28), Yubeni (11), Zinjimaru (4), Taishu (3), Japan Astringent (2), Thimphu astringent (2), Local (4)
Plum	Honey Rosa (3), Santa Rosa (3), Soldum (3), Kiyo (3), Oishi wase (3)
Wine grape	Cabernet Sauvignon 337 (48), Syrah 470 (48), Cot 598 (48), Sauvignon Blanc 906 (48), Chardonnay 96 (48), Pinot Noir 72 (48), Merlot 181 (48), Petit Manseng 573 (40), Cab Franc (40)
Guava	Thai guava (48), Bajo white (4), Bajo red (4), Babji white (2), Guma red (2), Pink flesh (2), Thai giant (2), Allahabad Safeda (2)
Mango	Himsagar (3), Dashehari (5), Langra (14), Amrapali (3), Irwin (2), Tommy Atkin (3), Himsagar (3), Dunkin (3), Alphanso (2)
Chestnut	Unknown (2)
Pomegranate	Amarsurin, Chawla, Bedana, Bajosendu-1
Pecannut	Burket, Mahan, Nellis, Bajo Thasa Taku-1, Bajo Thasa Taku – 2, Kingwa, Cheyenne, Desirable
Sacha Inchi	One cultivar
Lemon	R3P4, R4P5, Banpeiyu
Walnut	Bajo-1(17)
Citrus	Cant star ruby, MC Mahon, Affourer, Taracco Ippolito, Caffin, Dorokha local
GS677	Root stock for stone fruits
Ziziphus budhensis	One cultivar (10)

The new cultivars introduced by the project will be identified, evaluated and proposed for the release for the fruit plant diversification in the country. The germplasm is maintained as a mother block for budwood and fruit production. The scion wood from this mother block is used for the grafting purposes at the Centre, if need be, provided to the nursery growers for seedling multiplication. The promising varieties with better adaptability characters will be released after thorough research in the coming future. Data from the evaluation germplasm is recorded and maintained by the sector for the analysis and to release the variety after meeting the required traits.

ii. Fruits and nuts germplasm maintained at ARSDC-Menchhuna

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

iii. Observation trial of Sacha Inchi

Sacha Inchi (*Plukenetia volubilis*) also known as Inca peanut, or mountain peanut belongs to the Euphorbiaceae family. It is a native plant of the Amazon basin in South America. It is a perennial vine, monoecious, open-pollinated or cross-pollinated. Sacha Inchi is found widely cultivated in Peru and Southern Columbia and can be grown at an elevation of 200 masl to 1500 masl with a temperature range of 10-15 ^{o}C. The seed contains 25-30 % protein, 35-60% lipids and vitamin E which is suitable for dietary use. Sacha Inchi can be used to extract oil or can be consumed by roasting, boiling and steaming. Propagation is through seed or vegetative means, but mostly vegetative means are preferred. With the seedling support from ARDC, Wengkhar, an observation trial was set up on-station in the FY 2020-21 with a planting distance of 2mX3m. In total 19 plants are set up for the trial. The data are collected on yield, phenology, number of seeds per plant, seed size, and seed weight as per the protocol.

Table 36 Data on yield and yield parameters of Inchi

Total Plants (nos.)	17
Total weight with shell cover (g)	31605.9
Total weight of seeds (g)	15101.5
Mean (with shell cover)	1859.17
SD (with shell cover)	909.17
Mean (seed)	888.32
SD (seed)	458.31
Mean (seed weight in grams)	1.09
SD (seed wt.)	0.14

Inchi (*Plukenetia volubilis*) also known as wild peanut, mountain peanut or false peanut belongs to the Euphorbiaceae family. It is a native plant of the Amazon basin in South America. It is a perennial vine, monoecious, open-pollinated or cross-pollinated. Sacha Inchi is found widely cultivated in Peru and Southern Columbia and can be grown at an elevation of 200 masl to 1500 masl with a temperature range of 10-15 ^{o}C. The production is obtained from 17 plants as tabulated

in Table 36. A plant yields 1859.17± 882.03g with shells and 888.32±444.62g without shells. Shelling loss is 970.85±461.67g per plant. The mean seed weight is 1.09g.

iv. Citrus Varietal Evaluation Trial

Varietal evaluation of six different types of citruses (Citrus reticulata) is ongoing at ARDC-Bajo for the third year to evaluate the promising varieties for release. Except Dorokha Local, the source of all cultivars is from Australia.

Table 37 Experimental design for Citrus varietal evaluation

Variety	Cant star ruby, MC Mahon, Affourer, Taracco Ippolito, Caffin, Dorokha local (check)
Design	RCBD
No. of treatment	6
No. of plants per variety	5
No. of Replication	5
Layout	P-P= 3 m, R-R = 4 m
Established	27.7.2020

Data are collected based on the plant health, adaptability in the region and pests and diseases The Mc. Mohan and Cant Star Ruby varieties indicated poor performance and were highly susceptible to trunk borer in comparison with the rest of the varieties. The Affourer and Dorokha local remain better variety in Bajo condition but not the best. However, the experimented variety will remain for some more years in the station and after a thorough examination, it will be taken as FFT.

v. Citrus trials at ARDSC-Menchhuna

There are in total about 2 trials in ARDSC, Tsirang.

1. Citrus rootstock compatibility trial (Established in 2008)
2. Citrus varietal evaluation trial (Established in 2009)

These two trials are maintained at the subcentre and the data collection is ongoing.

vi. On-farm Citrus Varietal Trial at Baychu Royal Orchard

The ARDC Bajo established a citrus variety trial consisting of Hayaka, Mc.Mohan and Okitsu Wase at Baychu Royal Orchard in 2021. The initial data was recorded on the 8th of May 2022 and the following was the information recorded variety-wise.

Table 38 Baychu Citris Trial Initial Data

Variety	**Average plant height (cm)**	**Average canopy (cm)**
Hayaka	144.30	84.60
Mc.Mohan	63.30	38.30
Okitsu wase	65.00	63.60

vii. An on-farm citrus varietal trial at Punakha

ARDC, Bajo is continuing observation and data recording in citrus orchard management at Punakha (Khamsum Yulley Namgyel Chorten). The orchard consists of varieties viz. Clementine,

Taraku, Otsu, Othaponkan, Teishuponkan, Bearss lime. The evaluation is focused on the growth rate including canopy, pests and disease incidences. The orchard was established in 2020 and in a two-year time almost all the varieties have flowered and even some of the lime varieties already started bearing fruits which were removed as per the technical recommendation.

viii. Citrus Phenology Study

A citrus phenology study was carried out based on the 4th ARCM resolution in all ARDC to find out whether the phenology stages in different ARDC regions on the possible changes of the phenology characters developed earlier by ACIAR could have been changed due to changes in the weather patterns. However, the study showed that there is not much alteration in the phenology stages except in a few cases. For data collection, a citrus phenology monitoring template was used to maintain uniformity.

Table 39 Citrus phenological traits

Phenological stages	Details of phonological stages	Phenological stages developed by ACIAR	Study findings
Bud Break	When 50%of buds are 3mm in length	February to March	March
Start Flowering	When 5% of flowers are open across the block	March to April	March-April
Full Bloom	When 50% of flowers are open across the block	April to May	April
Petal Fall	When 80% of petals have fallen off the trees in the block	April-May	April to May
Cell Division	Fruit sink into water	May to June	May to June
Cell Expansion	When fruit float in water	June to October	June to October
Final Fruit Drop	When a large number of fruit lets have fallen from the tree	June to July	June to July
Colour Break	When 50% of fruit are light green to light yellow	November	November
Fruit Maturity	When desired Brix/acid ration achieved	Dec. to Jan.	Dec. to Jan.
Harvest	Start of harvest	Dec. to Jan.	Dec. to Jan.

There were not much of differences in the phonological stages in comparison with those developed by the ACIAR. However, the study showed that some difference in bud break which was in February - March shifted to March and accordingly full bloom timing which was in April - May shifted to April as shown in the above citrus monitoring template. This activity should include in the annual work plan and need to report the updates annually by the Research Centres of respective regions and plan activity according to the effect of weather patterns.

ix. Citrus orchards establishment

Citrus is an important export commodity of our country. Despite being an important fruit crop, citrus farming has been greatly affected due to poor orchard management and some vigorous pest and disease infestation. The citrus growing area has been decreasing since the detection of citrus greening disease in the country as all citrus which is tested positive for the presence of HLB virus have been recommended to destroy the plant by the government to prevent further spread of the virus. ARDC- Bajo being the National coordinating Centre for citrus, took an initiative to revive citrus production in the country with different activities like canopy management, citrus germ plasm collection etc. For the financial year 2021-2022, the National Citrus Program under the Department of Agriculture allocated Nu.0.2M for the establishment of two acres of citrus orchards as a demonstration in the region.

The program was led by the National Citrus Repository of ARDSC-Menchhuna under the guidance National Citrus Coordinator. The program was implemented in collaboration with Dzongkhag Agriculture Sector and the Gewog Agriculture Extension office. The DAO office selected the gewog and the GAE selected the site based on the selection criteria. The program was implemented at two sites in each dzongkhag of Punakha, Wangdue Phodrang, Tsirang and Dagana dzongkhags. Based on the list of selected sites sent by the DAO office, a feasibility study was conducted where the soil of each site was lab tested for nutrient content. Ten farmers were selected for the demonstration orchard development. Two promising varieties of citrus were selected for orchard establishment. The details of the two selected varieties are:

1) Okitwasu: - It is a delicious and early ripening variety that is suitable to warm temperate to subtropical climatic zones. With its thin skin, it's easy to peel and the flesh is very juicy. The fruit is larger than most other citrus varieties with a 70.53mm average diameter weighing an average of 152.7 gm. It is reported to be taster as reported average TSS of Okitsu wase is 9.47 with excellent flavours and juicy with average juice per fruit is 51.93 per cent of the fruit weight. It is colder and hardy than other varieties of citrus as it can tolerate at least 20^0 F or less, making it more suitable for higher altitudes.

2) Bears lime: - It is one of the new varieties of mandarin in the country and is most sought after by many peoples. The fruit is aromatic and juicy. It is also cold and hardy than other varieties of lime and grows well in sub-tropical climatic zones. The fruits are larger than Mexican lime with 2-2.5 inches in diameter and are seedless.

The propagation of selected varieties of mandarin was done under protected structures of the National Citrus Repository. The scion woods were collected from HLB-negative tested mother plants. Grafting and post-grafting management were carried out in a clean environment making sure to avoid pest and disease infection. Orchard layout was carried out in February 2021 by a team from NCR-Menchhuna, based on the slope, opinion of farmers and availability of land. The triangular orchard layout method was used with a spacing of 5 m by 5m.

Farmers were briefed on pit digging methods and pit filling after a month using organic manures like FYM, Leaf moulds and top soil. Based on the distance between the orchard site and the nearest irrigation source, each orchard was provided with a 100 m length HDP pipe to carry out the watering of the demonstration orchard.

Table 40 Beneficiary list of citrus orchard establishment program

SN	Dzongkhag	Gewog	Name of farmer	House no.	Alt (masl)	No. of plant	Area (ac)
1	Tsirang	Kikorthang	Leki Tshomo	Ba-6-325	1543	41	0.25
2	Tsirang	Kikorthang	Rub Maya Limbu	Ba-6-nil	1450	67	0.41
3	Tsirang	Kikorthang	Dal Bdr	Ba-6-86	1505	44	0.27
4	Dagana	Tshangkha	Moni Kumar Gurung	Ga-10-115	1570	32	0.19
5	Dagana	Tshangkha	Dhan Bdr Tamang	Ga-10-121	1575	33	0.20
6	Dagana	Tshangkha	Jat Bdr	Ga-10-128	1514	31	0.19
7	Punakha	Talo	Sangay Tenzin	Tha-9-47	1680	32	0.19
8	Punakha	Talo	Mindu Zam	*Tha-9-*	1660	32	0.19
9	Wangdue Phodrang	Daga	Passang Wangmo	*Sa-3-100*	1512	32	0.19
10	Wangdue Phodrang	Daga	Tshering Penjor	*Sa-3-84*	980	30	0.18
Total						**374**	**2.26**

These 10 demonstration orchards will be monitored by ARDC Bajo in collaboration with National Citrus Program. Besides these citrus orchards, the Centre developed one Grape demonstration orchard at Wangdue Phodrang.

x. Improvement of local cultivars through top working

During the FY 2021-22, the horticulture sector collected more than 10000 scion wood from promising varieties of temperate fruit crops but due to the national lockdown in February 2022, the Centre could not top work all the scion wood to rejuvenate the old trees as well as to improve the existing local cultivars in the farmers' field. The number of topworked and scion wood issued is presented in Table 41.

Table 41 Details of local cultivars improved through top working

SN	Dzongkhag	Gewog (site)	Cultivars	No. of trees topworked	Remarks
1	Wangdue	Nisho	Walnut	100	
2	Wangdue	Kazhi	Walnut	150	
3	Trongsa	Tshangkha	Assorted	50	
4	Tsirang	Menchunna	Assorted	150	
5	Paro	NSC	Walnut	200	Scion wood issued
Total				**650**	

xi. Production of quality seeds and seedlings

The grafted and non-grafted seedlings of both released and promising cultivars of fruits and nuts are produced and maintained yearly at the Research Centre. Scion woods are collected from these varieties from November to January. Grafting activities are done towards the end of February (green house) and February-March (open field). In the FY 2021-2022, a total of 8270 grafted and seedlings fruit plants were produced. The fruit nursery block serves as management technology

generation and demonstration sites for providing hands-on training for researchers, extension agents and farmers. It is also to generate nursery management technologies for the production of quality seeds and seedlings.

Table 42 Details of fruit seedlings produced

SN	Crops	Qty produced (Nos)		Remarks
		ARDC Bajo	ARDSC Menchhuna	
1	Citrus	500	0	seedlings
2	Avocado	400	1200	seedlings
3	Dragon fruit	1300	0	cuttings
4	Loquat	400	0	seedlings
5	Guava	100	0	seedlings
6	Persimmon	500	380	200 grafted, 680 rootstocks
7	Grape	100	0	grafted
8	Pear	0	360	180 grated, 180 rootstocks
9	Peach and plum	0	2280	rootstock 2000, grafted 100
10	Kiwi	0	750	rootstock
	Total	**3300**	**4970**	**8270**

xii. Evaluate and maintain Citrus Repository Germplasm

While progress in citrus research on production management is progressing, a system of a nursery to marketing through production must be further explored and institutionalized to sustain increased production and yield especially when the whole world's citrus industries are getting streamlined due to dreaded graft transmissible diseases (Huanglongbing (HLB) Citrus Tristeza virus, citrus exocortis viroid, phytoplasmas). Therefore, this citrus repository is a cornerstone for initiating and institutionalization of the citrus nursery system to enable the supply of health-tested citrus planting material in the country. The overall objective is to increase citrus production and productivity through sustainable research and development. As of June 30, 2021, NCR has been able to collect 115 numbers of citrus germplasm cultivar species through bud wood cutting and seed in total. These cultivars are maintained in the National Citrus Repository as evaluation, foundation, mother plant, root stock and in quarantine as indicated in Figure1. The cultivars are collected from Australia, Japan, Nepal and locally from Bhutan.

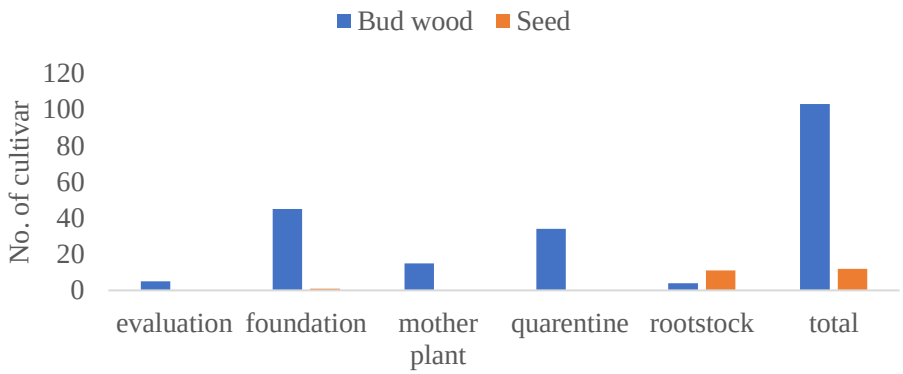

Figure 1 Crop stage of citrus germplasm at NCR

The National Citrus Repository has successfully achieved its annual target of 115 citrus germplasm collection under the Annual Performance Agreement (APA), of which 69 and 46 citrus germplasms are collected locally and globally respectively. However, 34 collections are in quarantine house growing for Huanglongbing (HLB) test in the future. Nine collections are in biological indexing house screening for HLB through biological indexing and TR PCR by NPPC. 4th batch of TR PCR test is completed by NPPC scientists and has detected 2 samples as HLB positive which will be retested by NPPC scientists in the next batch. Negatively tested plants will move to the foundation house as germplasm through propagation. Eight varieties are given to ARDC, Samtenling, 9 varieties to NCOA, Yusipang, 16 varieties to Chimipang Royal Project (CRP), 20 varieties to NSC, Tashi Yangtse, 15 varieties to Floriculture Land Amenity Centre (FALC) Dechencholing, Thimphu, 11 varieties to ARDC, Bajo, 26 varieties to ARDSC Tsirang and 7 varieties to RDTC for its performance evaluation research in the multi-environment of 500, 1000, 1500 and 2000 masl.

A total of 5 foundation plants are well maintained in an insect-proof screen house as germplasm. A total of 13 varieties are being developed for characterization in the repository for research and development purposes. Five new varieties are being put into protected cultivation trials with high density in farmer's fields in collaboration with the Dagana Dzongkhag Agriculture sector. Micro grafting (STG) is being initiated in the NCR laboratory wherein rootstock is successfully grown in agar-based media for the first time to convert HLB positives plants into negatives in the future. Installation of smart irrigation is completed. Standard protocol is well maintained in managing the citrus repository

xiii. Evaluate and maintain cardamom germplasm

Currently, there are 11 lines of cardamom raised inside the protected structure at ARDSC Menchhuna. They are of pure lines exhibiting all the characteristics of respective varieties collected from other Research Centres, and farmer’s fields in Dagana, Tsirang and Sarpang. These varieties are maintained to identify and characterize based on the morphological characteristics and also to maintain germplasm for breeding works in future.

The two recently collected varieties namely Barlangey and Seremna from farmer’s fields in Dagana and Tsirang respectively are maintained outside in open. However, the rest of the varieties in the open field were recommended to be removed by the consultant from Nepal during his visit in 2018 as he found them to be of mixed varieties. It was further recommended that pure lines/varieties be brought from credible sources in Nepal, and Sikkim in India. The regular management practices are carried out as per the cropping schedule.

xiv. Promoted improved MAP crops

Turmeric cultivation is gaining popularity in Bhutan and it was identified as one of the commodities for commercialization under the National Organic Flagship Program. In continuation to the last financial year, turmeric cultivation was continued on 3.5 acres at Barshong, Tsirang. In the land rented for the royal program by Ms Pema Wangmo. The average yield per acre is computed at 2057. 14kg. The detail of the program is mentioned in the table shown below in Table 43.

Table 43 Turmeric production 2021-2022

Program owner:	Royal (land rented by Ms Pema Wangmo)
Crop Type:	Turmeric
Altitude:	700masl
Total Area:	5acres
Area under cultivation:	3.5acres
Total Production:	7200kgs

With the momentum gaining for the black paper in the country, the Centre has initiated black paper nursery production at Karmaling gewog, Dagana with financial support from FSAP Project by supplying protected cultivation, nursery pots and technical assistance from 2020. During the FY 2021-22, the nursery could produce 900 seedlings and distribute them to 20 households of Omchu chiwog covering which is intercropped with an areca nuts plantation of about one acre.

xv. Oyster mushroom spawn production and supply for mushroom cultivation

Mushroom cultivation in Bhutan has created employment opportunities, due to its high market value. However, the lack of quality spawn supply in the market hindered production at a commercial scale. Therefore, DoA, entrusted all the regional ARDCs to produce spawns, and other technical support for mushroom cultivation in the region, with technical backstopping from the National Mushroom Centre. In the FY 2021-22, a total of bottles 2900 oyster spawn and 820 bottles of oyster mother spawn were produced and supported by farmers in mushroom cultivation. The spawn was supplied to interested farmers of the West-Central Region (Table 44). The spawn was supplied on-demand basis and supplied based on the base work done by farmers and after through technical verification.

The mother spawn was supplied to lead farmers of mushrooms in Punakha and Tsirang region and to CRP, Chimipang. The mother spawn will be used by them to further multiply and start mass production at the village level. It will help in starting businesses and entrepreneurship and help in establishing small and cottage industries in a rural area

Table 44 Quantity of spawn supported in the Region in the FY 2021-2022

SN	**Dzongkhag**	**Mushroom spawn supplied for cultivation**		**Mother spawn supplied (qty)**		
		Bottles	**HHs**	**Bottles**	**HHs**	Remarks
1.	Wangduephodrang	928	21	450	1	ARDC, Centre
2	Punakha	740	14	100	1	Pvt. firm
3	Tsirang	250	4	120	1	Pvt. firm
4	Zhemgang	450	6	0		
5	Dagana	405	8	0		
6	Trongsa	150	3	0		
7	Punakha			150	1	CRP, Chimipang
Total		2923	56	820	4	

During the FY 2021-22, the Centre supported 10 HHs with Shiitake mushroom cultivation technical support as farmer training of Wangdue, Dagana and Tsirang Dzongkhags based on the extension demand. The unit caters its technical services to the five Dzongkhags of the West-Central regions.

