ROYAL GOVERNMENT OF BHUTAN
Agriculture Research and Development Centre
Bajo: Wangduephodrang
Department of Agriculture
Ministry of Agriculture and Forests

ANNUAL REPORT 2020-2021

June, 2021

Published by:
Agriculture Research & Development Centre-Bajo, Wangduephodrang,
Department of Agriculture,
Ministry of Agriculture & Forests,
Royal Government of Bhutan.

Write-up contributors: All sectors

Editors, Layout & design: Tanka Maya Pulami & Ugyen Dorji
Suggested Citation:
ARDC Bajo 2021. Annual Report 2020-2021.
Agriculture Research and Development Centre, Bajo, Wangduephodrang,
Department of Agriculture
Ministry of Agriculture & Forests

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ANNUAL REPORT 2020-2021

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ROYAL GOVERNMENT OF BHUTAN

FOREWORD

It is an immense pleasure to publish the 36th Annual Technical Report of Agriculture Research and Development Centre (ARDC), Bajo, coinciding with the financial year 2020-21. 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, 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, 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, establishment of horticulture germplasm blocks, quinoa evaluations, citrus management trials and demonstrations, establishment of demonstration orchards, National Citrus Canopy Management, vegetable evaluations and top working of fruit trees. The Centre carried out three social studies namely IHPP-JICA impact assessment, assessment of low-cost water harvesting and electric fencing using IHDP However, regular monitoring and evaluations have still remained weak and wanting. The Centre has now ventured into hydroponic farming research, In the FY 2020-21 we have facilitated in conducting "De-Suung Skilling Program on "Hydroponic and climate smart technologies"

Amidist the COVID-19 pandemic, ARDC- Bajo could complete all the planned activities for the financial year (FY) 2020-21. The successes and achievements made were possible because of tremendous supports from the central agencies and the projects in general and unwavering and concerted supports and efforts from JICA and Japanese Experts. 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 2020-21, 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 one 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

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A. FIELD CROPS RESEARCH AND DEVELOPMENT ACTIVITIES

1) Rice

i. Rice Advance Evaluation Trial (AET)

In AET, eleven lines were evaluated including check during 2020 cropping season. The test lines were basically the best performers from IET of 2019. This trial is conducted basically to identify the suitable varieties with high yield potential, medium height, optimum maturity and resistance to pest and diseases for mid altitude rice growing area.

The trial was led out in a randomized complete block design with three replications. Seedlings were transplanted on $10m^2$ plot and spacing of 20X20cm was maintained. Chemical fertilizer was applied at the rate of 70:40:40 NPK kg/ha with half N as top dress at panicle initiation. Butachlor 5G was applied at the rate of 1.5kg a.i ha^{-1} after two to three days of transplanting to control weeds. At the later stage, hand weeding was done depending on the weed pressure specially to control Shochum (*Potamogeton distinctus*). Irrigation was given as and when required with timely monitoring for pest and disease incidences. Grain yield was estimated from crop cut sample area of 5.04 m^2 and grain moisture content standardized at 14%. Basic agronomic traits such as plant height, days to 50% flowering, number of productive tillers per hill and grain yield were assessed. Among the varieties, IRRRI 154, IRRI 123 and IRRI 180 were tallest with mean plant height of 153 cm, 131 cm, and 120cm respectively (table 1). The shortest was IR11A534. In terms of grain yield, there was not much difference, IR146 has the highest mean yield of 1284 kg/ac whereas, the lowest yield of 1100 kg/ac was recorded from IRRI306 and IRRI 123.

Table 1 Agronomic performance of rice AET lines 2020

Designation	FLW 50%	Plant height (cm)	No. Tillers/hill	Grain yield (kg/ac)
IR11A534	122	101	12	1230
IR11A255	117	115	17	1250
IRRI306	155	111	14	1100
IRGSR 1-2-45	116	105	13	1110
IR12L248	124	112	14	1150
IRRRI 154	102	153	11	1200
IR146	112	114	14	1284
IRRI 180	118	120	14	1200
IRRI 123	121	131	15	1100
IR12 N168	120	105	12	1230
BK2 (local check)	132	109	15	1200

ii. Rice Observation Nursery

In the FY 2020-21 total 40 lines in observation nursery trial taken from 2019-20 new rice lines. The test lines were selected from INGER module 1. This trial is conducted to screen and advance promising lines for further testing based on selection criteria.

All the trials procedures as per the protocol were followed. The trials design was a single observation plot with 5mX2m with spacing of 20cm X 20cm. Recommended fertilizer dose of 70:40:40 NPK kg/ha application was carried out in time. Herbicide Butachlor 1.5 kg a.i/ha is used to control weed. Crop cut samples were taken from five random samples. The maximum yield observed was 3920kg/ac of the of SVIN329 line and the minimum was computed at 1200 kg/ha SVIN329 line. The promising entries were selected for further evaluation.