Table 45 Shiitake mushroom cultivation in the FY 2021-2022

SN	Dzongkhag	No. of HH	No. of billets
1	Wangduephodrang	06	4900
2	Dagana	02	950
3	Tsirang	02	830
Total		**10**	**6680**

xvi. Strengthen floriculture production

ARDC-Bajo started floriculture research and mass production in 2016. The Centre has developed a floriculture on-station site with a collection of assorted ornamental plants, herbs and medicinal plants. Not only in ARDC-Bajo but the ornamental multiplication has also been carried out at ARDSC-Menchhuna. During the FY 2021-22, the Centre has produced more than 11300 potted plants. The Centre has catered by supplying more than 6300 ornamental potted plants for the beautification of various institutions within the region and outside. At present the Centre has stock maintained more than 5000 plants in the nursery.

Table 46 Inventory of the different types of ornamental plants in nursery June 2021

SN	Ornamental Plant	ARDC Bajo	ARDSC Menchhuna	Total potted	Remarks
1	Evergreen/hedges	2000	1000	3200	mixed variety
2	Annual flowers	4200	800	4850	assorted
3	Deciduous flower	2000	500	2500	assorted
4	Orchid	300	0	300	wild orchid collection
5	Medicinal herbs	500	0	500	assorted
Total		**9000**	**2300**	**11350**	

xvii. Million Fruit Trees Plantation Project

Million Fruit Tree Plantation Project (MFTP) is a Royal Command Initiative by DoA under MoAF in collaboration with Desuung National Services with the main objectives to promote fruit diversity and create employment opportunities and commercialization of the potential fruits. The different stakeholders involved in taking the million fruit trees program in the country are Desuung National Services and the Department of Agriculture. National Seed Centre, ARDCs, Dzongkhags and the Farmers. During the FY 2021-22 the MFTP coordinated by ARDC Bajo carried out the following activities

Desuung Skilling Program

In total 43 *Gojay* Desuung consisting of 27 males and 16 females were trained at Tsirang for five days on planting fruit saplings and also a collection of socio-economic data from the fields. The trained Gojay Desuups further trained the fellow desuups for the data collection in the field. In

addition to the above 43 Gojay Desuups additional 17 Gojay Desuups trained at Yuesipang were also deployed under the Bajo region to cover 54 fruit trees growing gewogs under the Bajo region.

Plantation of the Saplings

Plantation of the seedlings was divided into two categories viz: Temperate and Sub-tropical consisting of 22 types of crops. Temperate fruit plants consist of almond, apple, persimmon, pear, walnut, cherry, apricot, kiwi, peach, chestnut, pecan nut and plum Sub-tropical fruit plants are avocado, banana, citrus, dragon fruit, mango, passion fruit, litchi, guava, papaya and pomegranate. Though NSC is the main distributer of the saplings ARDC-Bajo in its capacity supported 3406 numbers of seedlings comprising dragon fruit, citrus, pear and so on. In addition to it, 3784 plants were procured from the private nursery operators through the fund from MFTP.
The table below is the

Table 47 Dzongkhag-wise plantation information of fruit saplings

Fruits and Nuts	Gasa	Punakha	Wangdue	Tsirang	Dagana	Total
Temperate	3874	24485	34625	14524	21637	99145
Sub-tropical	0	9037	14280	41127	65647	130091
Total	**3874**	**33522**	**48905**	**55651**	**87284**	**229236**

xviii. Citrus orchard management training

During the FY 2021-22, the National Citrus Program based at ARDC Bajo has provided hands-on training on citrus orchard management to extension personnels and citrus-growing farmers. Through this hands-on training 36 Extension staff and 204 farmers were trained and 9359 citrus trees were brought under Citrus Canopy management. Each participant received a set of pruning toolsbas incentative to encourage them to continue orchard management and other related activities in future.

Table 48 Citrus canopy management details

SN	Dzongkhag	No. staff trained	No. farmers trained	No. tree managed	Remarks
1	Zhemgang	09	37	642	In collaboration with ARDSC, Tingtibi
2	Trongsa	00	50	250	Korphu & Langthel
3	Dagana	21	91	8926	
4	Wangdue	06	26	183	
Total		**36**	**204**	**9359**	

Besides canopy management, the participants were also taught about Bordeaux mixture preparation and application procedures and other citrus related pest and disease control. They were also briefed on fertilizer application methods.

2) Vegetable Research and Development

i. Evaluation of Disease Tolerant Chili lines

Chilli production in Bhutan is severely affected by major pests such as chilli pod borer, and blight diseases. To make available a few disease-tolerant chilli varieties, Vegetable Coordinating Centre, National Centre for Organic Agriculture-Yusipang have introduced thirty (30) chilli lines from World Vegetable Centre. All these introduced varieties are tolerant varieties to many major diseases such as mosaic virus, tobacco mosaic virus, leaf curl, and bacterial wilt. Four Research and Development Centre for agriculture across Bhutan has been evaluating these chilli varieties from the fiscal year 2020 to 2021 as part of a Nationally Coordinated Trial. ARDC Bajo during the fiscal year 2021-2022, seven varieties with one local variety as a check is under evaluation to ascertain its yield and tolerance level to the major diseases of chilli. The crop is still under the vegetative stage.

Table 49 Resistant cultivars of chilli from the World Vegetable Centre

SN	Variety Name	Resistant/Tolerance
1	AVPP9703	Resistant to CVMV, Phytophthora and bacterial wilt
2	AVPP0520	Resistant to Phytophthora, Bacterial Wilt
3	VI062407	Resistant to PVY, CVMV, bacterial wilt, Phytophthora
4	AVPP1509	Resistant to CVMV, Phytophthora
5	AVPP1502	Resistant to CVMV, anthracnose
6	AVPP1517	Resistant to Tobacco Mosaic virus, bacterial wilt
7	AVPP1508	Moderately resistant to bacterial wilt and Phytophthora

ii. Phenotypic Characterization of Local varieties of Chili

Evaluation of chilli landraces is the Nationally Coordinated Trial among four Agriculture Research and Development Centres in Bhutan. ARDC Bajo currently has five cultivars under evaluation. These varieties were collected from various chilli-growing areas of western Bhutan**.** Through this study, the phenotypic characterization of the varieties will be carried out, and the germplasm of traditional lines will be maintained besides ascertaining its yield potential and other yield attributes.

Traditional chilli varieties under evaluation at ARDC Bajo

1. Sha Ema
2. Babji Ema
3. Khasadrapchu Ema
4. Yangtsep Ema
5. Tamchi Ema
6. Kabji Ema

iii. Evaluation of Cold Tolerant Chili Varieties

Through the seed support from National Vegetable Coordinating Centre, NCOA, Yusipang, ARDC Bajo evaluated six cold-tolerant varieties of chilli lines during the fiscal year 2021-2022 intending to find out a few cold-tolerant varieties that could be cultivated even in the cold winter conditions of Bhutan. The nursery for these varieties was raised in the first week of August 2021. Main filed transplanting was carried out in the first week of October 2021. However, it was found

out that none of the lines was found tolerant varieties as it succumbed to frost and cold injury during the cold months of November and December. No growth and yield data could be recorded as total crop loss was recorded.

iv. Evaluation and Germplasm maintenance of Traditional Bean varieties

Germplasm for nine traditional bean cultivars is maintained on the station. The germplasm of these varieties will be maintained at the station for future improvement purposes. Through this, some of the potential varieties can be preserved for future crop improvement and cultivation as traditional lines are considered resilient and tolerant to some biotic and abiotic stress. These lines are collected locally from the farmers's field.

Table 50 Traditional Bean Cultivar Names and types

SN	Cultivars	Type
1	White local	climbing
2	Brown Local	climbing
3	Pink local	climbing
4	Chaskharpa Shepey	climbing
5	Punakha Local	climbing
6	Kengkharpa	climbing
7	Muka Orey	climbing
8	Kalo Bori	climbing
9	Black bean	climbing

v. Adzuki bean production and different planting times

Adzuki bean production is becoming popular among Bhutanese farming communities. Realising the important of helth benefit, the market for adzuki beans has been growing in recent years owing to its yield potential, easy cultivation and its ability to substitute most of the pod legumes used for culinary purposes. Its dry pod is the main economic part. Since this crop is considered new as it is introduced just a few years ago, farmers lack proper knowledge of cultivation aspects as well as its usage. Therefore, to disseminate the information about the cultivation aspects of adzuki beans, and more specifically to disseminate the information regarding its sowing season for higher production, the crop has been evaluated for one year in 2021-2022.

The trial was laid out in a randomized complete block design. The seeds were sown at three different months of the year. The first sowing time was on 12th May 2021, the 2nd sowing was on 6th July 2021, and the 3rd sowing was on 7th August 2021. The Japanese variety of Adzuki beans was used for the evaluation. The plants were spaced at 25cm between the plants and 3 0cm between the rows. The number of days taken for germination, germination percentage, and production were recorded. Through this study, it was observed that there is a significant difference (P value=0.0001) in the yield of adzuki beans planted during different months of the year. Statistically, the seeds sown during July (6th July) showed the highest production followed by the May month (12th May) sowing time. Those seeds which were sown in August (7th August) showed the lowest yield among the three treatments. The number of days taken for germination statistically remained equal.

Table 51 Yield and germination information of Adzuki beans

Treatment/Planting time	Yield(kg/ac)	Germination days
12th May 2021	187b	8
6th July 2021	287a	10
7th August 2021	166.8c	9
P value	*0.000*	

vi. Sweet potato varietal performance evaluation

On station adaptability and performance trial for a purple variety of sweet potato with a check variety (Bajo Kewa Ngam 1) was carried out. The trial was laid out using a randomized complete block design with two treatments and three replications. The vine cuttings containing seven nodes were planted at ARDC Bajo farm field, located at an altitude range of 1210masl. All the management practices were carried out as per the vegetable cultivation guidebook. The same trial will be carried out for another year to ascertain the yield consistency of the variety before trying it out in the farmer's field to further authenticate the adaptability and performance of the variety. However, it was observed that during the evaluation year 2021-2022, it was ascertained that there are no significant differences in the yield between the treatments.

Table 52 Sweet potato varietal performance

Variety Name	On station mean yield(t/ac)
Beni Azumi	10.51a
Purple variety	9.78a
Mean yield	10.2
P-value	0.06

vii. Carrot varietal evaluation (Daucus carota)

The pure red variety of carrots which was introduced from Japan was evaluated for its yield potential with the control variety New Kuroda. Concurrently the variety has been evaluated at Phobjikha (2800masl) under Wangdue Dzongkhag. From the station varietal evaluation study, it was found that there is no significant difference in the yield among the treatments with Pure red of 7.58 t/ac mean yield against Khuruda of 5.73 t/ac. Pure red, the variety under evaluation showed yield potential at par with the check variety New Kuroda. However, when the variety was evaluated at the farmer's field, it demonstrated a significant difference in yield (P-value: 0.005) between the treatments. This research will be conducted in the following year to ascertain consistency and also to find out the interaction between the locations on the yield of a variety.

Table 53 ANOVA table for yield of carrot

Source	DF	SS	MS	F-value	Pr(>F)
Rep	2	1.1152	0.5576	1.86	0.3492
Treatment	1	5.1523	5.1523	17.22	0.0535
Error	2	0.5984	0.2992		
Total	5	6.8659			

viii. Varietal evaluation of Cabbage varieties

One cabbage hybrid was under fast-track evaluation at ARDC Bajo, and in addition to this, one open-pollinated variety (Fujiwase), introduced from Japan during the IHPP-JICA project period was also under varietal evaluation to find out its adaptability and yield performance. The hybrid variety was evaluated as part of a fast-track evaluation. The trial was laid out using Randomized Complete Block Design with three treatments and three replications. The seedlings were planted at 50X50cm between the plants and rows. The cultural practices of the crop were carried out as per the vegetable cultivation book. From this evaluation study, it was that there is a significant difference in the yield between the varieties (Table 54 and Table 55). Golden acre, a check variety, showed the lowest yield.

Table 54 ANOVA table for Yield (ton/acre) of cabbage

Source	DF	SS	MS	F-value	Pr(>F)
Replication	2	0.3033	0.1517	4.79	0.1727
Treatment	1	42.6667	42.6667	1347.37	0.0007
Error	2	0.0633	0.0317		
Total	5	43.0333			
CV(%) = 2.72			Mean yield = 6.53 t/ac		

Table 55 Pairwise mean comparison summary (Tuckeys's HSD test) of cabbage trial

Treatments	Means	N group
1	9.20	3a
2	3.87	3b

ix. Varietal evaluation of Cauliflower varieties

The two cauliflower varieties (hybrids) were under fast-track evaluation at the ARDC Bajo farm field. The trial was laid out using Randomized Complete Block Design with five treatments and three replications. White top, Wengkhar Metocopi-1, Wengkhar Mtocopi-2, snow mystique, and hybrid 1 were evaluated for their yield performance at an altitude of 1210masl. From this study, it was observed that there is a significant difference in the yield. Snow Mystique demonstrated the highest yield potential of 16.04 t/ac followed by the hybrid variety yielding 10.0 t/ac. Among fie treatments, Wengkhar Metokopi yielded the lowest with a yield record of 5.34t/ac.

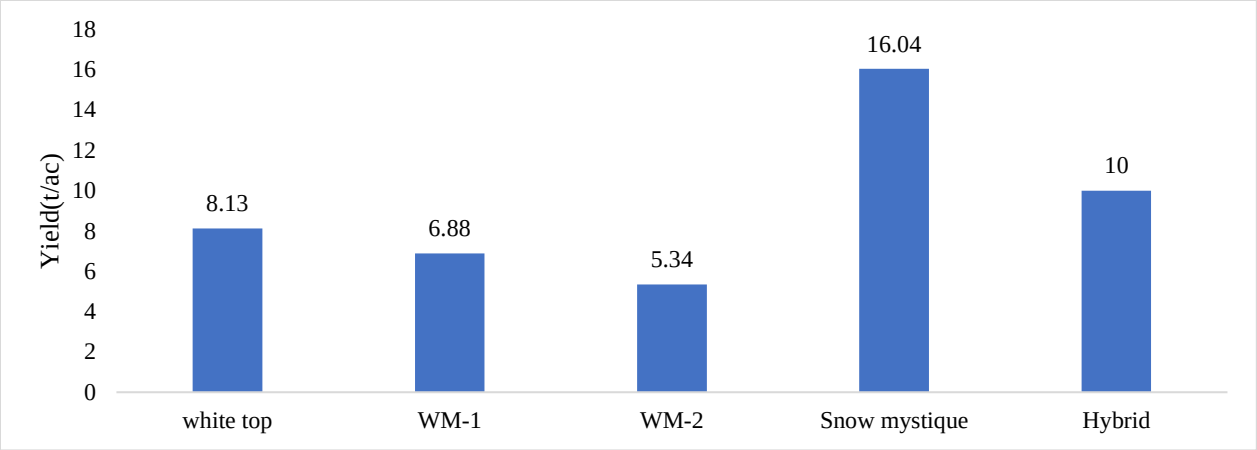

Figure 2 Yield potential of Cauliflower cultivars

x. Colocasia varietal trial

Two improved Colocasia varieties; Japan Green and Japan Red from Japan were under varietal evaluation trial along with two local varieties as a check variety. The tubers were sown in the month on 15th March 2021, and the tuber was harvested on 27th December 2021. Through this varietal evaluation study, it was observed that there is a significant difference (**P-value: 0.03**) in the yield between the varieties evaluated. Among four treatments, Japan red outyielded all other treatments. Nonetheless, Japan white performed statistically equal to that of local white but it demonstrated lesser yield than the local red, check variety. Similarly, a significant difference was observed in individual tuber weight, tuber length, and tuber diameter. However, there was no observance of a significant difference in tuber number produced.

Table 56 Yield and yield parameters of Colocasia cultivars

Variety	Per Plant Yield (g)	Tuber No	Tuber weight (g)	Tuber Dia (cm)	Tuber Length (cm)
Japan red	1197.0^{a}	17	86^{a}	19.89^{d}	7.70^{b}
Japan White	508.93^{bc}	11	62.38^{b}	43.77^{a}	5.79^{c}
Local red	999.6^{ab}	16	64.67^{b}	53.52^{b}	10.45^{a}
Local White	317.87^{c}	8	35.41^{c}	26.22^{c}	7.13b^{c}
P Value	0.03	0.0849	0.0003	0.00	0.0012

Note: Means with different superscripts differ significantly at α= 0.05.

xi. Brinjal (Solanum melongena) evaluation trial

Brinjal *(Solanum melongena*) belongs to Solanaceae or nightshade family. Pusa Purple Long is the only variety released and available for cultivation in Bhutan. To diversify eggplant varieties in Bhutan, four varieties of Japanese eggplant were evaluated ARDC-Bajo for their yield potential. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. All the management practice of brinjal is followed as per the vegetable cultivation guidebook and research protocal.

From this evaluation, it was observed that the Nagako variety demonstrated the highest yield potential followed by the Manryo variety. Among all the varieties evaluated, Senryu had the lowest yield, even lower than the check variety, Pusa Purple long.

Table 57 Agronomic performance of brinjal varieties

Variety	Yield (t/a)	Average fruit length (cm)	Average fruit size (cm)	Weight (gm)
Nagaoka	3.9	14.8	4.76	158.2
Manryo	3.2	16.8	5.34	158
Shinkurowase	2.7	16	5.92	186.5
Senryo	2.3	14.3	4.66	130.6
Pusa Purple Long(Check)	2.5	17.1	3.43	81.7

xii. Potting soil mix for growth and yield of tomato

A good vegetable nursery is crucial for the good production of the vegetable crop. Farmers owing to the lack of knowledge, and time constraints as an accrued problem, the farmers hardly use poly pots and potting soil mix to raise their vegetable seedlings. They rather directly uproot their seedlings and transplant them into the main field at the transplantable stage. Therefore, under the guidance of experts, during the IHPP-JICA project period, the Centre has been perfecting the improved vegetable nursery technologies. The poly potting of vegetable crops such as tomato, chilli, cauliflower, cabbage, brinjal, and broccoli are recommended as the research conducted on these crops since 2020 has shown improvement in the growth as well as in the yield. ARDC Bajo did carry out an evaluation of potting soil mix on yield and growth of tomatoes in the 2021-2022 fiscal year. The seeds were sown in the greenhouse. The seedlings at their two-cotyledon leaf stage, it is potted in the poly pots containing the potting soil mixes. The trial was laid out using Randomized Complete Block Design with four treatments (volume basis potting soil mix, weight basis potting soil mix, and leaf mould, non-potted seedlings) with three replications.

- Treatment 1: Soil: Biochar: Compost: Bokashi: (100:20:0.5:10) and 50 g Suphala
- Treatment 2: Soil: sand: Biochar: Bokashi: compost (4:3:3:1: 0.5) 50g Suphala
- Treatment 3: Leaf mould
- Treatment 4: Non-potted Seedling

Table 58 Effect of the potting mixture on plant growth

	Plant Height		Stem girth		No. of leaves	
Treatments	Mean	*SD*	Mean	*SD*	Mean	*SD*
Weight Basis	2.17	0.35	0.72	0.15	1.63	0.30
Volume basis	2.58	0.40	0.94	0.12	2.37	0.04
L. Mould	2.10	0.16	0.78	0.23	0.17	0.06

From the study, it was found that there is a significant difference(*P-value;0.02*) in the yield of tomatoes potted under different potting soil mixes. The highest yield was obtained by weight basis media (Soil: Sand: Biochar: Bokashi: compost (4:3:3;1: 0.5, and 50g Suphala). Both the potting soil mixes treatments showed a seedling survival rate of 95-100% irrespective of the day of the transplantation. However, non-potted seedlings showed a minimal seedling survival rate.

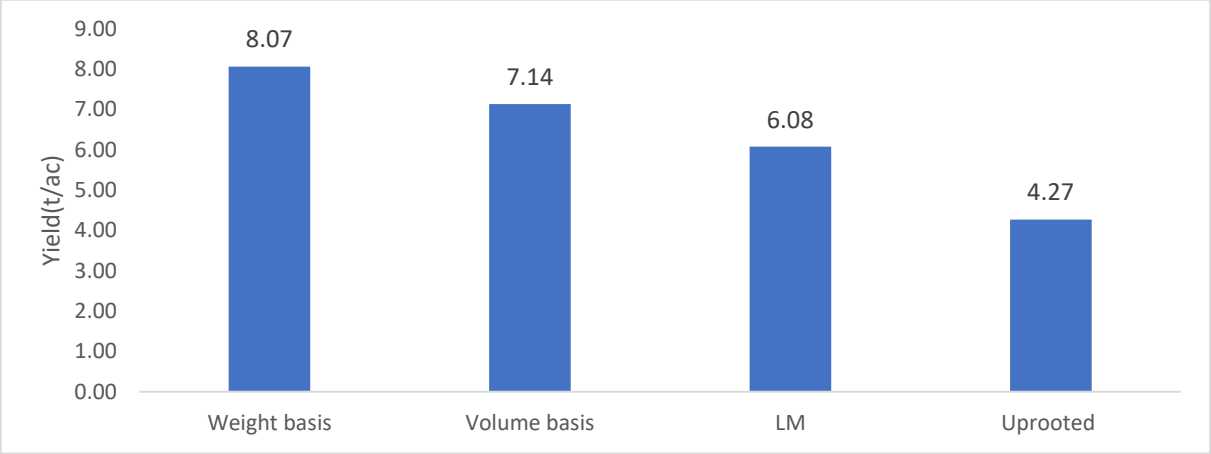

Figure 3 Effect of potting mixture on yield of tomato

xiii. Winter chilli production under three different growing conditions

During the cold winter period, there is an acute shortage of chilli production in Bhutan. The Department of Agriculture, Ministry of Agriculture, and Forest has been making a constant effort to make chilli available in the domestic market during those lean periods. Chilli can be best grown from 18-28°C, and when the air temperature during the cold winter period goes extremely low, the growth of a chilli plant is retarded. Therefore, protected cultivation inside the greenhouses, low-cost greenhouses, and rain shelters is recommended in recent years to improve the production trend. Therefore, under the coordination of the National vegetable Coordinating Centre, NCOA Yusipang, ARDC Bajo also did carry out a production trial of winter chilli under three different growing conditions. SHP4884 chilli variety was grown inside the fabricated greenhouse, rain shelter, and in the open conditions to find out the production. The yield for 5 tagged plants was recorded. From this trial, it was found out that at ARDC Bajo condition, it was feasible for winter chilli cultivation as the yield for 5 tagged plants ranged from 111-600g during the whole production season under green-house conditions, and there was no record of production from open space and a rain shelter.

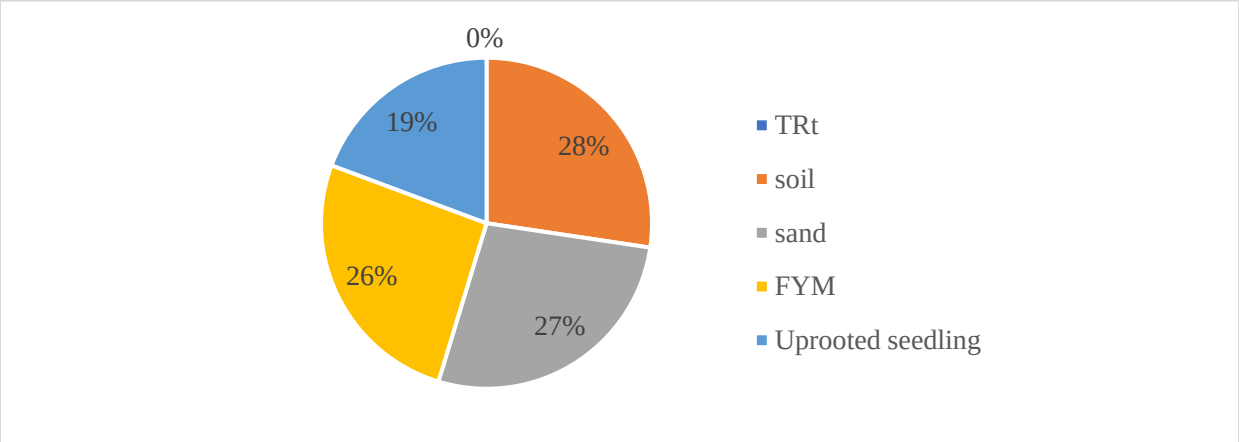

Figure 4 Seedling survival rate at mid-day planting

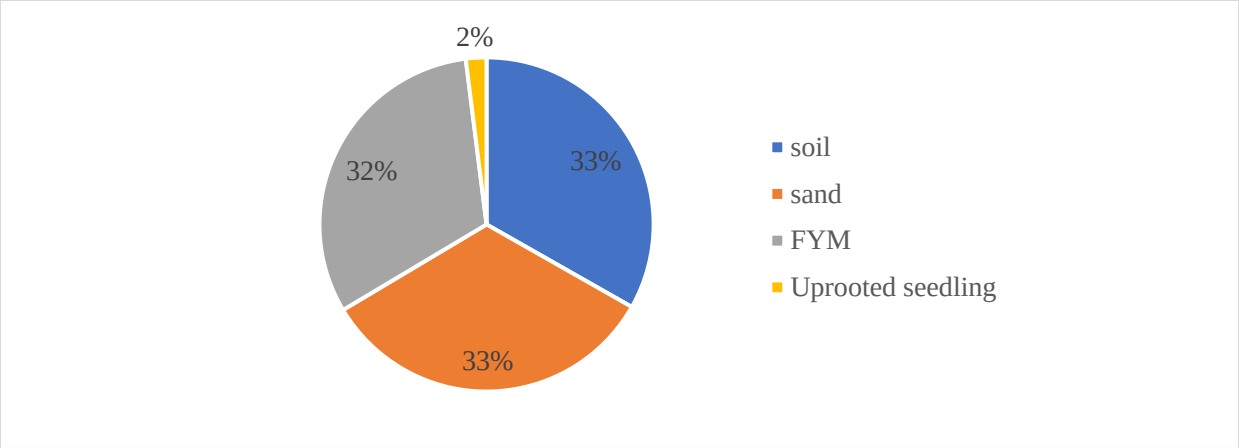

Figure 5 Seedling survival percentage when planted after sunset

xiv. Breeder seed production and maintenance

As ARDCs are mandated to maintain the breeder seeds of various vegetables released from their Centres and make them available whenever the National Seed Center (NSC) require. Breeder seed of fourteen vegetable varieties that were released from ARDC Bajo is under maintenance of breeder seed at the Centre. During the FY 2021-22 the Centre could produce more than 50 kg of assorted vegetable seeds as mentioned in Table 59.

Table 59 Breeder seeds produced and maintained in stock

SN	Crop variety	Quantity produced (kg)	Quantity issued to (kg)	
			NSC	Other
1	Bean- Borloto	1.00	0.00	
2	Bean- Pusa Parvati	1.00	0.00	
3	Bean- Top Crop	0.50	0.00	
4	Bean- Bajo Semchu kaap	35.00	0.00	
5	Brinjal- Pusa Purple Long	0.60	0.00	
6	Carrot- Early Nantes	2.00	0.00	
7	Spinach- All Green	5.00	0.00	
8	Tomato- Roma	0.20	0.00	
9	Tomato-RRTO	0.30	0.00	
10	Tomato -Ratan	0.20	0.00	
11	Tomato- Master	0.20	0.00	
12	Water melon-Black ball	1.00	0.3	
13	Water melon-Sugar baby	0.20	0.00	
14	Water melon-Kabuki	1.00	0.30	
15	Zucchini (yellow)	2.00	1.00	
Total		**50.2**	**1.60**	

xv. Promotion of beans seed for commercial production

Through the fund support from GEF LDCF the Centre the Vegetable Unit at the Centre facilitated in sourcing out the dwarf beans seeds and supplied to farmers on commercial scale. The unit had sourced and issued more than 160 kg of beans of three varieties (borloto interminate, borloto determinate and white pole beans) seeds which are calculated to cover more than 26.73 ac of dryland.

Table 60 Promotion of climate-resilient bean seed to Punakha and Wangdue Dzongkhags

Geogs/ Dzongkhag	Types of Beans (kg)			Total (kg)	Area (acre)	No. HHs
	Borloto (Indeterminate)	Borloto (Determinate)	White Pole Bean			
Kabjisa, Punakha	22.40	25.60	0	48.00	4.00	32
Toep, Punakha	6.30	12.60	6.30	25.20	2.10	21
Kazhi, Wangdue	11.90	8.20	6.10	26.20	2.18	41
Athang, Wangdue	10.70	12.80	0	23.50	1.96	16
Nahi, Wangdue	42.00	15.00	5.00	62.00	5.16	43
Gasel Tshogom, Wangdue	20.00	20.00	0	40.00	3.33	35
Bjena, Wangdue	16.50	14.30	3.60	34.4	2.86	34
Dangchu, Wangdue	14.70	14.70	0	29.4	2.45	21
Daga, Wangdue	15.50	16.80	0	32.3	2.69	21
Total	**160.00**	**140.00**	**21**	**321**	**26.73**	**264**

Besides this, the Centre has produced and supplied more than 32 kg of seeds of assorted high-yielding vegetable varieties to farmers of West-Central regions for commercial vegetable production and household nutrition.

xvi. Demonstration of protected structure installation

By the end of FY 2020-21, JICA IHP Project supported the farmers through the supply of 267 numbers of greenhouses in the West-Central Region to enhance income generation and household nutrition through vegetable production in protected cultivation. So, to install the greenhouses, the DAOs requested technical assistance at the beginning of FY 2021-22. The horticulture sector provided hand-on demonstration cum training to install the greenhouse in the Region covering more than 308 households. Besides, the installation of the greenhouse, the farmers were explained on the vegetable cultivation inside the greenhouse. Type of vegetables and time were brifed to the farmers so that they can cultivate varieties of vegetables in all seasons to enchance income generation and nutrition security. Timely monitoring and technical assistance on greenhouse cultivation will be provided by the Centre.

Table 61 No. of households demonstrated greenhouse installation and vegetable production

SN	Dzongkhag	No. of greenhouses issued	No. of HHs trained	No. of gewogs	Remarks
1	Gasa	35	40	3	5 HHs demonstrated on the Sunken greenhouse at Laya
2	Punakha	38	40	11	
3	Wangdue	78	78	13	
4	Tsirang	72	80	12	
5	Dagana	44	70	6	Trained even the not listed gewogs HHs
Total		267	308	45	

xvii. Seed samples tested for various parameters

National Seed Testing and Referral Laboratory at ARDC-Bajo is responsible to carry out basic tests such as germination per cent, physical purity per cent, and moisture per cent of seeds. Th clients include ARDCs, BAFRA, NSC, farmers and private seed companies. The seed parameters to be tested depend on the interests of clients and the capacity of the laboratory to perform tests. The seed samples submitted through BAFRA are tested for germination per cent, purity per cent and moisture per cent whereas seed samples from farmers are usually tested for germination and purity per cent only. The results and recommendations are then provided to the beneficiaries The seed samples collected are usually from vegetables and cereals crops.

Figure 6 indicates the mean germination and purity percentage rate of 13 crops seed samples test conducted in the FY 2021-22. Although the germination rate varies from 41% (mustard green) to 99 (cabbage), the purity percentage is high 99.7 to 100 per cent.

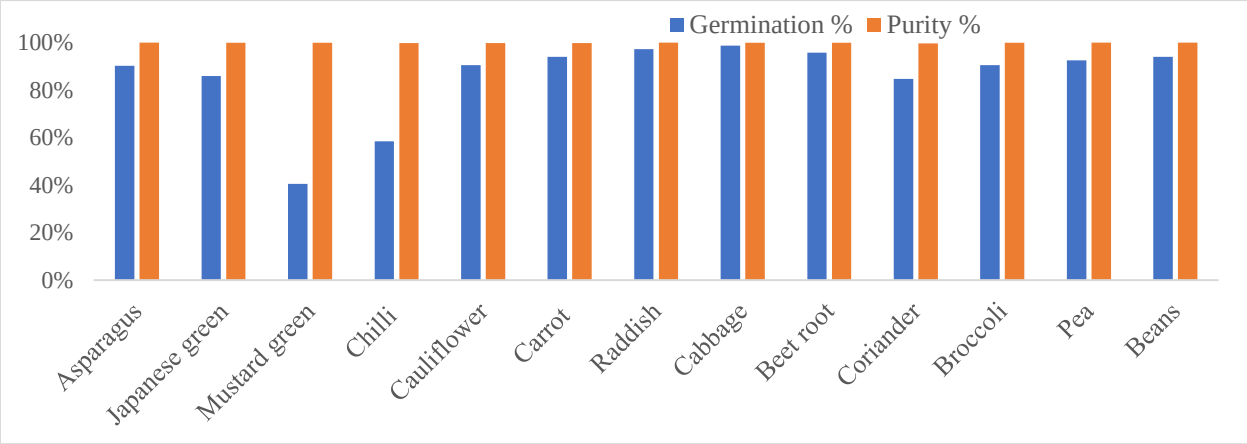

Figure 6 Germination and purity mean of crop seed sample tested

SUPPORT SERVICES RESEARCH AND DEVELOPMENT PROGRAM

1) Integrated Pest Management

i. Evaluation of different pesticides for Fall Armyworm Management

Maize, an important source of food and nutritional security widely grown as a staple crop closely associated with household food security in Bhutan. Starting in 2019, the Fall Armyworm (FAW), *Spodoptera frugiperda* (G.E. Smith) was detected in Bhutan which now has become a major pest in the region.

The FAW is indigenous to the Americas but has fast spread to other parts of the world. FAW is highly destructive, highly mobile(Westbrook et al., 2016), and has high fecundity now present in Africa and Asia. It feeds on more than 350 plant species including economically important crops such as maize, millet, wheat, potato, soybean, cowpea, peanuts, sorghum, rice, sugarcane, vegetables and cotton. This recent discovery of FAW poses a significant threat to the country's food security as it can suddenly become a major pest. The presence of ideal climatic conditions and maize-based cropping systems (as of summer and winter crops) present in many parts of the country further aggravates the threat as the pest may become endemic/established and remain a significant pest not only for maize but also for other important crops.

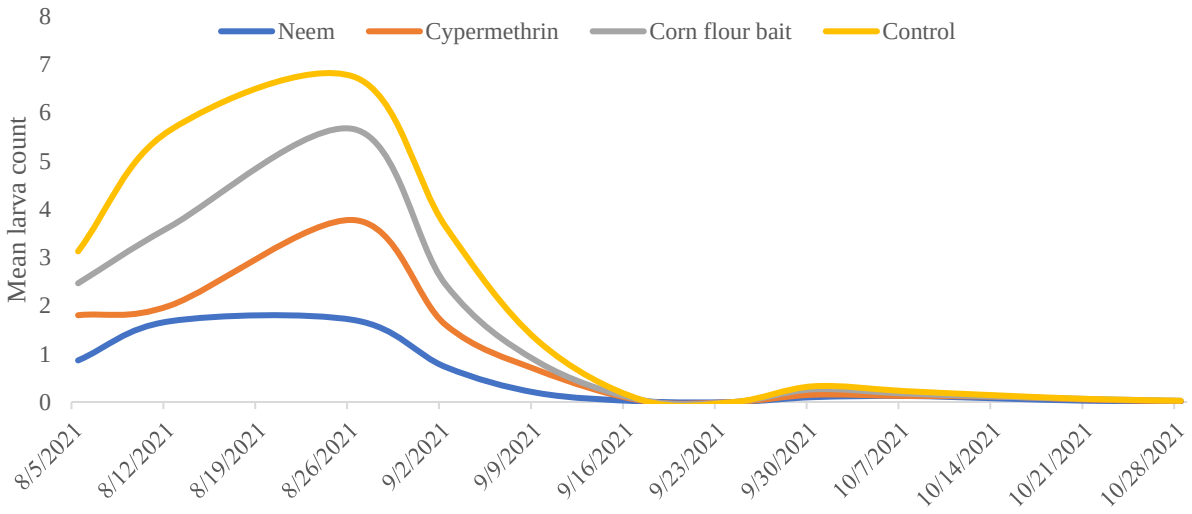

Figure 7 Infestation differences in different treatments (Mean live larval counts)

For its management, ARDC Bajo (PP Unit) in collaboration with National Plant Protection Center evaluated pesticides at Dzomlingthang, Guma under Punakha in 2021. From the assessment from July to November, Neem oil had the best effect on the FAW caterpillars indicated by lesser numbers of live caterpillars (see **Error! Reference source not found.**) and damage (see
) during the study period. From this study, though early to conclude we recommend a weekly spray of Neem Oil (1000 ppm) if the infestation is heavy. Otherwise, a fortnightly spray of Neem should be made.

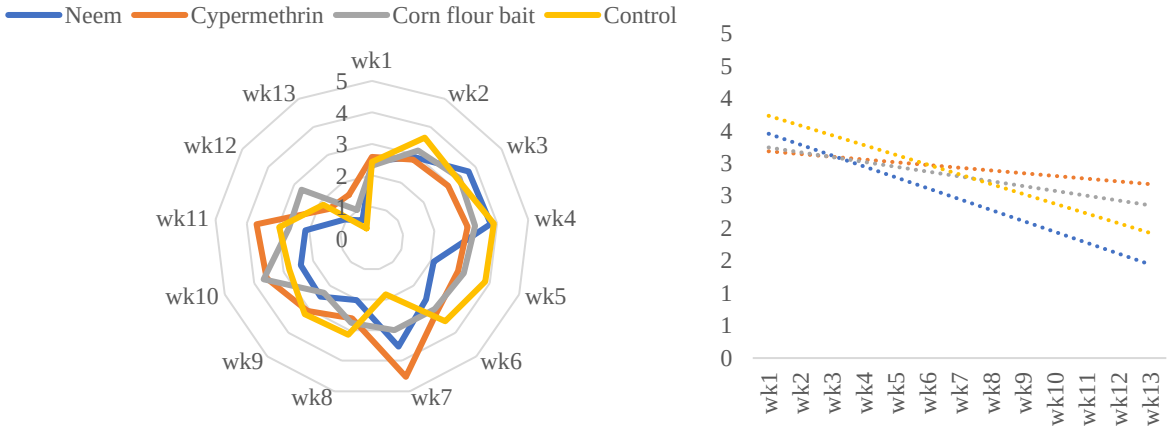

Figure 8 Damage (Davis's scale of 0-9) differences in different treatments

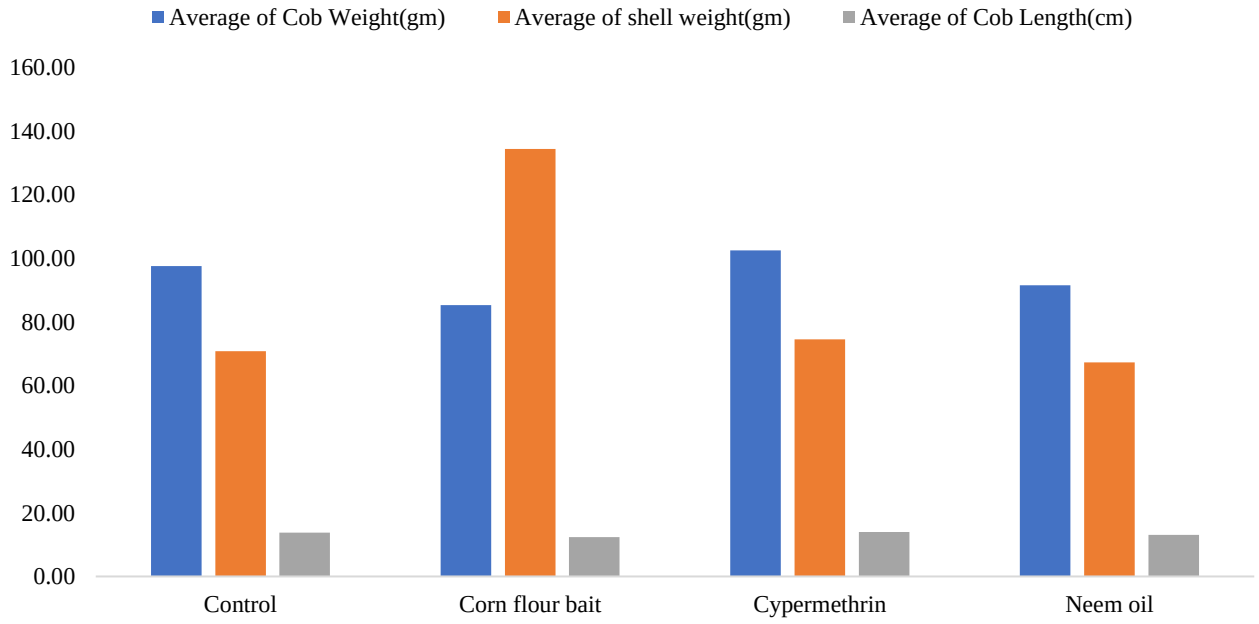

Figure 9 Differences in yield and yield parameters

Since treatments from this study did not give desired control, we are evaluating a few more pesticides for FAW management. The activity is under process at ARDC Bajo station. The updates on this evaluation will be updated at the end of the experiment.
New chemicals under evaluation are **Emmamectin benzoate** and **Chlorantraniliprole** with some of the previous treatments.

ii. Monitoring of Fall armyworm population and evaluation of Pheromone lures

As part of the deposit activity with the National Plant Protection Center, we evaluated pheromone lures at three different sites viz., Thedtsho (Wangduephodrang), Guma (Punakha), and Damphu (Tsirang).