Table 2 Agronomic performance of observation nursery lines

ENTNO	SVCODE	50% FLW	Plant height(cm)	Tillers/hill (n)	Maturity Days	Yield kg/acre
38	SVIN330	100	109.2	14	152	2650
1	SVIN375	102	102.4	13.4	154	1212
54	SVIN022		95.4	14	148	3590
78	SVIN367	99	87.2	13.6	145	2550
22	SVIN317	100	100.2	15	149	1250
51	SVIN034	120	112.4	13.4	148	2110
57	SVIN024	100	102.2	14.8	145	1750
23	SVIN318	105	101.6	12	145	2100
12	SVIN372	109	98	14.6	145	2600
37	SVIN329	98	117.8	13	145	3920
60	SVIN287	100	99.4	14	145	2070
71	SVIN357	93	95.4	13.2	145	3590
35	SVIN044	100	99.6	12.4	142	1850
42	SVIN334	108	97.8	12.6	142	1480
34	SVIN056	99	112.8	13.8	142	2510
43	SVIN031	91	87.2	12.4	142	3210
44	SVIN028	102	111.8	12.4	142	2080
7	SVIN305	101	89	13.2	145	1710
73	SVIN360	99	108	11.8	150	2760
24	SVIN319	100	104.4	11.8	150	3260
70	SVIN356	99	95.4	12.2	152	3080
76	SVIN365	98	94.6	11.4	145	2470
17	SVIN036	100	111	13.2	152	2090
6	SVIN304	98	99	12.4	152	3690
30	SVIN325	98	98.6	12	152	1360
36	SVIN047	100	95.4	10.2	148	3480
12	SVIN372	101	115.8	12	150	2600
64	SVIN344	95	109.6	11.8	145	3060
15	SVIN311	99	114	12.6	146	1700
10	SVIN308	107	112.4	13.6	150	2180
79	SVIN368	87	106	13	152	2500
23	SVIN318	100	105	13.2	152	1330
78	SVIN367	99	100	13.6	152	2280
32	SVIN327	83	107.4	10.8	148	2060
34	SVIN056	98	109	10.4	148	2910
37	SVIN329	95	80	10.4	148	1200
5	SVIN303	100	107	10.4	148	2730
65	SVIN346	98	99	11.2	148	2020
9	SVIN307	102	108	12	148	2620
52	SVIN032		107	14.2	140	2920

iii. Rice initial evaluation trial (IET) 2020

In the IET, eleven lines including check were evaluated (table 3). This trial was advanced from observation trial based on the performance of lines. The trail was conducted to identify the suitable varieties with high yield potential, medium height, optimum maturity and resistance to pest and diseases. All obligatory data were collected timely and analysed.

Table 3 Agronomic performance of rice IET lines

Designation	FLW 50%	Plant height (cm)	Tiller/hill (no)	Grain yield (kg/ac)
IRRI154	127	97	14	1250
IRRI156	124	104	16	1120
IRRI11A306	126	112	15	1146
IRRI123	122	109	14	1460
IRRI146	118	107	16	1250
IR12N110	116	109	19	2156
IR14D155	124	119	18	2010
IRRI248	122	100	13	1750
IRRI179	118	108	12	2450
IRRI180	125	115	15	1120
BK2 (Local check)	116	125	15	1125

iv. Phenotypic Characterization of Traditional Land Races of rice

During the FY 2020-21 the Centre received a total 45 accessions of traditional land races of rice for the phenotypic characterization from NBC of which 16 to evaluate at ARDC Bajo and 29 number at ARDSC-Menchhuna. As in the previous season the trials were conducted following all the procedure as per the research protocol. At Bajo all accession germinated well whereas in Menchhuna one accession did not germinate at all and four accessions were totally damaged by rice blast. Basic morphological data were collected from accessions. The basic qualitative characters such as leaf blade pubescence, leaf sheath colour, flag leaf angle, ligule colour, ligule type and culm habit were observed and data recorded.

Under quantitative plant characters, basic agronomic traits and grain information were assessed. Basic agronomic traits included the plant height (cm), days to maturity (DTM), panicle length (cm) and number of grains per panicle including estimated yield (t/ac). The data has been submitted to NBC for further analysis.

v. Effect of Azolla on the Growth Parameters and Yield Components of Rice

With introduction of azolla for research purpose, the Field Crop sector has initiated research on "Effect of Azolla on the growth parameter and yield components of rice" with the objective: To quantify the effect of Azolla on the growth and yield of rice variety IR 64 under the dry sub-tropical environment at ARDC Bajo, Wangdue. RCBD with three replication design trial were set in each plot of 5mX4m.