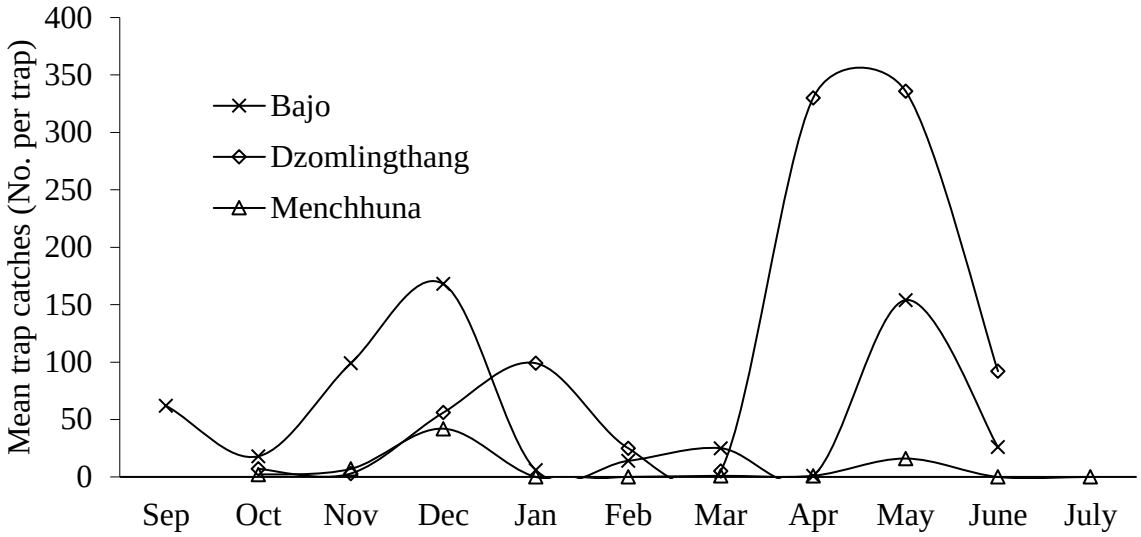

Figure 10 FAW moth population change at different sites

The FAW moth population and peak population period varied between three sites. At Thedtsho (Bajo), the FAW population peaked in November-December and May moths. The peak moth population for Guma (Dzomlingthang) was in April-May. For Menchhuna (Tsirang), the moth population fairly remained low during the study period.

The evaluated pheromone lure trapped non-target moths as well which is a setback. Therefore, six more different types of lures are under evaluation at different locations. Updates on the results will be shared at the end of the maize season.


Figure 11 Pheromone traps installed at different sites

iii. Fall armyworm biology and damage in west-central Bhutan

The life cycle of *Spodoptera frugiperda* completes in 33(±3) days under laboratory conditions (see Table 62). The egg incubation period lasts 2(±1) days. The larval stage lasted 15 to 19 days with an average of 17 days while it pupated for 10(±2) days. The adult lived for 5(±2) days under laboratory conditions. The egg masses were observed in a single layer or two layers. The eggs (mean of 120 numbers) measured 0.3 to 0.4 mm as described by Tendeng et al (2019). The six instars (1-6 instars) larvae measured 2.60, 5.27, 9.45, 13.70, 21.93 and 30.53 mm respectively. A gradual increase in the size of the larvae was observed till the mid-sixth instars and reached a size

of 34.2mm. However, the larvae size decreased towards the last three days of the 6th instar until it reached 23.1mm. The pupa size measured 19.7 to 15.5 mm. Pupal size also decreased until the emergence of the adults. Qualitative characteristics of larval stages were similar to that reported by Schmidt-Durán et al (2015).

Table 62 Details of Fall armyworm biology

	Size (mm)			
Stages	Mean	Initial	Final	**Days (x̄)**
Egg	0.35	0.30	0.40	2± 1
Larvae (Length)				
First instar	2.60	1.60	3.60	2
Second instar	5.27	4.10	6.60	3
Third instar	9.45	8.60	10.30	2
Fourth instar	13.70	13.40	14.00	2
Fifth instar	21.93	16.50	27.10	4
Sixth instar	30.53	27.10	13.90	5
Pupa (length)	16.72	19.70	15.50	10± 1

FAW was present in all the farms surveyed (see **Error! Reference source not found.**). Percent FAW infestation was highest in Wangdue while least in Dagana. Leaf damage was highest at Bajo, followed by Punakha. The mean larval count per quadrant was highest at Bajo where a majority of larvae were neonates or early instars. For all three sites, the larvae in the late instars recorded were 1±1 larvae per plant.

Table 63 Level of infestations in three districts

Site	**Incidence (%)**	**%FAW infestation**	**Leaf damage ratings (0-9)**	**Larval count**
Wangdue	100	100±0	6±0	700±89
Dagana	100	63.59±41.47	5± 0.47	358±42
Punakha	100	93.25± 9.55	4.5±2.01	360±32

iv. Wood vinegar for agriculture uses; production, evaluation and demonstration

With the two ovens constructed at the research station with the help of IHPP and NOFP, we produced 60+ litres of bamboo vinegar during this fiscal year. Modern agriculture uses wood vinegar as fungicides, insecticides, termiticides, growth regulators, and other similar agronomic uses. Preliminary tests conducted indicated its effectiveness to control cabbage aphids (@ 0.1 and 0.5% conc.), cabbage white butterfly larvae (@0.1 and 0.5% conc.) under lab conditions. Herbicidal effect on different weed species under greenhouse conditions was also observed at 5+ % concentrations. To achieve desired effectiveness, more than 20% concentration should be applied during the early vegetative stages of the weeds. Parthenium at the flowering stage is tolerant to 20% Wood vinegar under greenhouse conditions. Most of

Figure 12 Wood vinegar extraction oven

the grass species found in the research station are tolerant to 20% wood vinegar. Further, research is planned and will be carried out in the appropriate
coming crop seasons.

Since preliminary findings indicated its effectiveness for use in pest management, its production and uses are demonstrated with support from different projects. With fund support from NOFP, one oven for extraction was established at Lul, Kazhi under Wangdue with hands-on training on its production. Similarly, two more ovens were constructed at ARDSC Menchhuna and Gangtey GAP sites. Awareness of the use and its effectiveness were made to the staff and ESPs of ARDSC-Menchhuna. With support from GCF, GEF and FSAPP, awareness of the use of Wood vinegar was made among farmers of the west-central region including Zhemgang and Trongsa.

v. Organic pest management in Cole crops

Management of Cole crop pests using Organic Input As recommended by the National Center of Organic Agriculture and Vegetable program, different types of Jholmols were evaluated at the on-station.

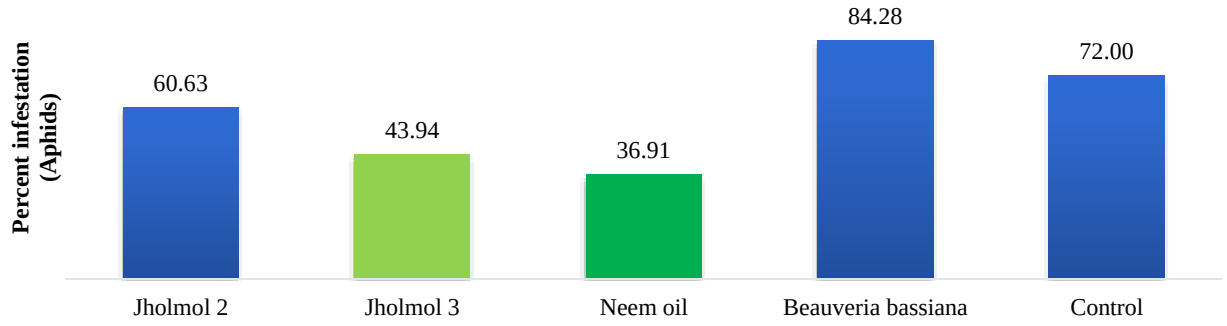

Figure 13 Percent infestation by aphids on cauliflower

Neem oil (1500ppm) at 5ml per litre of water proved to be the best of the options for organic pest management in Cole crops. For yield differences, Jholmol 3 yielded the highest followed by Jholmol 2. The higher yield (mean curd weight) in Jholmol applied treatments may be due to the nutrient contents in cow urine.

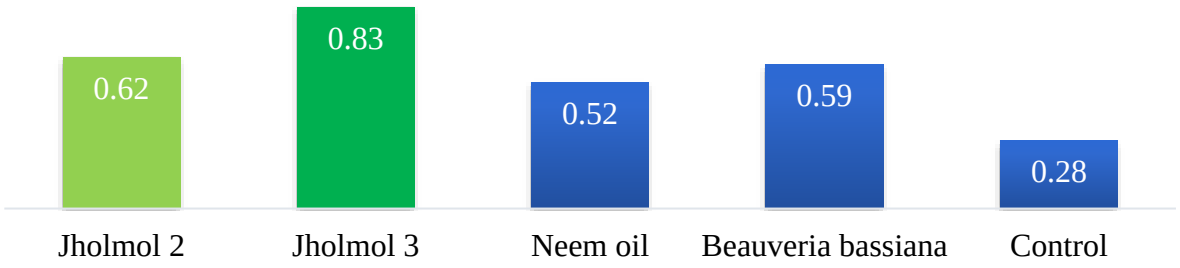

Figure 14 Yield differences in different treatments

It needs further studies to confirm the findings. The data is based on the final assessment only. The all-season infestation assessment was not completed due to COVID-19 pandemic lockdowns.

vi. Demonstration of Plant Protection Technologies

Pheromone traps and Sugar syrup traps

Pheromone traps for different pests (Fall armyworm, Cabbage looper, Common cutworm, Beet armyworm, Chilli pod borer, Common armyworm and oriental fruitfly) were demonstrated. ARDSC-Menchhuna and ARDC Bajo research stations were used for the demonstration sites. The pheromone traps were collected due to a shortage of pheromone lures.

Brown sugar and alcohol syrup was also demonstrated for use to trap insect pests. Cabbage armyworm and fruit piercing moths are the usual target insects for the trap. However, the attractants also attract other insects which is beneficial. Further work on the efficacy and reduction of non-target insect attraction may be required.

Sweet potato weevil management

Sweet potato weevil is currently the major pest of sweet potato. One of the methods to manage the pest is using water traps around the field. The weevil is a crawler and does not fly thence successful control using the water traps. Standing water if about 2cm deep is enough for the trap. Weeds crossing the trap should be removed which otherwise might serve as a bridge for the weevils. Other methods include pesticide application and mound preparation. Mound preparation reduces the weevil's attacks on the tubers. This method was promoted for other crawlers as well.

Fruit bagging against birds and insects

Most of the fruits are attacked by birds and insects when near ripe. To protect the fruits from pests, the wrapping of fruits/ fruit bunches was covered using bags made from different materials. Fruit wrapping/bagging is the best method of fruit protection from birds and insects.

IPM on chilli pests and diseases management

Blight and chilli pod borers are the major biotic factors that affect chilli production. Aphids also cause serious damage resulting from viral transmission by the aphids. Aphid control using wood vinegar and neem oil was demonstrated with support from GEF, GDF, NOFP and FSAPP. The use of *bokashi* for chilli blight management was promoted.

Gelatine solution for aphid management in cole crops

The use of gelatine solution or corn flour mixture was promoted as per project activities supported by GEF, GCF, NOFP and FSAPP. For aphid management, a 0.2% solution of gelatine is effective in greenhouse conditions.

Jholmol for aphid and cole crop pest management

The fermented cow urine, fermented Artemisia and cow urine extracts, and different plant extracts which are commonly called 'Jholmol' were promoted to farmers for management of aphids and pests of cole crops. Its awareness was made as part of different project activities.

vii. Pest Surveillance; pest reports in west-central Bhutan

Through consultations with farmers, extension officers and field visits during outbreaks, pest information for west-central Bhutan is collected. Some information is from field visits and outbreak reports. The pest incidences in the region are in Table 64.

Table 64 Pest incidences in the region

Districts	Pests
Wangdue	*Mythimna separata* (Paddy, maize, potato, and forage grasses) at Nabisa, Nahi & Khotokha
	Thysanoplusia orichalcea (Potato and maize) at Nabisa, Nahi
	Spodoptera frugiperda at Thedtsho
	Garlic rust (Garlic) at Gorgoena, Nyisho
	White grubs in potato at Gangtey and Phobjikha
Gasa	*Mythimna separata* (Paddy, maize, potato, and forage grasses) at Khatoed and Khamoed
	Thysanoplusia orichalcea (Potato and maize) at Yemina, Khamoed
	Helicoverpa punctigera on potato
Punakha	*Mythimna separata* (Paddy, maize, potato, and forage grasses) at Baygana, Toepisa
	Thysanoplusia orichalcea (Potato and maize) at Gemsa (Toepisa) and Wokuna (Kabisa)
	Spodoptera frugiperda at Dzomlingthang, Guma
	Japanese beetle on peach, avocado and plums
	Colletotrichum blight in chilli at Dzomlingthang
Dagana	Citrus fruitfly, citrus trunk borer and aphids in mandarin at Kana and Laja
	Blight in chilli, and cardamom
Tsirang	*Spodoptera frugiperda* on maize at Kilkhorthang

viii. Pest Diagnostic services

Table 65 List of diagnostic and technical services provided during the FY 2021-2022

Locality	**Pests**	**Crop**	**Remarks**
Gasa (Khatoed and Khamoed)	*Mythimna separata*, and *Thysanoplusia orichalcea*	Paddy, potato & forage grasses	53 HHs demonstrated management
Punakha	Japanese beetle	Peach, & Avocado	Palace, Singye Pelri
Punakha (Dzomlingthang)	*Spodoptera frugiperda* and *Colletotrichum* blight	Maize & chilli respectively	technical support of spray of pesticides provided
Wangdue (Nyisho)	Garlic rusts	Garlic	Technical support on spray provided
Wangdue (Nahi)	*Mythimna separata*, *Thysanoplusia orichalcea* and blights (both early and late blight)	Paddy, and Potato	Field visit with damage assessment. wood vinegar spray and rice husk biochar application demonstrated
Wangdue (Athang)	Chilli blight	Chilli	Wood vinegar was supplied for seed treatment.

Insect population monitoring for important horticultural pests is conducted till December 2021 as spill-over activity of 2020-2021. The activity was discontinued due to a shortage of pheromone lures due to the pandemic. Detailed reports will be submitted as technical reports.

2) Soil and Land Management Unit

i. Establishment of regional soil and plant analytical laboratory

The regional soil and plant analytical laboratory is established with technical support from National Soil Services Centre. The equipment was supported by a budget from RGoB and FAO. The soil parameters like pH, EC, N, P, K, Ca, Mg, Na, Soil moisture and bulk density can now be analysed at the regional laboratory.

The 10 samples from paddy in ARDC Bajo, 10 samples from cardamom in ARDSC Menchhuna, 10 Samples from vegetable farm in Oathbar Mountain Horticulture Promotion Project, and 10 samples from NSC farm in Phobjikha and 10 samples from Petari organic farm in Punakha were collected and analysed. The analysed results are shared with clients and recommendations are followed.

ii. Bhutan Agri-microbial Solution plant

This technology will help in solving the problem of organic input shortages in the country. The domestic production and availability of organic inputs play an important role in practising organic farming. The production and use of BAMS will ultimately lead to organic farming. BAMS also forms an important component of hydroponics cultivation by fermenting cattle urine. BAMS has the potential to make agricultural activities more environmentally friendly.

500 litres and 300 litres capacity plants were established at ARDC Bajo and ARDSC Menchhuna respectively. Another 500 litres capacity plant was also established at NSSC Semtokha. In total 2000 litres of BAMS from Bajo and 800 litres from Menchhuna were produced in a year. The produced BAMS are utilized for on-station usage and distribution to farmers and schools.

iii. Vermicompost production for Soil fertility management

The vermicomposting was done twice a year. In total 500 kg of vermicompost was produced, which was utilized to improve the potting mix soil. About 100kg will be utilized for the aqua-biota trial to check its efficacy. Vermiculture is also done at the centre and earthworms are multiplied. 5 kg of worms is maintained. Vermiculture is the science of breeding and raising earthworms. Vermicomposting is the process of producing organic fertilizer or worm compost using earthworms. Earthworm turns common soil into superior quality with enhanced fertility content. The by-product produced by those worms is also called casting. Castings are rich in N, P, K, Ca and Mg as compared to other organic manure. Leachate is also produced during Vermi-composting called Vermi-wash. The application of this liquid to plants through the foliar application was found to have a remarkable improvement in the growth, nutrient contents of shoot and yield of young and mature tea compared to the untreated plants (Ishan, K. P. and Savapondit, 2011). Therefore, Vermi-biotechnology has the potential to play an important role in organic farming.

iv. Response of rice to different nitrogen application rate

The trial was conducted at Bajo in collaboration with National Soil Services Centre. Three different paddy varieties were treated with five different treatments of nitrogen fertilizer. The pre and post-soil samples were collected and a crop cut was done at the end. The three-year data were collected and submitted to NSSC and reports were generated and submitted in the coming BJA. The trial will not be continued since data are sufficient for the result.

Table 66 Response of rice to different nitrogen application rate

Trial design	**Design parameters**	**Levels = V1, V2, V3**	
Split Plot Design	Number of Trials = 1	V1 = Bajo kaap 1	Subplot Factor = Nitrogen
Randomized Complete Block Design	Number of Blocks = 3	V2 = Bajo maap 1	Levels = N1, N2, N3, … N6
	Main plot Factor = Variety	V3 = IR 64	

Table 67 Fertilizer rate calculation

Treatment	**Nitrogen (gm/10m^2)**	**1] Urea (gm/10m^2)**	**2] Urea (gm/10m^2)**	**SSP (gm/10m^2)**	**MOP (gm/10m^2)**
N_0	0	0	0	125	20
N_1	40	43.5	43.5	125	20
N_2	80	87	87	125	20
N_3	120	130.5	130.5	125	20
N_4	160	174	174	125	20
N_5	200	217.5	217.5	125	20

A treatment replicated 9 times (3 factors*3 treatments)
Total Urea need = 1305 gm
Total SSP needed = 6750 gm
Total MoP needed = 1080 gm

v. Effect of aqua-biota supplementation on growth and yield of Paddy

There is an increasing need to explore organic alternatives to chemical fertilizers to improve soil fertility and increase rice production. The use of aqua-biota could be one organic option in the rice production system. The aqua-biota is a complex of micro-biota selected amongst 200 strains for their properties to benefit plant growth and development. Studies have shown that the use of aqua-biota improved soil fertility, reduced diseases and pests, increased crop yield, reduced the need for chemical fertilizers and increased the concentration of bio-actives in the rice. The present study aims to assess the use of aqua-biota on the growth and yield of rice in Bhutan. The trial was carried out for two years, and data was collected and submitted to NSSC and will not continue further. The objective of the study is to evaluate the efficacy of aqua-biota on the growth and yield of rice. The experiment will be conducted in collaboration with Agriculture Research & Development Center Bajo (ARDC Bajo) at Royal Project Chimipang (RPC).

The efficacy of aqua-biota in Paddy was checked in two ways:
1. Three replications of five treatments were done in a plot of 5m x 2m size.
2. Two 250m^2 terraces were used as control and aqua-biota-treated plots to study the effects.

The design of the experiment would be Randomized Complete Block Design (RCBD) with 3 replications and 5 treatments. The size of the treatment will be 5m X 2m (L X B) with 250 plants, one plant per hill. To control the competition effect, the plants from the two outermost rows (L & B) will be discarded.

Treatments:

T1- Control
T2- Aqua-biota
T3- Effective Microorganisms Activated Solution (EMAS)
T4- Biochar and
T5- Vermicompost

vi. Sequestration of carbon and addition of organic matter into the soil

Sesbania aculeata, popularly known as Dhaincha is the most commonly used summer green manure crop in Bhutan. It is used for the fixation of atmospheric nitrogen and the addition of organic matter into the soil. Its cultivation must be done 60-70 days before the main crop. The seeds are broadcasted in fields at the rate of 30 kg/acre. At 40-50 days after sowing, the plants are incorporated into the soil. The biomass residues are left to decompose in the field for 20-30 days before cultivating the main crop. The use of green manure crops to sequester carbon into the soil is new in Bhutan. The use of Dhaincha as biochar, which can add carbon to the soil was studied. An experiment was conducted to determine the development stage of plants at which they must be converted into biochar and applied into the soil. Two plots each measuring 100m2 were used. The seed rate (30kg/acre) was maintained in both plots. The sowing time differs by 20 days between the two plots. The first plot was referred to as a matured Dhaincha block in which early seed sowing was done. The second plot, in which the seed-sowing was done 20 days later, was referred to as a young Dhaincha block. At the time of sampling, the matured Dhaincha block was 60 days old and was at the flowering stage. Whereas the young Dhaincha block was 40 days old and was at the vegetative stage. Biochar was prepared from the two different samples using the same method of barrel and cone system. The comparison of carbon per cent of the biochar prepared from the dried biomass was done. The biochar prepared from the young Dhaincha block was found to have a significantly higher content of carbon per cent as compared to matured Dhaincha block. Therefore, the use of Dhaincha for carbon sequestration must be done at the vegetative stage of the plant. The trial was carried out for the third year and will not continue further.

vii. Study on fermented rice bran in selected vegetable cultivation

1900 kg bokashi was produced at the Centre which was utilized for soil fertility management of field and nursery soil of the Centre. Its efficacy was also checked in vegetables like chili, tomato and cabbage. It shows potential in yield improvement by 20 %, soil-borne disease suppression by 30 % and also resulted in quality production of vegetables.