The treatments were:

1 Azolla 15 t/ha, 20 DBT
2 Azolla 15 t/ha, 14 DAT
3 Recommended NPK kg/ha: 70-40-20
4 Control (no fertilization)

In Treatment 1, grown Azolla for 20 days, then incorporated into the soil before transplanting rice. In Treatment 2, introduced Azolla 14 days after transplanting and grown for 3 weeks then incorporate into the soil. Applied 60 kg P per ha for growth of Azolla in Treatment 1 and 2. Transplanted single seedling per hill. Data like Fresh biomass of Azolla before incorporation, sowing/transplanting/harvesting dates, productive tiller per hill, plant height at maturity, panicle length, number of grains per panicle, thousand grain weight and yield/plot were recorded timely for the research.

Treatment	means	N group
1	1044.00	3 b
2	2173.33	3 a
3	1647.67	3 a
4	1993.33	3 a

Rice yields are best in treatments 2,3, and 4. The yields of treatment 1 significantly ($p = 0.0134$) different from the other three treatments.
The average number of tillers per hill is maximum with Treatment 1 having 14 number and minimum is 10 with Treatment 3. The treatment 2 has the maximum yield computed compared the other three treatments with 2255.67 kg/ac whereas the Treatment 1 has the lowest average yield in all the replication (annexure 1). The trial will be repeated for some years until the Centre could come out with some appropriate recommendation.

vi. Local rice characterization

ARDSC-Menchhuna has carried out 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 3mX2m area taking six samples each and the result computed in average as recorded in table 4.

Table 4 Agronomic performance of local rice characterization

Variety	Plant height(cm)	Tiller/hill (no)	Panicle length(cm)	Shattering nature	Threshing nature	Yield kg/ac
Krishna bhog	115	10	23	high	easy	1106
Attey	112	12	24	moderate	easy	1380
Chottey	117	13	26	moderate	easy	1031
Sipsodhan	93	16	25	low	easy	1396
Local red	107	14	23	moderate	easy	942
Sukmey	121	10	25	moderate	easy	1143
Gawrey masino	125	11	24	moderate	easy	1071

vii. Participatory technical assessment of evolutionary plant breeding

The Research Center in collaboration with National Biodiversity Centre (NBC) and Dzongkhag Agriculture Sector has been conduction "Participatory technical assessment of evolutionary plant breeding (EPB)" trials on mid altitude rice and 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 most popular traditional and improved varieties collected and contributed by farmers and ARDCs from specific locations.

The treatments used at Punakha were Dawa (local), Bajo Maap 1, IR64, Bonday, mixture, Ngabja & Tan Tsheri. For Tsirang the treatments were Attey, Chottey. Masino, Gawri, WR-II & IR64 & mixture (annexure 2). The trials were conducted as per NBC's protocol. Timely data are collected like date for germination, flowering & maturing, blast score and other parameters like crop height, number of tillers, panicle height, yield, were collected along with the crop cut. The trials will be carried out for four years for coming up of 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 $10m^2$ is taken randomly from five samples.

viii. Demonstration of released rice varieties

As the Centre receives different groups of visitors with different learning objectives like 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 technologies available or adopted in the Centre. In order 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.

Table 5 List of released rice varieties for demonstration

SN	Variety	Altitude (m)	Crop	Yield potential (t/ac)
1	Bajo Kaap 1	600-1500	Main single	2.0-3.4
2	Bajo Kaap 2	600-1500	Main single	2.0-3.4
3	Bajo Maap 1	600-1500	Main single	2.0-3.2
4	Bajo Maap 2	600-1500	Main single	2.0-3.0
5	IR 64	600-1500	Main single	2.0-3.2
6	IR 20913	600-1500	Second double	1.6-2.4
7	Khangma Maap	Above 1500	Main single	1.6-2.4
8	Bhur Kamja	<700	Main single	1.0-1.5

Altitude: Recommended agro-ecological zone

ix. Demonstration on direct seeded rice using drum seeder

Direct seeding using drum seeder is a new technology widely practiced in Asian countries. Direct seeding method avoids any raising of nursery, pulling up seedlings and transplanting them so that labour requirement for crop establishment is negligible. Farmers can take up paddy cultivation at any time as there is no requirement or delay of raising a nursery. Duration of the crop can shorten by 10-20 days compared to traditional practice. This type of seeding is very convenient and is adopted in areas where there is scarcity of water. It reduces huge amount of production cost and planting materials. The production is at par with normal conventional method which is computed at 2503.6 kg/ac. The crop matures 15-20 days earlier than normal transplanted rice. The drawback of direct seeding is emergence of heavy weeds leading to intensive weeding. Farmers reported that if there is heavy rainfall right after the direct seedling than the line seeding is disassemble so the weeding by using paddy weeder is not possible. The demonstration trials were set on-station at ARDC-Bajo and ARDSC- Menchunna.