Outline of the experiments:

Bokashi-biochar combination efficacy test

A: Biochar three(3) different materials (rice husk, dhaincha, wood chip), metal canisters, precise weight scale, dryer oven, biochar maker, sampling tubes, paper, straws, lab glasswares

B: Efficacy test Mustard/spinach/chilli seeds, plastic pots (12x5x2=120), suphala, potting soil (dolomite lime mixed, pH adjusted), river sand, bokashi (precisely prepared from 100% rice bran), rice husk biochar

Methods:

Biochar yield and water holding capacity comparison

1: Biochar yield estimation: prepare biochar from each material. Measured 10-20g of 24hours oven-dried materials put in a metal canister then burn in biochar maker. After cooling down, measure the biochar produced in the canisters.

2: Biochar water holding capacity: soak each biochar for 24 hours underwater, then drip for 1-2 hours. Measure the biochar weight precisely. Check water phase pH and EC as reference data.

Efficacy test

Experimental plots: total 5 plots (Control suphala only, bokashi only, biochar only, biochar + suphala, bokashi + biochar)

B-1: Yield comparison and Growth analysis Comparison of dry weight (upper part/root part) twice, 15-20 days sowing, and the harvesting time. The data taking (# of leaves, height) weekly basis together with the photo. Watering carefully, if possible, using a tape dripper tube and fix the time every day.

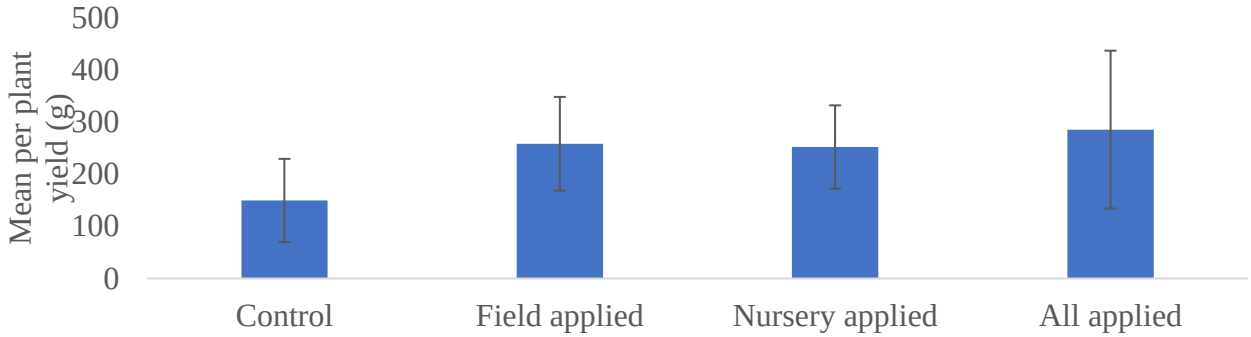

Figure 15 Effect of fermented rice bran on yields of chilli

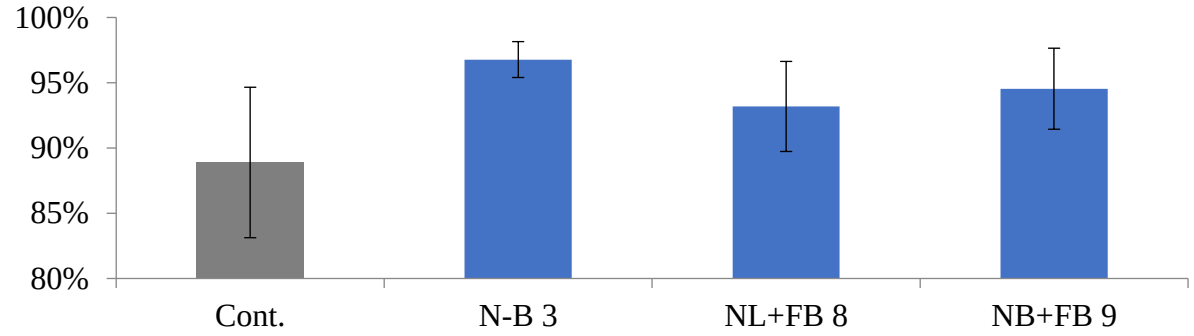

Figure 16 Effect of fermented rice bran on plant survival

Control: No bokashi

N-B 3: Bokashi at nursery

NL+FB 8: Bokashi at field only

NB+FB 9: all applied (Both nursery and at the field).

The survival rate of the chilli increased might be due to the suppression of soil-born fungal diseases (blight and wilts).

viii. Hydroponics farming research

Hydroponics is the soilless method of growing plants, using nutrient solutions. Six different types of hydroponics systems are established at the Centre and research was carried out with different vegetable crops. The result and experiences are presented in Table 68.

Table 68 Different types of hydroponic farming research carried out at ARDC Bajo

Types	Structure cost (M)	Crop grown	Advantages	Lesson learnt
Nutrient Film Technique	1.6	lettuce, celery, Dwarf Beans and Parsley	Suitable for growing herbs and leafy vegetables, the number of cropping cycles doubled as the same yield of soil-cultivated plants achieved 15 days earlier	GW% in oasis cube, rice husk, rice husk biochar, and pebbles were all 100% except pine bark powder (35%). Daily monitoring and nutrients supplementation were found best (System when operated for eight hours daily, pH level on average increased from 6.3 to 7.2 and EC decreased from 2.2 mhos/cm to 1.4 mhos/cm).
Dutch Bucket System	0.1	chilli and tomato	Suitable for growing fruit-bearing vegetables, the life span of chilli plants on average increased by 25 days with 3 times more yield compared with soil-cultivated chilli	Algae infestation was observed. Nutrient supplementation using fermented rice bran bokashi was found effective as top dressed to increase yield. The average plant height was 2 times taller and the numbers of branches were 50 % more (Pruning might be practised in future)
Drip Substrate Culture in Pot	0.005	lettuce and mustard green	Suitable for both leafy and fruity vegetables, water and nutrient use efficiency is higher. Root vegetables can also be grown successfully in a biochar/sand mixture	Germination of mustard green was lowest in sterilized rice husk (0%) and highest in the mixture of rice husk biochar and sand (100%). Both lettuce and mustard green on average has an 80% germination rate in pebbles. Automation of drip system found critical.
Drip Substrate Culture in Trough	0.005	tomato	Suitable for all types of vegetables and fruits, with no weeding, the average tomato yield was 20% higher compared with soil-cultivated plant	Top dressing with 50gm of bokashi per plant every week was found very critical in improved yield, quality and growth and development of plants. Automation of drip systems can be efficient.
Vertical Tower System	0.05	Lettuce, strawberry	Suitable leafy vegetables and herbs, Maximum vertical space use efficiency, can be easily kept and used on the balcony for herbs and salad production. The system is portable.	Leakages must be fixed as and when found. Automation of the system was found critical. Covering the top part of the PVC pipe can increase water and nutrient use efficiency.
Deep Water Culture	0.05	lettuce	Suitable leafy vegetables and herbs, Water and nutrient use efficient	Ground and water levels must be maintained uniformly. Supply of oxygen with oxygenator found critical.

Up-gradation of NFT system at the Centre

ARDC Bajo upgraded the NFT system due to the following reasons:

i. The size of the growing trough is small (2").
ii. It can be used to grow only leafy vegetables. Crops like chilli and tomato are not suitable.
iii. Crops can be grown for a short period. The vigorous root growth causes blockages in the growing channel which results in uneven distribution of the nutrient solution.
iv. Maintenance and cleaning of the system are tedious as zip lock and adhesives used are for one-time use only.
v. Frequent leakages occur which decreases both water use efficiency and nutrient use efficiency of the system.
vi. The present trough sizes are designed for commercial purposes and are uniform but different sizes of troughs are required to conduct suitability research on different crops.

Hydroponic technical assistance

During the FY 2021-22, the Centre has provided technical assistance to set up a Hydroponic system in the region.

a) Hydroponics at Oathbar farm, Punakha

The Department of Agriculture has provided fund support for **Nu. 0.777m** to Oathbar farm based at Punakha to set up a Hydroponics structure at the farm following their proposal presentation to DoA on 14th October 2021 and ARDC Bajo on 24th November 2021.

b) **Hydroponics at Gaselo Primary school**

The Greenhouse (5*20 m) supported by the project for the rural development for practising and teaching hydroponics to the students was installed with technical support from ARDC Bajo.

c) Hydroponics at Bajo HSS

A hand on training was provided to two teachers of Bajo HSS on nutrients formulation, addition and calibration and reading of pH and EC using the portable equipment.

Figure 17 (a) Vertical tower system (b) Dutch bucket system (c) Measurement of pH and EC using portable meter

ix. Soil sampling analysis for soil nutrient status

The National Citrus Repository (NCR)based at ARDSC Menchhuna maintains about 100 varieties of citrus germplasm collected from both outside and inside the country. For the propagation and

maintenance of the germplasm, potting soils are used and fertilizers are added. Before the availability of the laboratory facilities at Bajo, they do not know the nutrient status of their potting soil and usually follow the blanket fertilizer recommendation. Now with the availability of soil testing facilities they can understand their soil nutrient status and follow the fertilizer recommendation.

Table 69 Soil test result of NCR

Sample ID	N (%)	P (mg/kg)	K (mg/kg)	pH (H2O)
1-LT/TS/KT	1 0.08 vL	43 M	423.77 vH	5.76 M
1-LT/SS/KT	0.17 L	2.17 vL	235.87 H	5.54 M
2-RM/TS/KT	0.12 L	1.88 vL	300.31 vH	5.51 M
2-RM/SS/KT	0.05 vL	8 L	223.68 H	5.78 M
3-DB/TS/KT	0.18 L	5.58 L	132.90 M	5.22 L
3-DB/SS/KT	0.19 L	45 H	217.54 H	6.12 M
4-MK/TS/TK	0.17 L	11.37 M	201. 98 H	5.42 L
4-MK/SS/TK	0.19 L	34 M	287.05 H	5.88 M
5-DB/TS/TK	0.08vL	125 vH	177.48 M	5. 90 M
5-DB/SS/TK	0.19 L	11 M	120.00 M	5.71 M
6-JB/TS/TK	0.12 L	22 M	188.21 M	5.58 M
6-JB/TS/TK	0.15 L	67 vH	127.75 M	5.53 M
7-PO/TS/DG	0.18 L	23 M	104.32 M	6.02 M
7-PO/SS/DG	0.05 vL	112 vH	119.60 M	5.75 M
8-TP/TS/DG	0.15 L	14 M	189.00 M	5.23 L
8-TP/SS/DG	0.13 L	34 H	455.85 vH	5.89 M
9-ST/TS/TL	0.07 vL	1.99 vL	123.39 M	5.23 L
9-ST/SS/TL	0.12 L	15 M	166.56 M	5.57 M
10-MZ/TS/TL	0.19 L	2.46 vL	152.53 M	5.92 M
10-MZ/SS/TL	0.17 L	37 H	176.12 M	5.87 M

vL: Very Low L: Low M: Medium H: High vH: Very High

3) Progress as per signed Organic Flagship Performance Agreement

As per the APA 2021-22 agreement with NOFP, the Centre carried out Organic research and promotion of organic technologies within the region. A various research study conducted. Dhaincha seed production for green manure purposes was also carried out. The production technology of wood and bamboo vinegar is also established and perfected at the Centre and conducted research at multi-locations. With support from NOFP, 1000kg rice husk biochar, 1900kg fermented rice bran bio-fertilizers and 500kg vermicompost and 20 MT compost were produced. Climate-smart technologies for organic farming like potting media and BAMS packaged, adapted and endorsed by the fourth Technology Release Committee meeting held at Department of Agriculture conference hall on 30th June 2022. Quarterly monitoring and submission of a monthly progress report on every 25th of the month was done to the NOFP co-ordination unit.

The efficacy of rice husk biochar, fermented rice bran bokashi and fermented cattle urine are also tried in cultivation of vegetable using both soil and hydroponics system. The technology on the fermentation of cattle urine for use as organic nutrients in hydroponics system are also perfected. The organic substrate culture using wood chip biochar and husk biochar as media and bokashi and

fermented cattle urine as nutrients source are also established at the centre. The demonstration and training are also given through Desuup skilling program, youth skilling program and through farmers training.

During the Fifth Agriculture Research and Co-ordination Meeting held on 8th May 2022, detailed presentation on Bhutan Agri-microbial Solution, Bamboo vinegar technology and azolla technology was done. Subsequently, Bajo potting mix 1and BAMS technology were endorsed by the Fourth TRC to address the organic inputs shortages in the country.

4) Demonstration and promotion of climate-smart technologies

Table 70 Demonstration of climate-smart agriculture technologies in the WC Region

SN	Dzongkhag	Participants details	Number of Participants			Remarks
			Male	Female	Total	
1	Trongsa	RTDC, Zhemgang with financial support from FAO	25	25	50	Farmers' hand-on training on Climate-smart technologies, mushroom cultivation, IPM, and Improved nursery management for two weeks at ARDC Bajo
2	Dagana	COVID-19 displaced youth	07	02	09	Youth skilling program with financial support from FSAPP and facilitated by ARDC Bajo for six days at ARDC Bajo
3	Dagana	Youth farmers, progressive farmers & school drop out	14	09	23	FSAPP Skilling program conducted at the Centre for six days at ARDC Bajo
4	Dagana	Farmers of six FSAPP project gewogs	148	79	222	Farmers' hands-on training on Climate-smart technologies and IPM through FSAPP
5	Tsirang	Rice farmers (Rangthaling, Kilkhorthang & Tshokona)	09	07	16	Field day on alternative wetting and drying (AWD) of rice cultivation
6	Tsirang	Mendrelgang farmers	15	10	25	Demonstration of climate-smart technologies through GCF Funding
7	Wangdue	Rubesa farmers	18	11	29	
8	Trongsa	Nubi, Langthel, Drakteng	28	32	60	
9	Punakha	Youth Oathbar Farm, Goenshari	13	07	20	
10	Dagana	Tshangkha	15		30	
11	Wangdue	Gyalsung Project, Khotokha	17	14	31	Demonstration of climate-smart technologies through GEF-LDCF Funding
12	Wangdue	Desuung, Gangtey	05	09	14	Training on climate smart technologies
Total					**529**	

During the FY 2021-22, the Centre has demonstrated eight main climate-smart agriculture namely bio-char, bokashi, Azolla, improved method of potting media, composting and mulching, rice husk biochar, fermented rice bran fertilizer, Bhutan Agri-microbial solution, Gelatine solution, starch solution, wood and bamboo vinegar, Azolla, water harvesting technology are promoted in every farmer training in West-Central Region.

More than 500 heads availed of the training during the FY 2021-22. The training was conducted through a tailor-made skilling program at the Centre and with a hands-on training program for farmers in fields to promote the climate-smart technologies which will help farmers/youth/agriculture entrepreneurs in practising organic agriculture. The technologies were imparted through financial support from RGoB and projects namely NOFP, FSAPP, GCF and RDCAP. Table 70 summarizes the demonstration conducted in multi-locations.

i. Rice Husk Biochar

This technology addresses the shortage of organic inputs for practising organic farming in the country. It will also be a useful input in establishing nurseries for the hydroponics systems. It will help in achieving the fourth objective (Promote research and development, affordable integrated technologies and inputs for organic production) and the second outcome (Increased domestic production of bio-inputs leading to import substitution of some agro-chemicals). Easy availability of organic inputs will be necessary to support organic agriculture in Bhutan. This technology would utilize waste biomass available at the farm and convert it into biochar. Biochar has unique properties that make it not only a valuable soil amendment to sustainably increase soil health and productivity, but also an appropriate tool for sequestering atmospheric carbon dioxide in soils for the long term in an attempt to mitigate climate change. This 400-year-old technology is an adaptation from Japan and was introduced at Bajo by Mr Kazuyoshi Yuasa (JICA expert working for IHPP) in 2019. It has been modified and improved in terms of portability of the equipment and reduction of fire hazards to the minimum. The proposed technology produces biochar from biomass, by a process known as pyrolysis. Pyrolysis means heating in absence of oxygen, which prevents the complete burning of organic biomass. The equipment is designed in such a way as to produce fine quality biochar under controlled conditions.

The production technology requires a metal barrel, a metallic cone and a chimney set which would cost the maximum Nu. 10000/-. 25kg biochar can be produced in less than seven hours. The training cum demonstration includes:

- Preparation of rice husk biochar using cone and barrel.
- Benefits of rice husk biochar in agriculture were done along with the procedure of preparation and application.
- The production of rice husk ash and vinegar as a by-product along with its benefits.
- The use of optional materials like wheat straw, wheat husk, dried lady finger, dried beans cover, dried sunflower head and maize stalk for biochar preparation.
- The pyrolysis process and carbon sequestration in agriculture soil
- The ways and methods to produce quality biochar using a stirring technique
- The quenching process to stop the fire
- Activation of rice husk using cattle urine and bokashi

ii. Fermented Rice Bran Bokashi

This technology addresses the shortage of organic inputs for practising organic farming in the country. It will also be a useful input in establishing nurseries and as a substitute for chemical fertilizer. It will help in achieving the fourth objective (Promote research and development, affordable integrated technologies and inputs for organic production) and second outcome (Increased domestic production of bio-inputs leading to import substitution of some agro-chemicals) of the National Organic Flagship Program. Easy availability of organic inputs will be necessary to support organic agriculture in Bhutan. This technology would utilize waste biomass available at the farm and convert it into organic fertilizer. 100 kg rice bran fertilizer can be produced in less than seven days, whereas the same quantity of compost requires at least 45 days. Rice bran if composted takes four months due to high lignin content. Compost remains in the soil for a maximum of five years, biochar remains in the soil for hundreds and thousands of years. Compost can be a source of insects' pests, diseases and weeds, whereas biochar is thermally sterile and stable. Compost production is dependent on the season; fermented fertilizer can be produced throughout the year. The efficiency of compost increases if it is used with biochar. The know-how of the technology along with its benefits

- The bran to water ratio and water to sugar ration for quality preparation of bokashi
- The three different methods of bokashi preparation (Mother stock, ingredients and BAMS)
- The application of bokashi in vegetable and fruit plants was explained in detail along with the use of bokashi as deodorant, in enhancing compost and sterilization of soil
- The usages of bokashi in a hydroponics system and floriculture
- The procedure to shade dry and package the bokashi for commercial purpose
- The hands-on practice in preparation for Bokashi following all three methods.

iii. Bhutan Agri-Microbial Solution

This solution is similar to an effective micro-organisms solution and plays an important role in practising organic farming in the country. The multiplying ratios of the mother solution to apply in different usages were explained along with its benefits. BAMS is utilized as a compost enhancer, deodorants, preparation of bokashi, preparation of plant extract and preparation of pesticides. The demonstration on the preparation of plant extract using BAMS was also done and an application rate of BAMS was also clearly explained along with its benefits.

iv. Bio-digester

The cattle urine being more concentrated than dung can be a good source of nutrients for crops. Bio-digester technology plays an important role in collecting cow urine from cow sheds. The use of cattle urine for foliar spray and as an organic source of nutrients in the hydroponics system was demonstrated. The technique of fermentation of cattle urine using BAMS to enhance the quality of urine was also demonstrated on-station.

v. Open Air Bio-char

The training cum demonstration on open-air Bio-Char include

- Benefits of open-air biochar in agriculture with the procedure of preparation.
- The pyrolysis process and carbon sequestration in agriculture soil
- The ways and methods to produce quality biochar using a stirring technique
- The quenching process to stop the fire

vi. Integrated Pest Management

Based on the pest and disease issues raised by the participants IPM session was designed for each group training and IPM knowledge and skills were imparted.

Session 1: Why do plant pests and diseases occur?

Training participants were briefed on plant requirements and the different factors influencing plant pest occurrence and disease developments such as climate change, agronomic practices, irrigation water management, and soil nutrient management. Principles of IPM were imparted. The importance of the following practices was also discussed:

- Cultivar and seed selection: choice of cultivar and seed is the basic requirement for crop production where a farmer should consider the crop suitable to his/her farm.
- Soil sterilization: soils containing plant pathogens can be sterilized using different methods such as mustard green manure, rice bran *bokashi* or simply using plastic mulches.
- Seed treatment: bacterial or fungal inoculum on the seeds can be removed or reduced by different techniques such as soaking the seeds in chlorine bleach, wood vinegar, and chemical pesticides. Different techniques of seed treatment were highlighted with their limitations and benefits.
- Crop rotation: cultivation of the same or same group of crops in a particular plot every year increases the risks of pest or disease inoculum built up. Crops of different families are recommended to be rotated to reduce pest and disease incidences.
- Irrigation water management: appropriate irrigation water management to reduce moisture (excess or scarce) stress to crops was recommended.
- Nutrient management: split application of fertilizers was recommended for better nutrient management.