Table 6 Agronomic traits of direct seeded rice

SN	Plant height (cm)	Tillers/hill	Grains/panicle	Mean yield(kg/acre)
1	92.14	22	152	2900
2	109.20	20	155	3100
3	106.25	23	145	2205
4	115.00	25	135	2315
5	110.26	21	153	1998
Average	**88.80**	**22.2**	**148**	**2503.6**

x. On-farm production evaluation rice trial in Tsirang

Due to COVID-19 pandemic on-farm rice trials were not carried out at large unlike previous years since there was movement restriction so only in selected location important trials were carried out. Two gewogs under Tsirang dzongkhag were identified for on farm rice trial for mid and low altitude. Six promising low altitude and four mid altitude rice varieties were tested in each farmer's fields. The trials were conducted as per the protocol and all necessary data were collected timely. The crop cut of three samples for each trial field of the on-farm trials were conducted and the yield was computed. Other agronomic traits were also recorded as reflected in table 7.

Table 7 Agronomic traits of low and mid altitude on-farm trials

Gewog	Varieties	Height (cm)	Straw weight (kg)	Yield/plot (kg)	Yield (kgs/ac)
Ranthaling	HUA-564	122.00	4.35	1.43	863.00
Ranthaling	B-61-B	61.00	4.93	1.95	1208.00
Ranthaling	B-60-B	55.40	3.83	1.47	919.00
Ranthaling	RC-08	56.00	3.92	1.91	1228.00
Ranthaling	6527	80.40	4.22	1.35	847.00
Ranthaling	Mansuri	71.00	3.95	1.87	1187.00
Mendrelgang	Bondey	156.00	5.68	1.63	1023.00
Mendrelgang	Bondey	149.00	4.65	1.78	1102.00
Mendrelgang	HUR	65.00	3.67	1.36	843.00
Mendrelgang	Black rice	75.00	3.87	1.61	985.00

xi. Seed production and maintenance of varieties

The Centre produce and maintain paddy seeds of promising varieties every year basically to maintain the seed at research to meet the unforeseen circumstances and support to the Dzongkhags during the time of need. The seed is from the trial plots, seed production and demonstration blocks. In the FY 2020-21, the Field Crop Sector produced **10050.00** MT paddy seed was produced (Table 8) from ARDC Bajo, ARDSC Menchunna & CRP. Paddy seeds of the released varieties such as Bajo Kaap1 and 2; Bajo Maap1 and 2; IR-64; IR20913; were produced to support promotional programs in the Dzongkhags. Bajo also produced some seeds of unreleased varieties like IR28, Ceres, TME 80518 Vietnam Rice were for seed multiplication.

Table 8 Paddy seed produced from released and potential varieties

SN	Variety	Qty (kg)	Centre	Remarks
1	IR 64	1000.00	ARDC Bajo	Released variety
2	IR20913	500.00	ARDC Bajo	Released variety
3	Bajo Kaap 1	550.00	ARDC Bajo	Released variety
4	Bajo Kaap2	500.00	ARDC Bajo	Released variety
5	Bajo Maap 1	500.00	ARDC Bajo	Released variety
6	Bajo Maap 2	600.00	ARDC Bajo	Released variety
7	TMES 0518	500.00	ARDC Bajo	Not released
8	Wengkhar Raykaap II	600.00	ARDSC Menchhuna	Released variety
9	IR 28	700.00	ARDSC Menchhuna	Not released
10	Assorted	100.00	ARDC Bajo	Not released
12	Assorted	1500.00	CRP	Released variety
13	Mixture	3000.00	ARDC Bajo & ARDSC Menchhuna	
	Total	**10050.00**		

From the seed production more than 2 MT seeds was distributed to farmers for on-farm/demonstration trials and promotion of promising varieties at Tsirang and Dagana Dzongkhag. The performance of the crop in the farmers' field is monitored and crop cut will be carried out for record. Every year 192 kg of paddy seed is distributed to Tshetsho gewog farmers as share of Water User Group. As the National Coordinating Centre for rice, the seed is also issued to other sister Centers. This year, 100kg has been issued to ARDC Wengkhar for research purpose.

xii. Increased area under spring and upland rice in the region

Spring and upland rice cultivation plays vital roles in achieving the objective of 12FYP to achieve 60 % of rice self-sufficiency. ARDC Bajo mandated for National Rice, the Centre has 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 target of 100 ac in the FY 2020-21 for spring and upland rice. During this season, the Centre achieved 127.6 ac of area in promotion of upland and spring rice in West-Central region. This is through seed supply, technical support and other material like fertilizer, plastic for nursery (spring rice) distributed in Wangdue, Dagana and Tsirang Dzongkhags as detailed in the table 9.

Table 9 Promotion of spring and upland rice cultivation in FY 2020-21

Dzongkhag	Gewog	Support	Qty (kg)	Area (ac)	Remarks
Wangdue	Nahi	Seed &Technical	500	20	Upland rice
Wangdue	Kazhi	Seed & technical	250	10	Upland rice
Wangdue	Thedtsho	Technical	900	36	Spring rice
Wangdue	Daga	Technical	240	9.6	Spring rice
Wangdue	Gasetshogom	Technical	360	14.4	Upland &spring
Wangdue	Athang	Technical	240	9.6	Spring rice
Dagana	Tsangkha	Seed & technical	500	20	Upland rice
Dagana	Dorana	Seed & technical	500	20	Upland rice
Total			**3490**	**139.6**	

Besides, upland rice and spring rice promotion, the Centre has supported 840 kg improved varieties paddy seeds for irrigated cultivation on promotional basis for Tsirang and Dagana Dzongkhags.

2) Wheat

i. Introduction and Selection of 10th HPYT CIMMYT Lines

Annually, the International Wheat and Maize Improvement Center (CIMMYT) based in Mexico distributes wheat germplasm to institutions, national research centers and interested individuals for evaluation and selection of their lines under different ecological and environmental conditions. Bhutan has been part of the CIMMYT germplasm evaluation program for so long and we have received several germplasms sets for evaluation and varietal development under our own condition.

For 2020-21 seasons, the National Wheat Program received a set of bread wheat from CIMMYT with nursery name 10th HPYT (Harvest Plus Yield Trial) and trial ID 47756. A total of 98 different lines were planted on 15th December 2020 along with released variety Bumthangkaadruckhu as local check. The introduction trial was set up based on protocol and trial design shared by the parent organization. From the entire population, a total of 38 lines were selected based on plot uniformity, lodging incidence, agronomic score and spike observation. The selected lines will be planted in 2021-22 seasons for observation trial.

ii. Agronomic and morphology characteristics of released and Bio-fortified wheat

Wheat is considered to be the third important cereal crop in Bhutan after maize and rice. As per Agriculture statistics 2019, wheat is cultivated in an area of 2,691.28 acre at the national level. The total production of 1,318.54 MT from a harvested area of 2,481.46 acres is produced. So far 4 wheat varieties (Sonalika, Gumasokhakaa, Bajosokhakaa and Bumthangkaadrukchu) were released in the country with Sonalika variety being the first released variety in 1988. The variety is considered to be a mega variety in the country until it got broken down to rust. Introduction and evaluation of wheat commodity began in 2011 during participatory varietal selection (PVS) program in south Asia facilitated by Nepal Agriculture and Research Center (NARC), Nepal. The achievement of such collaboration came into light with the release of Gumasokhakaa and Bajosokhakaa in 2014. However, there was not much information

and scientific study being conducted on the agrological and morphological characteristics of released wheat varieties and promising bio-fortified wheat lines. Thus, in order to study and maintain special characteristics of released and bio-fortified lines, a simple study is carried out during 2021-22 seasons on station.

Table 10 Varietal traits of released and Biofortified lines

Characteristics	**Released Varieties**			**Bio-fortified lines**					
	GA	**BK**	**BS**	**BF-447**	**BF-422**	**BF-412**	**BF-411**	**BF-415**	**BF-450**
Days to heading	90	110	94	95	92	90	96	92	93
Days to Maturity	150	185	155	140	138	140	135	145	155
Plant Height(cm)	88	87	72	68	57	64	61	67	68
Peduncle Length (cm)	45	42	34	37	30	29	35	34	35
Spike Length (cm)	9	8	8	7	7	8	6	8	7
Spikelet/spike (no)	16	18	16	16	17	18	14	14	15
Grain/Spike (no)	39	46	41	41	29	41	38	41	30
Lodging	ND	ND	ND	ND	ND	ND	ND	ND	ND
Flag leaf color	Green	Green	Green	Green	Green	Green	Green	Green	Green
Presence of Awn (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Threshing	Easy	Easy	Easy	Easy	Easy	Easy	Easy	Easy	Easy

GA= Gumasokhakaa BK=Bumthangkaadrukchu BS=Bajosokhakaa

iii. Participatory Evaluation Trial of Biofortified wheat lines

Biofortification is a process to increase the bioavailability and the concentration of nutrients in crops through both conventional plant breeding (White and Broadley, 2005) and recombinant DNA technology (genetic engineering) (Zimmermann and Hurrell, 2002). It is an idea of breeding crops to increase their nutritional value. It can be done through conventional selective breeding or genetic engineering. Biofortification is seen as an upcoming strategy in dealing with deficiencies of micronutrients in the developing world.