Session 2: Wood vinegar production and usage

Production methods of pyroligneous acids commonly known as 'wood vinegar', which can be used for different functions in agriculture were demonstrated. Wood vinegar can be used as herbicide, insecticide and soil amendments. Further, it can be used for seed priming. Materials required, standards of production systems, and functions of the different structures of the oven were also explained.

Session 3: Gelatine solution for aphid and white flies with hands-on training

The process to make gelatine solutions that can be used for the management of aphids and other sucking pests was demonstrated. The formula for gelatine solution making is 2g of gelatine powder in 1 litre of water, along with 0.5 ml each of cooking oil and soap solution. Gelatine should be dissolved in hot/warm water for use.

Session 4: Jholmol preparation as a biopesticide

Jholmol, a kind of a formulation using cow urine, water, effective microbes, and plants such as artemisia are reported to be effective to repel pests in crops. Four types of formulation procedures were shared with the farmers

Session 5: Bordeaux pastes application at tree trunks: trunk borers and lichens can be managed using the Bordeaux pastes (mango and citrus).

- Fruit drop collection: one of the methods to reduce the fruitfly and fruit borer population is by picking up and destroying the dropped fruits. Collecting and covering the dropped fruits in airtight condition for about a month (using barrels) kills the larvae of the fruit flies and fruit borers.

- Insect traps:
    - Sex pheromone traps: functions of sex pheromones and applications were briefly explained. The sex pheromone traps are species-specific and have reduced impacts on the other species. Brown sugar syrup trap: insect trap using brown sugar and ethanol solution was also explained.

Session 6: identification of pests and beneficial insects

Sample insects of beneficial or pest nature were shown to the youths for familiarisation. Kinds of trunk borers (longhorn beetles), armyworms (moths) and weevils were presented. Beneficial insects such as parasitoid wasps, lady beetles, hover flies, mantid flies, and lacewings were also shown.

vii. Hydroponics farming research

In Bhutan, hydroponics is a new agriculture technology introduced at the beginning of 2019. The department of agriculture felt the need to introduce such technology to reduce drudgery and to make agriculture an attractive enterprise for entrepreneurs and youths of Bhutan. Currently, the Department of Agriculture has established four hydroponics systems ARDC Bajo, ARDC Samtenling, ARDC Wengkhar and NCOA Yusipang. Hydroponic farming training was imparted to the skilling program conducted at ARDC Bajo on the following:

- Know-how and importance and benefits of hydroponics.
- The benefit of increased water uses efficiency and increased nutrients use efficiency
- The importance of cleanliness and sanitation to prevent pest and diseases infestation
- The automation and use of IoT in agriculture
- The exposure to seven different types of hydroponics systems such as NFT system, Dutch bucket system, Substrate system, pot with drip system, Trough system, Deep water culture system and Vertical tower system with sprinkler was showcased to them.

viii. Improved Vegetable Nursery Management

Participants were made to comprehend the importance of vegetable nurseries in vegetable farming. They could learn that a vegetable nursery is a place where the young and immature seedlings are prepared for main field transplantation. The training participants were briefed not only on the advantages and disadvantages of the farmer's practice of carrying out the vegetable nursery but they were also enlightened on lots of advantages that improved nursery management practices that research is promoting has to offer.They were practically oriented with the nursery bed preparation, and seed sowing methods in the nursery. They have learned that the seeds have to be sown twice their size for increased germination rate and improved germination pace. Then the two-leaf stage seedling will be planted in the poly pots filled with media.

Poly potting technology, which ARDC Bajo has been promoting has proven very promising technology in vegetable crop production, and participants were made to prepare potting soil mixes which were prepared out of the **soil: sand: biochar: compost and bokashi at 4;3;3;1;0.5 ratios** by adding 100grams of Suphala and ash to the mixture. They were also taught on keeping the potted seedlings covered with green nets during summers and with plastics during the cold winter season to stabilize the seedlings.

Participants could see that the seedlings in the poly pots get ready for transplanting 20-25 days after potting. They were engaged in the planting of the seedlings in the field. Farmers learned that

field preparation a month before the planting time, and keeping the soil exposed to the scorching sun could help in controlling soil-borne diseases. They were also briefed that enough space should be provided between the plants for proper air circulation and sunlight which in turn would reduce pest and disease incidences. For good growth and yield, farmers were recommended to do spot application of one handful of rice bran bokashi, biochar, well-decomposed FYM, and small quantities of Suphala, mix it well and then transplant the seedlings. Participants got to plant the seedlings which ARDC Bajo have prepared as part of their practical learning.

ix. Alternative wetting and drying (AWD) of rice cultivation

A field day was conducted on 25th Oct 2021 at ARDSC Menchunna for farmers of Rangthaling, Kilkhorthang and Tshokona. Sixteen households (7 F, 9M) participated in the day program. As the productivity and overall output of rice have been low and stagnant for several years in the area and most of the field seems vacant due to irrigation constraints and an erratic pattern of rainfall, the rice cultivation in the region over the past has been drastically reduced. Most of the fields remained empty with a delay in rainfall. Further, the farmers in the area see permanent flooding of their fields as a boon to rice production and with decreases in the volume of irrigation water, they surrender the plantation. However, most of the farmers keep on growing their local varieties like Sukimey and Chottey only due to their adaptability and personal preferences whereas economically it has low yield and suffers crop losses through lodging every year.The objective of the program is to confront this problem and to increase rice production through adoption of the improved technology like Alternative Wetting and Drying (AWD) with varietal production evaluation trials.

The cultivation of improved varieties was not so popular in the region although some varieties like WRK-II and IR-28 and Khangma Maap were prevailing for a few years back in our station. As to popularise and upscale the cultivation or adoption of the higher-yielding varieties and other premium local rice varieties available at the same altitude, the premium rice grown in some other locations was collected and incorporated in our AWD trials to determine whether those rice varieties could adapt to their local environmental conditions of Menchhuna, and in addition to knowing the farmers' response for those paddy varieties and technology. Besides presenting the yield assessment of improved rice varieties available in our station, participants were made to observe the different varieties of standing paddy, which was yet to mature in our on-station and instructed them to observe the characteristics and appearances like height, grain quality resistance for lodging, sign and symptom of diseases in the leaves and in addition made them compare with the local varieties which they adapt in their areas. The pros and cons of adopting the improved varieties in the large family were clearly explained to the farmers by the resource persons keeping the goal of national food security as a priority.

5) Agriculture service delivery facilities established/improved

Agriculture faces a great challenge in coping with growing water scarcity and increasing demands for food production. Various initiatives are being made to increase the efficiency of the agricultural irrigation system. With the increased availability of the Internet of Things (IoT) and Information and Communication Technology (ICT), it is now possible to real-time monitor/control different processes of irrigation and water management in agriculture. The smart irrigation system is using water-saving technologies such as micro-irrigation systems combined with different IoT-based technologies for automation. With financial support from FSAP Project, the Centre carried out three major activities under SMART irrigation and automation. These activities are carried out to improve the water efficiency management in the Centre and showcase the latest and most important agriculture innovations to the visitor visiting the Centre and

i. Improvement of water efficiency management in the system

In the FY 2021-22 the Centre carried out a major renovation of the internal irrigation channel on-station for cereal crop production. This improvement of water efficiency management in the system by the maintenance of an internal irrigation channel on-station for cereal crop seed production covers five acres of land where cereal trials and demonstrations are carried out and for cereal seed production.

ii. Establishment of an efficient micro-irrigation system

The Centre has set up SMART Irrigation with automation covering eight horticultural fruits and nuts germplasm blocks covering 15 acres approximately. This is established through the technical support of Dr Tshering Penjor (PhD), Specialist, ARDC Wengkhar by skilling researchers through Training of Trainer (ToT) and setting up the SMART Irrigation and greenhouse automation. The trenching and layout of mainline and lateral drip lines and fitting and layout of mainline and lateral lines were carried out in eight fruits and nuts blocks carried out. Fitting and installation of watering zones, main filter, solenoid valves, 6 mm take-off, 6 mm extension tubes and button drippers are set up.

iii. Automation of 20X12 m size greenhouse and hydroponic system

The greenhouse (20X12M) and the hydroponic system were completed with the following work.

- fitting and layout of mainline and lateral lines for the production of high-value vegetables such as chilli and tomato under greenhouse condition
- Installation of automation of irrigation
- Installation of ventilation fan, fogger and heating system to regulate the environmental control inside the greenhouse
- Installation and configuration of automation device and software
- Testing of the device and software
- Installation of portable sprinkler irrigation system in the vegetable

iv. Climate Smart irrigation system for citrus orchard

ARDC Bajo with fund support from RDCCRP through National Citrus Program established efficient micro-irrigation demonstration facilities for 3 acres of citrus orchards in Phangyul gewog.

This technology is initiated basically to address the problem of insufficient water through efficient use of available water

xiv. Dryland Irrigation water harvesting pond construction.

ARDC, Bajo in collaboration with Dagana Dzongkhag agriculture sector with the fund support from RDCCRP has constructed a water reservoir in Drujaygang under Dagana Dzongkhag. The size of the pond is about 26m in length, and 11m in breadth with a water holding capacity of 903567 litres benefiting 5 households. This pond is expected to cover 40 acres of orchards including those cultivable lands currently left fallow without irrigation will be brought under cultivation

xv. Water harvest

ARDC, Bajo supplied 21 numbers of tech Pauline plastic sheet (300 GSM) to Tshanglajong in Trong gewog under Zhemgang Dzongkhag for harvesting of water. The purpose of plastic is to demonstrate water harvesting technology using plastic as underline materials in a water harvesting pond. As per the specification, it has a minimum of 15 years life span and is expected to hold 15000 to 27000litrs of water based on the size of the plastic. Besides, 2 numbers of plastic sheets were also supplied to Phuntsho Pelri based on the request and considering the acute shortage of water in the orchard.

6) Social and impact studies conducted

i. Paddy loss assessment at Wangdue and Punakha Dzongkhags

Background

The incessant rainfall between 17th to 20th October 2021 damaged harvested paddy across the country. Due to the importance of rice in the Bhutanese food system, the damage was a major loss to the farmers and the food security of our country as a whole. Punakha-Wangdue valley has the largest rice-growing area in Bhutan with 6526.26 acres in the country with an annual production of 13948.54MT as per the Agriculture Statistics 2020 (RSD, MoAF 2021). Farmers usually start harvesting the crop by the first week of October. The harvested paddy which is kept in the field to be sun-dried was heavily soaked in continuous rainfall over four days. The viability of seeds was lost and the eating quality of paddy recovered after rainfall has largely deteriorated. In many cases, the paddy seeds started sprouting due to continuous soaking and increased moisture content. Rice straw which is a main source of feed for cattle and horses during winter was also damaged. The harvested paddy which was kept in the field to be sun-dried was heavily soaked in continuous rainfall over four days (18-20/10/2021) as per reports of my farmers.

Weather data

The weather data showed that there was a major shift in the rainfall pattern of October month in Punakha-Wangdue in 2021 when compared to the average data for the past five years (2016 to 2020) as shown in the figure below. Rainfall generally stops towards October as observed in the year 2016-2020. However, the year 2021 saw an increase in rainfall towards October indicated in the graph unlike the last four years (data source: NCHM).

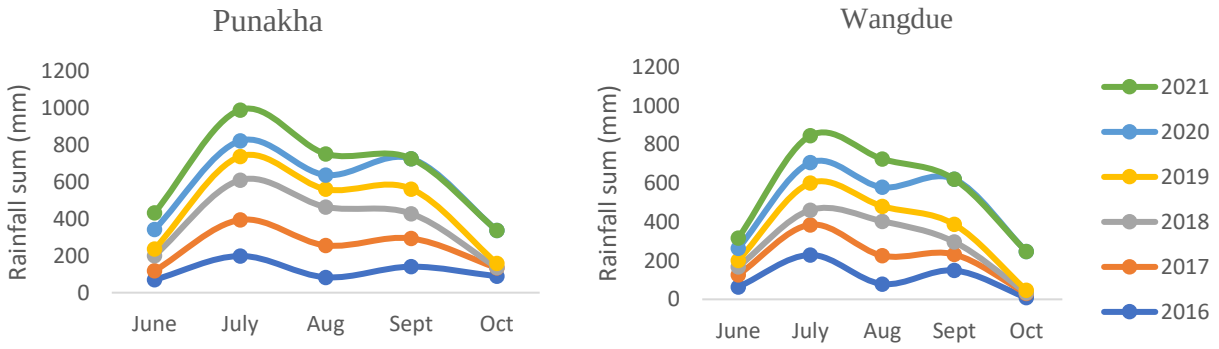

Figure 18 Rainfall trends from June to Oct from 2016-2021

Crop damage assessment

Crop damage by the rainfall was assessed by Dzongkhag Agriculture Team as per the format circulated by DoA. Local government also played a vital role in the identification of affected farmers and coordination of the assessment at their respective gewogs. The assessment of the loss was carried out at the site in consultation with the owners. ARDC-Bajo visited selected farms with severe damage for verification in discussion with the Dzongkhag Agriculture Team.

The uniform format was developed and used across all the gewogs. The major parameters on which the severity of damage was assessed were shattered seeds, sprouted seeds and paddy damage due to submergence in water. The affected cultivated areas were measured using GPS devices for

separate farms wherever possible and in some areas, the assumption was made through farmers' recall methods.

In Punakha Dzongkhag, since the severity of damage was similar across the gewogs, the actual loss was maintained at 50% uniformly as farmers could not use 50% of the remaining harvested paddy. Only the harvested crop left for drying in the field was assessed. Whereas for Wangdue Phodrang, crop damage was estimated at 60% loss with most of the fields submerged (60-70 % of the harvested paddy was submerged in water).

Crop damage at Wangdue Phodrang Dzongkhag

The average yield was based on the average production yield of the past five years (2016- 2020) which is calculated at 1600kg for Wangdue Phodrang. The cost of production for paddy (Mid-altitude) was used as Nu. 41/kg as per the CoP (DoA, 2020). The total affected area was 565.297 acres while the estimated yield loss due to the rainfall is 5,42,685.12 kg. A total of 742 households were affected by the recent rainfall with the highest number of households in Bjena (150) followed by Nyisho (127). The least affected Gewog was Dangchu with just one household.

Table 71 Crop damage expressed by weight (Kg) and cost (Nu.), Wangdue Phodrang, 2021

Gewog	HH counts	The affected area (Acre)	Estimated Production Loss (Kg)	Estimated Monetary Loss (Nu.)	CoP* in Nu. (Mid-altitude)
Nyisho	127	133.080	127756.800	5238028.800	8730048.000
Bjena	150	111.225	106776.000	4377816.000	7296360.000
Kazhi	72	68.010	65289.600	2676873.600	4461456.000
Rubesa	112	64.530	61948.800	2539900.800	4233168.000
Gasetshogom	75	47.006	45125.760	1850156.160	3083593.600
Phangyul	40	39.376	37800.960	1549839.360	2583065.600
Gasetshowom	42	36.790	35318.400	1448054.400	2413424.000
Nahi	64	31.070	29827.200	1222915.200	2038192.000
Thedtsho	31	20.760	19929.600	817113.600	1361856.000
Daga	28	13.150	12624.000	517584.000	862640.000
Dangchu	1	0.300	288.000	11808.000	19680.000
Grand Total	**742**	**565.297**	**542685.120**	**22250089.920**	**37083483.200**

**Cost of production is calculated for the affected area only.*

By area, Nyisho was the heavily affected gewog with 133.08 acres. The loss estimated is around Nu. 2.225 M. In many cases, the paddy seeds started sprouting due to continuous soaking and increased moisture content. The sprouting was mainly observed in the lower portion of paddy heaps where soaking was continuous. Rice straw which is commonly used as feed for cattle was also damaged due to rotting. The verification team visited a few farms where threshing was ongoing. About 50% of the thrashed paddy were observed sprouted. Grain quality may be largely damaged which is mostly observed when recovered from rainfall or soaked in water.

Crop damage at Punakha Dzongkhag

The average yield was based on the average production yield of the past five years (2016- 2020) which is calculated at 2145kg/acre. Based on the assessment, it was found that all 11 gewogs under Punakha dzongkhag were affected in pockets by the recent rainfall with 664 total households. A total of 384.64 acres of paddy field were affected with an actual loss of 412.53 MT which is

computed at 50% loss of the affected crop harvest. The total yield loss in monetary value was approximately Nu. 16.91M which was computed based on the cost of production conducted in 2019 for mid-altitude @ Nu 41/kg as detailed in Table 72. With 664 households affected with a total area of 383.29 acres of paddy fields, Limbukha gewog was the most affected gewog with 59.50 acres. Talo has the highest percentage of area affected which is 73% out of 11.81acres cultivated area with 6% crop damage, whereas Kabjisa has the lowest percentage of damage 10% with 3% of crop damage. Out of 1181.28 acres of area cultivated 33% of the area has been damaged by the recent rainfall which is estimated at 2532.40 acres of 664 households.

Table 72 Crop damage expressed by weight (Kg) and cost (Nu.), Punakha Dzongkhag, 2021

SN	Gewog	Total HHs affected	Total cultivated area (Ac)	The actual area affected (Ac)	Estimated production loss (Kg)	Actual Production Loss (Kg)	Loss in monetary value (Nu.)
1	Toep	60	96.47	45.04	96610.80	48305.40	1980521.40
2	Barp	73	102.27	51.18	109781.10	54890.55	2250512.55
3	Guma	97	226.63	51.94	111411.30	55705.65	2283931.65
4	Talo	32	30.51	22.37	47983.65	23991.83	983664.83
5	Kabjisa	69	115.05	11.81	25332.45	12666.23	519315.23
6	Goenshari	23	39.05	10.96	23509.20	11754.60	481938.60
7	Toedwang	54	174.95	35.29	75697.05	37848.53	1551789.53
8	Chhubu	65	154.66	35.81	76812.45	38406.23	1574655.23
9	Shengana	37	87.40	27.02	57957.90	28978.95	1188136.95
10	Dzomi	97	67.88	33.72	72329.40	36164.70	1482752.70
11	Limbukha	57	86.41	59.5	127627.50	63813.75	2616363.75
Total		**664**	**1181.28**	**384.64**	**825052.80**	**412526.40**	**16913582.40**

Recommendations:

Information on the weather forecast and crop advisory during critical crop stage should reach the farmers and extensions on a larger scale to create better awareness and prevent crop losses. Both extension officials and farmers need to be given more sensitization on Agro-Met services with support from the Agro-Met focal of ARDC support under ARED under the DoA.

Harvesting paddy manually is more labour intensive (13.2 man-day/acre) and the current trend of keeping in the field for sun drying lead harvested paddy exposed to erratic weather pattern leading to more damage. Farmers must buy combine harvester and get paddy harvested simultaneously with threshing. This will reduce the workload and also prevent incidents that occurred a week ago. Need feasibility study on types of machinery like a combine harvester, rice reaper and paddy thresher should be provided at a subsidized rate for farmers to be able to avail it.

The farmer who is in genuine need of seed support for next season must be made available since the crop has been damaged and may not be viable for next season. Seed supply from the government could be a very effective measure to address the seed loss that was caused to farmers. As per the former rice expert Mr Mashesh Ghimaray, rice varieties cultivated within Punakha and Wangdue shatter easily. It is not necessary for sun drying in the field after harvest and recommended to thresh right after the paddy attain maturity stage.

ii. Evaluate alternatives to wooden posts for Electric Fencing

Human-wildlife conflict is one of the major constraints in agriculture. Damage is mostly seen in the form of loss of human life, crop depredations, poaching etc... One of the common mitigation and management of wildlife problems is through using the electric fencing system. The current fencing system is largely supported using wooden posts. These wooden posts are often subjected to weather-related maintenance costs which are not sustainable. Therefore, ARDC Bajo initiated to look for alternative posts for the electric fences which are of low maintenance also sustainable.

Costs calculations

For this, different costs incurred in different post-based systems were calculated based on current market costs. Costs are presented as Initial costs (cost incurred during establishment) and recurrent costs (for maintenance and replacements of different fence materials). Total cost is presented as cumulative costs over the years. Costs for Wooden post preparation are based on a survey in the Wangdue district.

Table 73 Initial costs for Wood post-based system

Particulars	**Unit**	**Quantity**	**Rate**	**Total costs**
power chain operation	1 powerchain&1 man	5.1	1500	7602.9
preparing post	man-days	7.8	500	3882.4
preparing insulator	man-days	12.0	500	6000.0
Petrol	Litre	27.2	100.35	2729.1
Mobile	Litre	22.5	250	5632.4
32mm HDPE pipes	m	236.3	55.2	13041.0
Nails	kg	30.0	70	2100.0
Combined costs				
Cost of post preparation				*40987.8*
Post erecting	*man-days*	*32.3*	*500*	*16147.1*
transportation	*man-days*	*26.6*	*500*	*13323.5*
			TOTAL (Nu.)	***70458.4***

Benefits for crop protection is considered the same for all three types of system and 1 was used for the computation. The initial cost of Wooden post-based Electric fence system establishments is as given in the table above. The costs of the HDPE post and Plastic post-based Electric Fence systems were calculated based on current market rates of different inputs used and are in Table 74.