Wheat is considered to be the most important staple crop in most of the developing countries. Particularly in south and west Asia where half a billion people are iron deficient. Therefore, the International Center for Wheat and Maize (CIMMYT) has developed a number of biofortified wheat lines. The PET trial on biofortified has been carried out with the to develop nutritionally enhanced wheat to increase people's intake of zinc and iron. For adaptability and performance observation, the lines were distributed in wheat growing countries. Bhutan being part of CIMMYT activity and global wheat network, we received 50 biofortified entries during 2014-15 seasons. From these lines, 6 best performing lines were evaluated under PET in the FY 2020-21. Multi location production trials will be carried out in 2021-22 seasons.

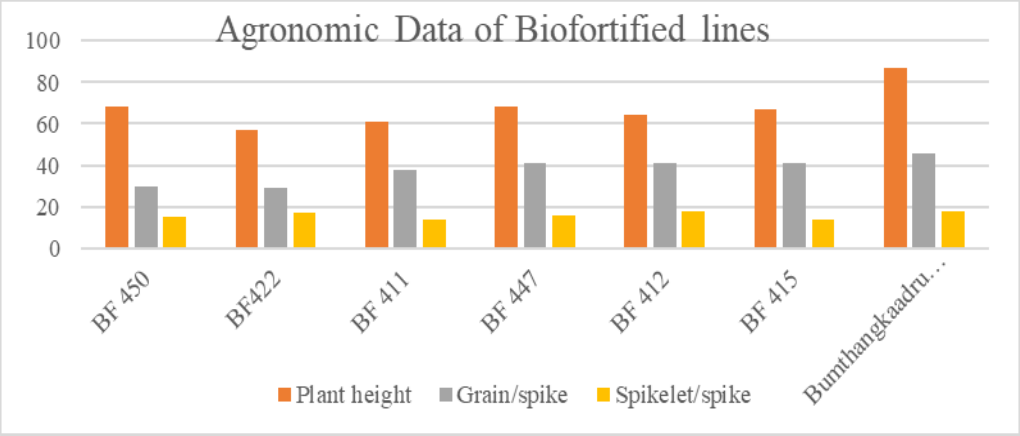


Figure 1 Agronomic Data of Biofortified lines

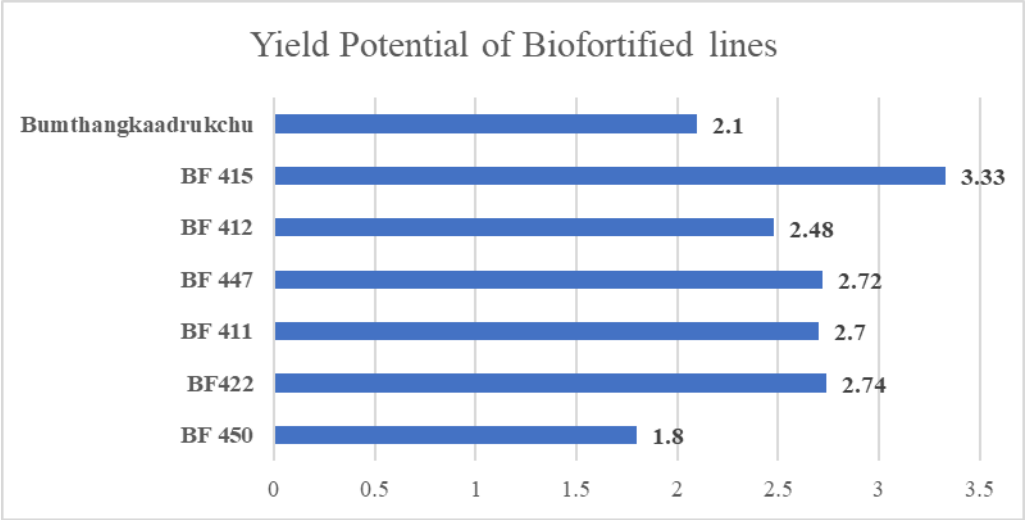


Figure 2 Yield Differences between Biofortified lines

iv. Performance evaluation of promising wheat varieties

Over the years, ARDSC-Menchhuna has been conducting wheat performance evaluation trials of some promising like NL-1073 and Swaedaywar and Bhutanese variety as check from following all the criteria set in the wheat protocol.