Table 74 Initial costs for HDPE system, and Plastic post system

Particulars	**Unit**	**Rate (Nu.)**	**Quantity (No.)**	**HDPE[1] (Nu.)**	**Plastic Pole[2] (Nu.)**
Driller charge	Days	1000		1000	1000
Energy Consumption				300	300
Post preparation cost				1300	1300
Post erecting cost	Days	32.3	500	16150.0	16150.0
transportation cost				3000.0	3500.0
Pipe/Pole cost (2m post)	2	340.4[1], 250[2]	450	306360	170200
			Total Initial cost (Nu.)	**326810**	**191150**

Recurrent costs were calculated based on its durability as per the survey and the manufacturers' warranty. Total costs were calculated as the sum of initial costs and the sum of recurrent costs annually.

Assumptions thus based are as below;

1. Wooden post-based fence: all poles are required to be replaced in 5 years (as recurrent costs)
    - In the 3rd year, 50% of the posts should be replaced.
    - In the 4th year, 30% of the posts should be replaced.
    - In the 5th year, 20% of the posts should be replaced.
2. HDPE posts: Lasts 30-50 years. So, no recurrent costs on posts.
3. Plastic posts: last 15 – 20 years. No recurrent costs till the 15th year.

Benefits calculations

All three posts provide similar benefits for crop protection. So, no differences in the benefits of crop protection. The benefits of a wooden post-based fence over HDPE are the sum of 'differences of initial costs of the two systems' and 'saving interests of the initial costs differences. Similar calculations were used for computing the benefits of Plastic pole post-based fences. Note: Savings interests of 5.5% per annum were used for the computation.

Benefit-cost ratio

The details of costs and benefits with the Benefit-cost ratio (BCR) for different years are presented in Table 75. By comparing the BCRs of different Systems, for the initial years, the Wooden post-based electric fences are preferable to the other two. In the fifth year, a Plastic post-based fence system is preferable to a wooden post and HDPE post-based fences. Also, HDPE post-based system is preferable to a wooden post-based fence system starting the fifth year.

Table 75 BCR for 50 years duration

BCR for 50 years duration

Years	Wooden system1	Wooden system 2	HDPE system	Plastic post system
5	-0.32824	-1.66716	1.139005	1.94744
10	-4.76325	-5.29127	0.455604	0.778979
15	-5.1393	-5.37051	1.139005	0.97372
20	-5.77465	-5.68448	0.455604	0.38949
30	-6.0416	-5.9544	0.455604	0.25966
40	-6.03041	-5.84522	1.139005	0.649147
50	-6.12996	-5.87093	1.139005	0.48686

If the fence systems are for a longer duration than 20 years, HDPE post-based electric fences are preferable to both systems.

Conclusion

If the fencing system is aimed for 5 years or less, the Wooden post-based electric fencing system is recommended. If more than 5 years but less than 15 years, a Plastic post-based system is recommended. Alternatively, HDPE post-based system may be used. If more than 15 years, HDPE post-based system may be used. Alternatively, a Plastic post-based system is recommended.

iii. Citrus canopy management impacts

Citrus is one of the most important agricultural commodities in the Bhutanese economy. It provides valuable export earnings and income and employment for at least 60% of the population.

Citrus is grown by more than 22,000 households in the low and mid-altitude areas. The current total area is about 13,900 acres and the average annual production is slightly computed at 25,660.8041,000 MT in 2020 (RSD, MoAF 2021). Unlike other agricultural commodities; it has a well-established export market in Bangladesh and India.

Conversely, Citrus cultivation in Bhutan is facing numerous challenges related to the impact of climate change and technology adoption. This has resulted in a rapid decline in citrus production as most citrus growing areas are becoming less feasible for production especially due to an increase in temperature resulting in moisture stress and low chilling hours during the winter season; delayed rainfall and long dry spells periods; increase in pests and diseases, etc. While the research information generated within the country is limited, management techniques applied in other countries are merely being reached and adopted to address these issues mainly due to inadequate research and extension capacity.

With the recent development and institution of the National citrus coordinating Centre in ARDC Bajo, holistic citrus orchard management was initiated as one of the priority activities under the national citrus program and covered as many as 11 dzongkhags and brought numerous trees under canopy management.

To assess and understand the impact of the citrus canopy management program, we conducted a study survey using a semi-structured questionnaire. The data were analysed using MS Excel. This study aimed to understand the first-hand experiences of the effectiveness of the rejuvenating program and to recommend the program as a package of practices for farmers.

Demography of respondents

Of the 82 respondents, 28% was from Tsirang, 28% from Dagana, 17% from Mongar, 11% from Chukha, 6% each from Wangdue and Zhemgang and 3% from Punakha. 60 % of the respondents were male while the rest were females.

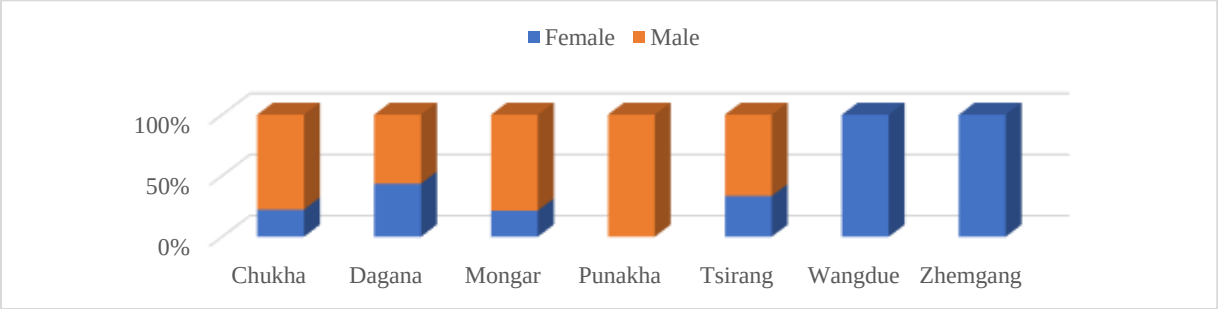

Figure 19 Gender of the citrus farmers

Road accessibility

Almost every respondent has (98%) road access to their Citrus orchards. One respondent from Tsirang and Punakha has limited access to roads. A 95% of the respondents require less than 15 minutes walk from road points, while 4% in 15 to 30 mins and 1% in 30 to 60 mins.

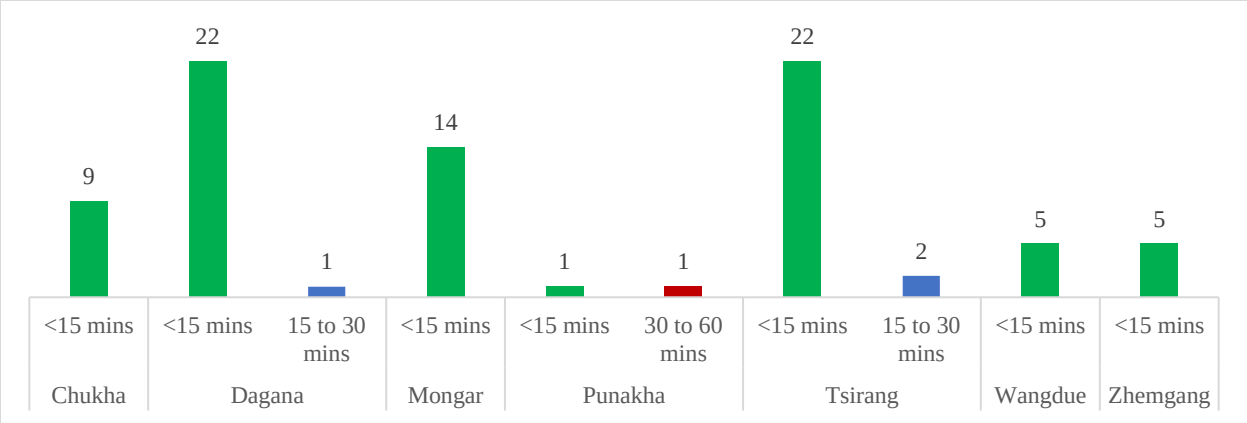

Figure 20 Road accessibility of the citrus farmers

Ownership, size and soil fertility status of the Citrus Orchards

Most (99%) of the respondents own the Citrus orchards they work at. Most of the Citrus orchards are in sizes of 1.79 acres (mean) with the highest of 10 acres and the lowest at 0.1 acres. The total acreage of the orchards covered in this study is highest in Mongar with 60.12 acres followed by Tsirang with 34.81 acres. The least is in Punakha with 2.67 acres.

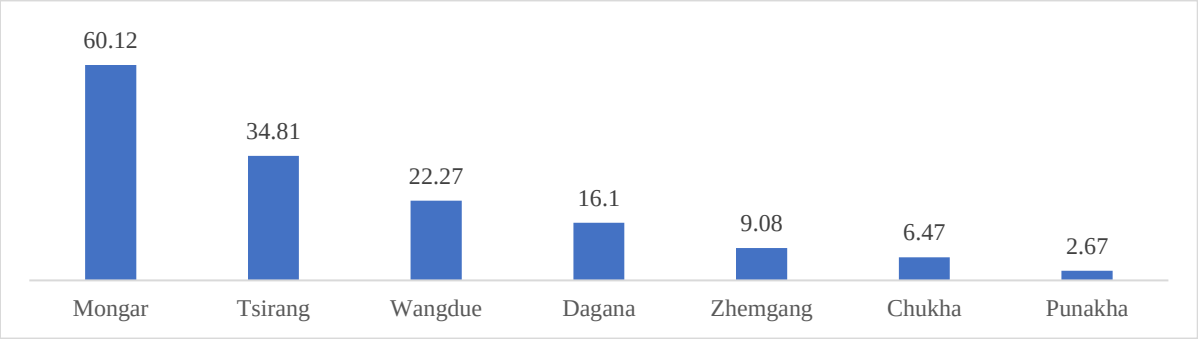

Figure 21 Citrus orchard acreage (acre)

Soil fertility status

According to the perception of the respondents, most (85%) of the orchard soils have medium soil fertility while 14% have high fertility.

Tree status of these owners in different districts

When the Canopy Management Activity was carried out, only 78% of the trees were in the fruiting stage. Of the recorded orchards, only 61% of the total orchards are in the productive age (15-70 years). The highest number of fruiting trees managed were at Dagana with 6255 followed by Tsirang with 3733 trees. The least fruiting trees managed were from Wangdue with 165 trees. Similarly, Dagana has the highest managed non-fruiting trees with 1655 trees followed by Tsirang with 1010 trees. Orchards managed at Punakha and Zhemgang had no non-fruiting trees during the Canopy Management activity. The highest orchard age was 70 years while the minimum was 1 and mostly in the range of 25 to 30 years.

Source of knowledge for Canopy Management

Dzongkhag/Extension was the largest source of information (48%) of the respondents learnt the Citrus Canopy Management while 46% of them learnt from ARDCs. Farmer-to-farmer learning

was just 55 while from family members was just 1%. No respondents had learnt from the mainstream news.

Practices before CCM

Some of the practices carried out by respondents before the formal or informal information about CCM were ranked. Fertilization was the most widely practised activity (63.6%) followed by pruning of dead branches and Loranthus weed (43.6%). The least practice was shoot selection followed by Bordeaux mixture application and trench fertilization.

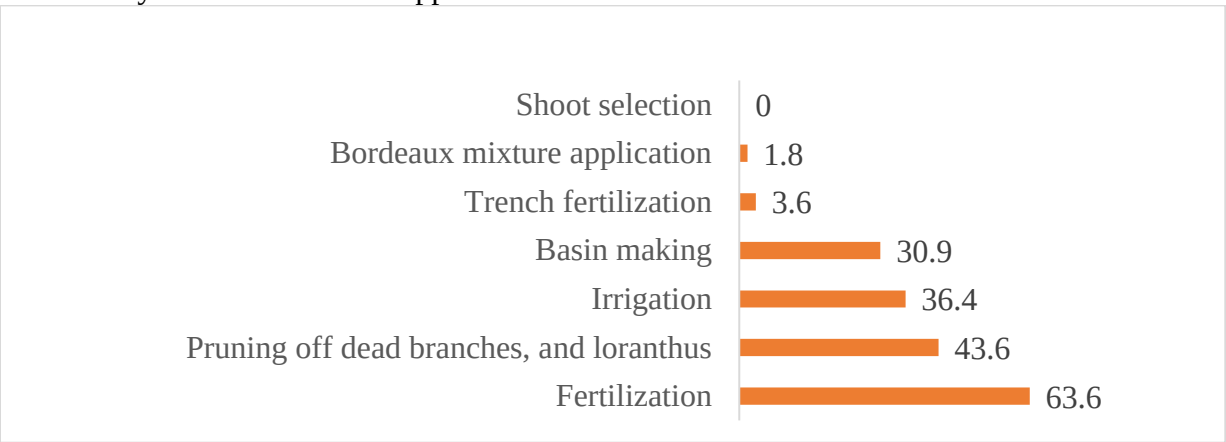

Figure 22 Activities farmers practised before formal training of Citrus Canopy Management

Year of first Citrus Canopy Management

Citrus Canopy Management Activity was largely carried out in 2018 (23 respondents) followed by 2019 (17). As early as 1998 the Citrus Canopy Management is done by a few farmers. Most (95%) of the Citrus Canopy Management was carried out by ARDCs and Dzongkhags while some were done by farmers themselves.

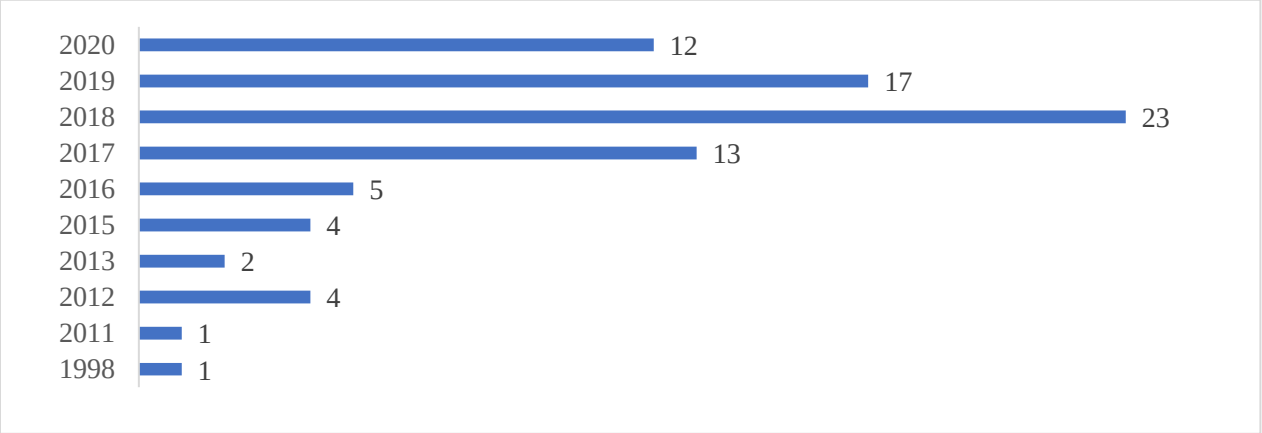

Figure 23 Year of first Citrus Canopy Management carried out by respondents

Reasons for Citrus Canopy Management

Reasons for Citrus Canopy Management were ranked as below. To ‘Improve tree growth with new shoots’ was the most opted reason followed by ‘Increase productivity’. Although the trees in the country are very tall, ‘height reduction’ was not the top priority of the Canopy Management Activities.

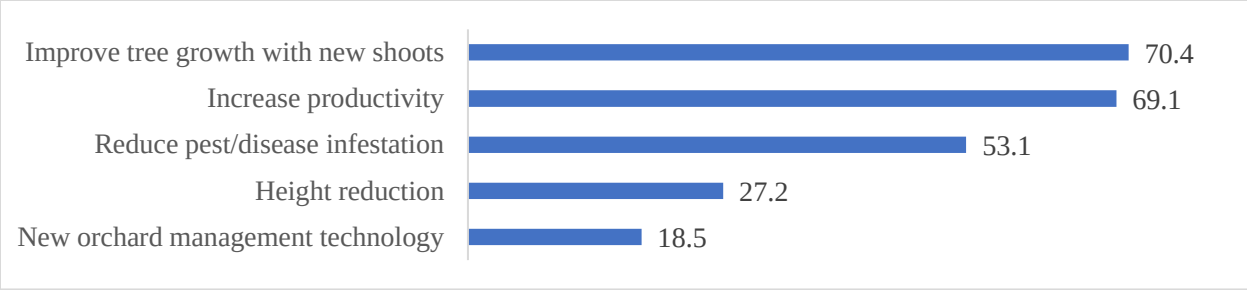

Figure 24 Reasons for Citrus canopy management

Activities in practice by farmers after attending the demonstration program
After the formal training on Citrus canopy management, 'Tree canopy pruning' was the widely adopted activity followed by 'Trench fertilization'. The least adopted activity is 'Shoot selection'.

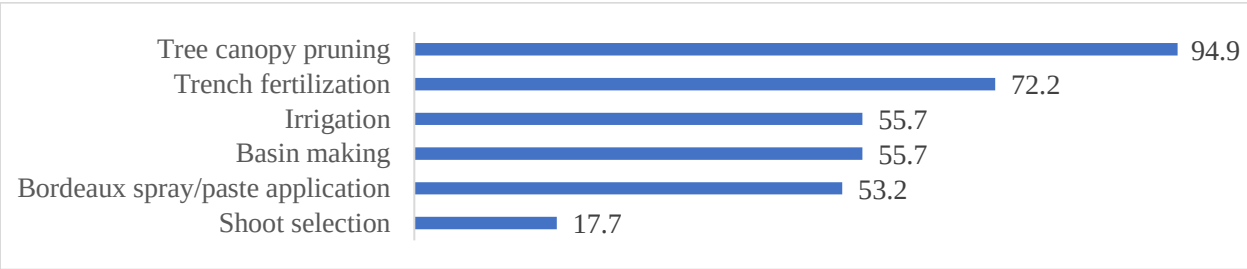

Figure 25 Activities in practice by farmers after attending the demonstration program

Impacts of Citrus Canopy Management on yield and fruits
Only 26% of the respondents have recorded an increase in yield while 39% of them had seen no change while 35% have seen a decline in the yield. About 40% of the farmers have reported 'No change' in the fruit size while 35% reported that fruit size has declined. Only 25% of the respondents noticed 'Improve' fruit size by the Citrus canopy management. Similarly, 25% of them have said fruit quality has improved while 39% said no change 36% have seen a decline in citrus fruit quality.

Future of Citrus Canopy Management
Most (70%) of the respondents wish to continue CCM while 29% of them do not wish to continue. Similarly, 70% of them recommend CCM while 29% discourage it.

Sources of income of the respondents
Citrus orchards, Livestock, Vegetables, Non-citrus fruits, cardamom, Cereals and Litchi were the common sources of income including Non-Wood Forest Products (NWFP). Remittances and off-farm employment are other non-agricultural sources of income for the farmers.

Constraints of the Citrus production
Insect pests are reported as the major constraints (60.5%) of citrus production followed by Scarce irrigation water (51.9%) and labour shortage (50.6%). Diseases, input unavailability, depredation by wild animals, and Loranthus weeds were some of the other important constraints. Marketing was also raised as a constraint for citrus growers. The major insect pest was Citrus Fruit Fly which damages a huge crop yield as fruit drops.

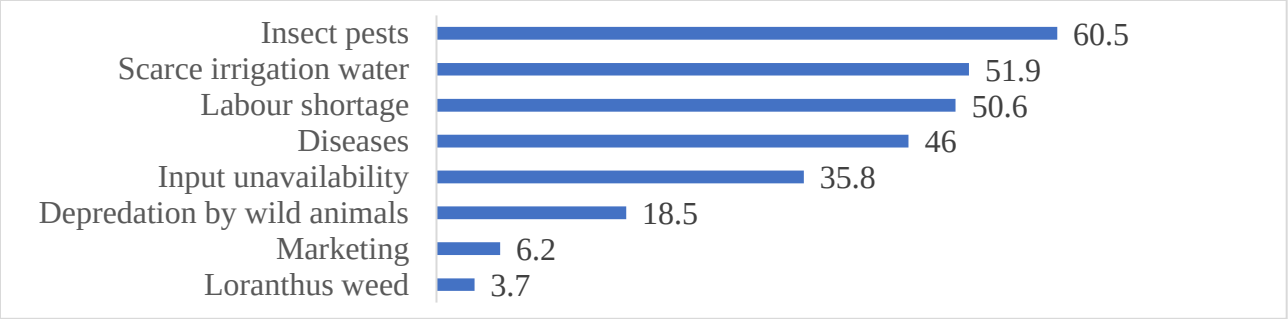

Figure 26 Constraints of citrus production

7) Agriculture technologies generated

i. Release of improved varieties and improved technologies

As ARDCs are mandated to release new improved varieties and improved technologies to be adopted by the clients. The Centre has proposed to release two vegetable crops and three climate-smart technologies during the FY 2021-22 but only three technologies could get released through Technology Release Committee (TRC) as listed in Table 76. These technologies will be disseminated to farmers and other clients for adoption.