Table of Means

Variety	Yield..kg.ac. Means
BHU varieties	470.67
NL-1073 (Wheat)	460.67
Swardgaywar	420.00

The yield from crop cut was computed and there is no significant difference between the mean yield of the three varieties.

v. Produce released wheat varieties seeds and maintain

Considering the importance of varietal evaluation, elite germplasm from both regional and international centres are introduced and tested. The seeds of the potential lines which can possibly make it to the commercial variety are multiplied in the station for wider on-farm testing in a sizable area. For the purpose of preserving breeder seeds

and maintaining available stock for promotion of released varieties, the below mentioned quantity of seeds were produced in 2020-21 season.

Table 11 Improved wheat seed produced and maintained in 2020-21

SN	Variety	In stock (kg)	Qty issued (Kg)	Remarks
1	Bumthangkaa Drukchu	1500.00	0	ARDC-Bajo
2	Bajosokha kaa	500.00	0	ARDC-Bajo
3	Gumasokha kaa	380.00	0	ARDC-Bajo
4	Assorted ((NL-1073 Swargadwar & BHU)	650.00	885.00	ARDSC-Menchhuna
Total		**3030.00**	**885.00**	

Beside maintaining as seed, 885 kg of NL-1073 is distributed to farmers in Serithang gewog, Tsirang on promotional basis to 22 households to evaluate the performance.

3) Quinoa

i. Quinoa Multi Environment Trial at ARDSC-Menchhuna

In the FY 2020-21, ARDSC-Menchhuna conducted Multi Environment Trial on Evaluating the adaptation of Quinoa in collaboration with National Centre for Organic Agriculture (NCOA) and The International Center for Biosaline Agriculture (ICBA) with the objective to phenotypically evaluate Quinoa genotypes through multi-environment testing (MET) and explore the variability of the microbial populations in the rhizosphere of studied areas and their possible use to enhance crop productivity under the marginal environmental stresses.There were 210 entries and 9 NCT entries of three replications. Data reported to NCOA for analysis and further submission to ICBA.

ii. Quinoa crop intensification and promotion

Unlike previous years the Centre has limited in seed production of quinoa since farmers can produce their own seed. This year, the Centre produced 500 kg of quinoa seed from on-station at ARDC Bajo and ARDSC Menchhuna. The seed was issued with technical assistance to farmers of Tsirang, Dagana & Wangdue Dzongkhags covering more than 100 ac.

Table 12 Quinoa seed distribution in West Central Region 2020-21

SN	Dzongkhag	Gewogs	Seed supply (kg)	Area covered (ac)
1	Wangdue	Gangtey, Sephu, Phobjikha	50	20
2	Dagana	Drujegang, Lhamoidzingkha	100	33.3
3	Tsirang	Serithang	150	20
4	Gasa	Khatoed & Khamoed	20	6.7
	Stock balance	**180 kg**		
Total			**320**	**106.67**

4) Maize

i. 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 on-station maize performance trial of three promising varieties. Timely data were collected. No pest and diseases were observed during the growth stages. Three crop cut samples were taken with a sample size of $7m^2$ each than computed to kg per ac as reflected in table 13.

Table 13 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	2.03	24	13.00	2774.99
Chaskharpa Ashom	2.48	23	18.30	3757.80

ii. Improved maize varieties seed production and promotion

As entrusted with developmental mandate, ARDSC Tsirang produced and maintained seeds of different released maize varieties. These seeds are exclusively used in on-farm demonstration, support to client Dzongkhags on request and other ad-hoc requests from both Department and Commodity Programs. In 2020-21 a total of 1316 kg of maize seed of promising varieties (Yangtsipa, Ganesh II and Chaskharpa) is produced and distributed to farmers on promotional basis covering about 75 acres. This is expected to make a substantial contribution to overall cereals production.

Table 14 Promotion of improved maize seed 2020-21

SN	Dzongkhag	Variety	Quantity issued (kg)	HHs covered	Area (Ac)
1	Tsirang	Yangtsipa	575.00	65	38.33
2	Tsirang	Chaskharpa	116.00	9	7.73
3	Tsirang	Ganesh II	130.00	22	8.67
4	Punakha	Yangtsipa	275.00	5	18.33
5	Gasa	Yangtsipa	20.00	2	1.33
6	On-station seed	Assorted seed	200.00		13.33
Total			**1316**	**103**	**87.72**

5) Grain legumes research

i. Participatory technical assessment of evolutionary plant breeding-bean

ARDSC-Menchunna in collaboration with National Biodiversity Centre (NBC) and has been conducted "Participatory technical assessment of evolutionary plant breeding (EPB)" trials on grain beans in Tsirang and Dagana. EPB trials in Bhutan have been initiated on rice and beans. 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 most popular traditional and improved varieties collected and contributed by farmers and ARDSC from specific locations. The study is on-going 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 15 Agronomic traits of different pole beans varieties, NBC trials