Table 76 New varieties and technologies proposed and released in FY 2021-22

SN	Variety/Technology	Number	Traits	Remarks
1	Bhutan Agri-microbial Solution	1	Solve the problem of organic input shortages in the country. The production and use of BAMS will ultimately lead to organic farming	Released
2	Potting soil mix	1	Efficient use of media, 99% survival rate of seedling transplanted	Released
3	Citrus Canopy Management and Rehabilitation Technology	1	Control Citrus pest diseases, improved fruit quality, and improve overall tree health.	Released
4	Carrot	1	Suitable for early or late production: High market demand in the domestic market	Not released
5	Cabbage	1	High yielding Suitable for early or late production	Not released
Total		5		

8) Publication of scientific journal papers and information

As a Research Centre, it is mandatory to publish journal papers every year. During the FY 2021-22 the Centre published a series of technical journal papers in both international and in the Bhutan Journal of Agriculture (BJA). Three international journal papers were published by officers who are currently undergoing PhD studies at the Centre. While ARDC-Bajo came up with three technical papers and submitted them to be published in BJA but it was sent back for revision. Table 77 provides the list of technical publications with details.

Table 77 Technical journal papers produced by the Centre, 2021-2022

Journal Publication Title	Author	Publisher (in)	Year
Rainfall anomalies and their impacts on Bhutan's agro-ecological landscape	Chhogyel, N, Kumar L, Bajgai Y	https://doi.org/10.1007/s10113-021-01851-6. Regional Environmental Change	2021
Microbial consortium inoculant increases pasture grasses yield in low-phosphorus soil by influencing root morphology, rhizosphere carboxylate exudation and mycorrhizal colonisation	Tshewang S, Rengel Z, Siddique KH and Solaiman ZM	(wileyonlinelibrary.com) DOI 10.1002/jsfa.11382	2021
Preliminary inventory on native natural enemies of Fall armyworm (Spodoptera frugiperda)	Dorji U, Jamtsho T, Kinley C.	BJNRD, CNR	2022
Sweet potato varieties to diversify cultivars in Bhutan	Wangmo D, Dorji U, Dema T, Dorji T	BJNRD, CNR	2022

In the FY 2021-22 the Centre has developed a series of pamphlets on varieties and technologies released by the Centre.

Table 78 List of pamphlets published 2021-2022

Type of publication	Name of Publication	Sector/Unit	Remarks
Pamphlet	Watermelon	Vegetable unit	Package of practices
Pamphlet	Cultivation practices of Bajo Laphu 2, Bajo Laphu 3 & Bajo Laphu 4		Package of practices
Pamphlet	Tomato		Package of practices
Pamphlet	Zucchini		Package of practices
Pamphlet	Bajo Kaap III	Field Crop Sector	Package of practices
Poster	Released rice varieties in Bhutan		Updated poster
Booklets	Rice Compendium		Compendium

9) Frameworks/Guidelines/Standards developed

During the FY 2021-22, the Centre has developed a Training manual on the installation of irrigation and greenhouse automation with technical support from Dr Tshering Penjor, ARDC Wengkhar and Strategy for research and development on Nutri/minor cereals 2023-2027.

i. Training manual on installation of irrigation and greenhouse automation

Agriculture faces a great challenge in coping with growing water scarcity and increasing demands for food production. Various initiatives are being made to increase the efficiency of the agricultural irrigation system. With the increased availability of the Internet of Things (IoT) and Information and Communication Technology (ICT), it is now possible to real-time monitor/control different processes of irrigation and water management in agriculture. The smart irrigation system is using water-saving technologies such as micro-irrigation systems combined with different IoT-based

technologies for automation. This manual is designed to provide both theoretical background information on different aspects of irrigation and greenhouse automation technologies and practical skills through hands-on training in real field conditions. The content and structure of this manual have been developed and tested through fieldwork involving Agriculture Researchers from ARDC Bajo and Agriculture extension officers from Dagana and Wangduephodrang dzongkhags for a one-week duration at ARDC-Bajo through FAO financial support. The manual covers the design, installation and maintenance of water-efficient irrigation technology such as drip and sprinklers on the farm. Demonstrate knowledge (theoretical and practical) on the application of SMART irrigation software (mobile apps) and hardware that are currently promoted in the country. Develop and demonstrate skill in the application of various greenhouse automation technologies in the field

ii. Strategy for research and development on Nutri/minor cereals 2023-2027

As a way to address the increasing burden of diet-related non-communicable diseases as well as undernutrition and micro-nutrition deficiencies and to enhance diversity for food and nutrition security, the 4th Agriculture Research Coordination Meeting (ARCM) was convened in Punakha from 16th-19th March 2021 identified and deliberated on the need to come up with a commodity research and development strategy for minor cereals. ARDC- Bajo in the capacity of the national cereal commodity coordinating centre has been tasked with formulating the strategy.

All cereals and other crops including amaranth, quinoa, barley, millets, and buckwheat other than rice, maize and wheat were technically included under minor cereals given their acreage under cultivation and utilization perspectives. Lack of clear understanding of crops under minor cereals as there are many crops under minor cereals makes it difficult to streamline research activities. Therefore, to assist in carrying out focused research and development programs, minor cereals are redefined as other cereals, which include finger millet, foxtail millet & common millet, barley, buckwheat, Amaranth, quinoa and amaranth. Technically minor cereals such as quinoa, millets, buckwheat and Amaranthus are popularly becoming health food in the global market and scientific societies which is interchangeably referred to as Nutri/Nutria cereal. It is perhaps largely due to this reason the need for developing the strategy has been prioritized.

Changing food habits, increasing malnutrition and growing health concerns and as well as the challenge of crop production due to climate change minor cereals such as millets have gained socio-economic importance in recent years as nutria food and climate-smart crop. For instance, the government of India renamed jowar, bajra, ragi and millets as “Nutri Cereals”, dispensing with the nomenclature “coarse cereals”. This provides an economic opportunity for Bhutan to foster policy and technical backstopping for millet research and development programs as part of the support for the year 2023 in pursuit of food and nutritional security in the kingdom. A five-year strategy for research and development on Nutri/minor cereals 2023-2027 intends to attain the following objectives to (i) Contribute towards realizing the Ministry’s long-term vision of National Food and Nutrition Security and (ii) diversify the cropping system (iii) diversify dietary consumption (iv) promote nutria cereals such as millets as an economic and health food, as well as CSA Crop (v) identify appropriate research needs, (vi) formulate a structured implementation mechanism (vii) provide a platform for stronger collaboration and systematic implementation between researchers and collaborating agencies. The following strategies for minor cereal research and development shall be adopted:

- Rebranding the cereals as Nutri cereal/health food
- Providing steady markets
- Increasing area, production and yield
- The intersection of agriculture and nutrition
- Incentivize minor cereal growers
- Identify change agents and drivers of food habits
- Preservation of traditional knowledge, attitudes, and practices
- Up-scale research activities on minor cereals
- Conservation of traditional landraces
- Bringing the Fallow and Waste Lands under Cultivation
- Focus on value addition and value chain development research
- Recognizing the National Year of millets
- Introducing the culture of Food festivals and Diversity fairs
- Seed production, maintenance and technologies
- Organic research and technologies
- Streamline research and development coordination

10) Visitors' information

During the FY 2021-22 there were 37 various groups of visitors comprising farmers, students, youths, trainees, and delegates from various organizations and agencies who visited ARDC-Bajo. The visits were made on study tours and exposure trips. Different groups came with different learning objectives: farmers were interested in seeing new crop varieties which yield more; extension personnel were keen on new technologies; and trainees, guests and visitors had specific objectives to visit the Centre. In general, many were interested in technologies available or adopted in the Centre. Figure 32 is cumulative of visitors categorized into male and female visitors' farmers, students and officials/guests who visited the Centre. In total, we had 671 heads.

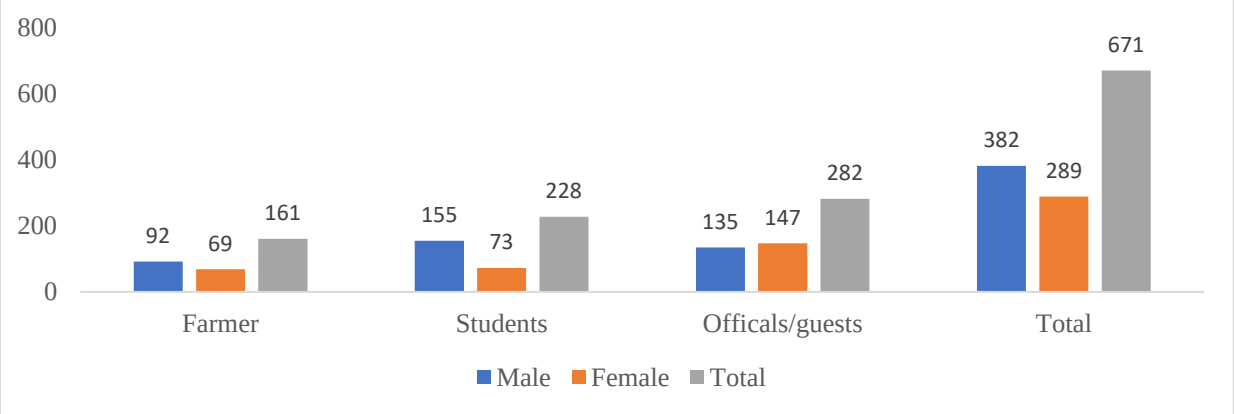

Figure 27 No. of visitors in 2021-2022

FINANCIAL REPORT

Table 79 Financial report as of June 30 2022

Title source	Approved budget (Nu. M)	Expenditure (Nu. M)	Balance (Nu. M)
RGoB	59.288	57.116	2.172
RDCCRP/GEF	2.911	2.737	0.174
Green Climate Fund	3.472	3.310	0.162
FASP Project	4.621	4.515	0.106
Deposit work	9.799	9.799	0.00
Total	**80.091**	**77.477**	**2.614**

Annexures

Annexure 1: Agronomic performance of Rice IET line

ENT NO	SVCODE	50% FLW	Plant height(cm)	Tillers/hill (n)	Maturity Days	Yield kg/acre
Replication 1						
54	SVIN022	105	97	12	145	3110
12	SVIN372	109	98	15	140	2110
37	SVIN329	100	110	13	149	3120
71	SVIN357	95	96	13	147	3250
43	SVIN031	91	87	12	142	2980
73	SVIN360	100	102	11	155	2121
24	SVIN319	101	106	14	150	2563
70	SVIN356	99	99	11	151	3112
6	SVIN304	100	99	16	150	3125
36	SVIN047	100	91	10	140	3145
64	SVIN344	99	100	11	141	3020
BK1(check)	116	1120	105	13	150	1113
Replication II						
54	SVIN022	105	89	14	139	2590
12	SVIN372	110	98	13	141	1985
37	SVIN329	95	112	13	140	3102
71	SVIN357	97	97	13	1448	3102
43	SVIN031	95	89	12	144	3102
73	SVIN360	102	102	14	151	1598
24	SVIN319	100	109	13	152	3120
70	SVIN356	102	99	11	149	3010
6	SVIN304	100	100	15	152	2580
36	SVIN047	100	98	11	148	2148
64	SVIN344	98	101	15	146	2540
BK1(check)	116	125	103	11	150	1120
Replication III						
54	SVIN022	107	100	14	15	2700
12	SVIN372	105	102	16	140	2200
37	SVIN329	90	112	13	143	2900
71	SVIN357	96	99	12	141	3120
43	SVIN031	91	92	12	140	2980
73	SVIN360	100	108	11	155	1985
24	SVIN319	100	109	13	155	3580
70	SVIN356	95	102	13	146	3120
6	SVIN304	98	101	14	150	2420
36	SVIN047	105	99	10	141	2155
64	SVIN344	98	109	14	140	2565
BK1(check)	116	125	109	12	144	1102

Annexure 2: Agronomic performance of AET lines

Designation	FLW 50%	Plant height (cm)	Tiller/hill (no)	Grain yield (kg/ac)
Replication I.				
IRRI11A306	122	114	14	1125
IR12N110	118	110	14	1956
IR14D155	120	117	17	2010
IRRI248	122	105	15	1520
IRRI179	119	108	11	1956
BK2 (check)	117	120	17	1125
Replication II				
IRRI11A306	1120	116	13	1114
IR12N110	117	110	14	2110
IR14D155	120	1120	17	2010
IRRI248	123	100	16	1350
IRRI179	114	112	13	2450
BK2 (check)	119	128	14	1120
Replication III				
IRRI11A306	121	111	12	1120
IR12N110	114	113	15	2110
IR14D155	128	114	14	2112
IRRI248	125	110	16	1620
IRRI179	114	111	11	2122
BK2 (check)	113	120	14	1125

Annexure 3: Agronomic performance evolutionary plant breeding, Punakha

Treatments	Tillers/hill	Plant height (cm)	Maturity days	Panicle Length	1000 GWT	Yield kg/acre
Replication I						
R1VI	11	85.20	150	20.45	20.15	2175.60
R1V2	12	85.10	155	23.14	19.12	2391.20
R1V3	9	155.10	161	23.1	18.24	2352.00
R1V4	16	135.12	165	22.36	22.45	2162.53
R1V5	14	125.21	153	24.15	19.22	2430.40
R1V6	10	165.10	158	26.25	16.89	2149.46
R1V7	11	145.20	156	24.1	21.11	2365.06
Replication II						

R2VI	13	90.12	150	21.26	19.23	2456.53
R2V2	15	80.25	155	20.14	20.23	2197.27
R2V3	10	150.21	161	25.36	20.25	2012.26
R2V4	14	130.45	165	22.25	20.12	2182.13
R2V5	11	140.15	153	25.12	22.10	2234.40
R2V6	12	155.45	158	27.26	19.25	2084.13
R2V7	14	152.12	156	25.25	22.20	2097.20
Replication III						
R3V1	13	102.11	150	23.45	21.23	2254.00
R3V2	16	89.15	155	19.23	20.12	2450.00
R3V3	10	143.10	161	23.25	19.34	2436.93
R3V4	13	138.21	165	21.23	21.68	2495.73
R3V5	14	136.25	153	24.45	19.25	2332.40
R3V6	15	161.25	158	24.45	17.24	2436.93
R3V7	10	142.25	156	22.12	20.12	1881.60

Annexure 4: Agronomic performance evolutionary plant breeding, Tsirang

Treatments	**FLW (DAS)**	**Tiller/ Hill**	**Plant height (cm)**	**Maturity days**	**1000 grain weight (gm)**	**Panicle length (cm)**	**Yield (kg/acre)**
Replication I							
V1	105	12	120.80	163	20.00	24.90	1354
V2	105	10	120.53	163	16.50	25.60	1425
V3	118	12	126.27	173	19.50	25.10	1479
V4	90	11	78.33	140	21.00	24.60	1505
V5	90	11	73.30	140	22.00	22.68	1416
Mixture	105	12	110.83	163	20.00	23.70	1522
Replication II							
V1	105	10	116.83	163	20.00	24.70	1407
V2	105	12	122.73	163	16.00	26.00	1353
V3	118	10	116.67	173	20.00	23.50	1319
V4	90	12	91.10	140	21.00	23.90	1333
V5	90	12	77.00	140	22.00	22.70	1553
Mixture	105	11	120.70	163	21.00	23.60	1352
Replication III							
V1	105	11	111.50	163	20.00	25.80	1594
V2	105	12	129.97	163	16.50	25.30	1688
V3	118	10	120.83	173	20.00	23.70	1662
V4	90	12	87.27	140	21.50	24.10	1550
V5	90	11	73.33	140	22.00	23.80	1722
Mixture	105	11	122.17	163	21.00	24.30	1448

Annexure 5: Agronomic performance of YP/K-Y/B-20 rice variety

Sample #	Varieties	MC%	No. of grains/ panicles	Straw yield (KG)	Plant height (CM)	Yield (6msq) (KG)	Yield per acres (KG)
I	YP/K-Y/B-20	28.80	150	9.56	105.00	2.90	1622.20
II	do	29.06	146	7.90	127.00	2.33	1293.50
III	do	28.60	128	7.52	135.00	2.17	1212.30
Average			**141**	**8.33**	**122.30**	**2.47**	**1376.00**

Annexure 6: Agronomic traits of different dwarf beans varieties, NBC trials

Treatments	Disease Score (1= No disease observed, 5= Severely incidence)	Mean Pods/Plant	Days to Maturity (Seed to Seed)	Mean Pod Length	Number of Seeds per Pod	Seed Yield Kg per sample	Number of plants per harvested area	Yield (Kg/ac)
	Replication I							
Rajma	2	8	92	12	4	0.24	50	97.13
Gew Bori	3	7	108	8	4	0.175	38	70.82
Azuki bean	1	23	107	10	8	0.52	102	210.44
Pink Rajma	2	6	96	10	4	0.149	37	60.30
Mixture	2	13	108	8	6	0.35	95	141.65
	Replication II							
Rajma	2	6	92	12	4	0.14	31	56.66
Gew Bori	3	5	108	8	4	0.29	55	117.36
Azuki bean	1	15	107	9	8	0.635	118	256.98
Pink Rajma	2	11	96	10	4	0.54	90	218.54
Mixture	2	13	108	9	5	0.34	92	137.60
	Replication III							
Rajma	2	8	92	11	4	0.315	79	127.48
Gew Bori	3	5	108	7	4	0.06	27	24.28
Azuki bean	1	19	107	10	8	0.75	124	303.53
Pink Rajma	2	10	96	11	4	0.45	94	182.12
Mixture	2	10	108	10	5	0.42	73	169.97

Annexure 7: Agronomic traits of different pole beans varieties, NBC trials

Treatments	Disease (1= No disease observed, 5= Severely incidence)	Mean Pods/Plant	Days to Maturity	Mean Pod Length	Number of Seeds per Pod	Seed Yield Kg per sample area	Number of plants per sample area	Yield (kg/ac)
Replication I								
Gew Bori	3	14	142	13.6	4	0.622	55	251.72
Kalo Gew Bori	3	18	130	13.2	4	2.18	85	882.25
Pole bean (White)	1	33	120	17.2	8	1.868	62	755.98
Pole Bean (Gray)	1	21	120	16.3	8	2.03	78	821.54
Boshi Bori	2	21	120	19.6	9	1.912	67	773.79
Mixture	2	16	130	16.2	5	2.36	72	955.09
Replication II								
Gew Bori	3	24	142	11.25	4	0.53	62	214.49
Kalo Gew Bori	3	18	130	12.2	4	3.056	94	1236.76
Pole bean (White)	1	31	120	15.5	8	2.052	45	830.44
Pole Bean (Gray)	1	21	120	15.6	8	2.706	84	1095.12
Boshi Bori	2	18	120	20.8	10	2.256	94	913.00
Mixture	2	14	130	18.2	6	2.318	78	938.09
Replication III								
Gew Bori	3	14	142	11.8	4	0.5	50	202.35
Kalo Gew Bori	3	22	130	14.4	5	2.552	62	1032.79
Pole bean (White)	1	24	120	17	9	2.286	79	925.14
Pole Bean (Gray)	1	19	120	18.2	9	2.34	73	947.00
Boshi Bori	2	22	120	23.4	10	2.73	84	1104.83
Mixture	2	22	130	13.8	5	2.2	72	890.34

Annexure 8: Assorted ornamental plants issued in 2021-22

SN	Location	Types of flowers				Remarks
		Annual	Hedges	Medicinal plants	Evergreen	
1	FMCL, Paro	50	20		70	From ARDC Bajo
2	Division Forest office, Lobesa	40	10	20	50	
3	Beautification office, Punakha	100	100	20	100	
4	Tashiding School, Lobesa	100	40		20	
5	DoA, Thimphu	100			20	
6	Gangtey Geog, Wangdue	50			30	
7	Pvt. Fruit and flower nursery, Punakha	170	50	50	150	
8	Audit office, Thimphu	20			10	
9	Dagana Dzongkhag	100			50	
10	Lobesa, private individual	150	100	20	300	
11	Toedpisa Geog, Punakha	20			10	
12	Bajo School, Wangdue	150	20		80	
13	Phetakha School, Wangdue	350	70	20	50	
14	Wolakha Anim Dratshang	70	20		10	
15	Desuung office	50			10	
17	EAs of Sarpang /Samtshi /Punakha /Wangdue/Haa/Paro/Thimphu/Dagana	100			100	
18	Gyalsung, Khotokha	200			220	

CENTRE AT A GLANCE

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

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

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

Sub-centre at Mithun, Tsirang was opened in 2006 to cater to the humid sub-tropical Dzongkhags of Tsirang and Dagana. It has about 36 acres of research area, office space and the National Citrus Repository is being developed**.** The Centre also cater the Chimipang Royal Project, Chimipang which was established in 2014 on Royal Command to demonstrate agricultural technologies and training of extension personnel and farmers.

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