Treatments	Average pod/plant	75% Maturity	Pod Colour	Seed Colour	1000 grain weight (gm)	Mean Yield kg/ac
Gew Bori	22	125	reddish	reddish white	543.00	439.67
Kalo Gew Bori	18	125	green	dark red	684.00	816.62
Pole bean (White)	17	116	green	white	287.00	672.31
Pole Bean (Gray)	13	116	green	brown	293.00	645.34
Boshi Bori	13	116	green	brown	395.00	793.02
Mixture	16	125	mixed	mixed	446.00	899.56

Table 16 Agronomic traits of different dwarf beans varieties, NBC trials

Treatments	Average pod/plant	75% Maturity	Pod Colour	Seed Colour	1000 grain weight (gm)	Mean Yield kg/ac
Rajma	8	95	green	brown	410	213.82
Gew Bori	9	105	mixed	reddish brown	383	102.52
Azuki bean	10	105	green	dark green	137	105.22
Pink Rajma	10	95	green	dark pink	435	325.11
Mixture	9	105	green	mixed	333	118.71

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. The mean yield from the mixture in case of pole beans was the maximum at 899.56 kg/ac whereas the yield from mixture in case of dwarf was low at 118.71.

ii. National Coordinated Soybean varietal trial

The National coordination trial on Evaluation of Soybean varieties at ARDSC-Menchhuna with the objective to study the performance and adaptability in Tsirang was continued on-station with six varieties.

Treatment	means	N group
Japanese White	0.40	3 b
KhangmaLibi 1	2.32	3 a
KhangmaLibi 2	1.82	3 ab
Local Brown	0.34	3 b
Soyabean Green	0.34	3 b
TGX-1740F	1.48	3 ab

KhangmaLibi 1 has the highest yield compared to others. Yields of TGX-1740F and KhangmaLibi 2 are comparable to yield of KhangmaLibi 1. Yields of Japanese White, Local Brown, and Soyabean Green cultivars are comparatively less.

iii. 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.

Summary of the Result:

Variety	means	N	group
Bharasharisha	448.54	3	a
Lumley	520.27	3	a
Pragati	294.53	3	b

The yields of Bharasharisha and Lumley are significantly higher than Pragati.

B. HORTICULTURE RESEACH AND DEVELOPMENT

1) Fruits, Nuts, Spices, Flowers

i. Evaluation of subtropical and temperate fruits and nuts germplasms

ARDC-Bajo with full support from Integrated Horticulture Promotional Project (IHPP)-JICA 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 are 25 cultivators germplasm. maintained at ARDC Bajo.

Table 17 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), Perlete (10), Campbell (32), Kyoho (7) Risamate (2), Nsehelena (2), Potland (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), amarpali (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. In addition to the existing fruit cultivars with 85 varieties, Sacha Inchi (one line) is also introduced at the Centre. The germplasm is maintained as a mother block for the bud wood 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 analysis and to release the variety after meeting the required traits. In addition to this ARDSC Menchhuna has also maintained germplasm collection different fruits crops. They are peach (5 varieties), plum (5 varieties) pear (4 varieties), sub-tropical apple (1 variety), pecan (4 varieties), kiwi (4 varieties), 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 also supplied to the private nursery growers. These varieties have been released or found to be promising and can be promoted for production in farmer's field. Presently ARDSC Menchhuna maintains on-going two fruit crops trials;

- Citrus rootstock compatibility trial (Established in 2008)
- Citrus varietal evaluation trial (Established in 2009)

ii. Observation trial of Sacha Inchi

Sacha Inchi (Plukenetia volubilis) is also known as Inca peanut, or mountain peanut belongs to Euphorbiaceae family. It is a native plant of 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 oc. 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 is 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 will be collected on yield, phenology, number of seeds per plant, seed size, seed weight as per the protocol.

iii. Citrus Varietal Evaluation Trial

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

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

The data will be collected based on the plant health, fruit size, fruit weight, adaptability in the region, yield, pest and diseases.

iv. Establishment of Fruits and Nuts Demo Orchards

The purpose of the demonstration orchard is to research and demonstrate the appropriate cultivars and cultural methods that can be adapted and adopted by farmers in their field and to inspire and motivate community for further adoption of the innovation for the economic benefit. This approach focuses on the method (Cultural operations) and result (yield, quality and market) demonstration. Based on the guidelines prepared by IHPP, demonstration orchards were established. In the FY 2020-2021, 41 demo-orchards in five different dzongkhags were established. In total 1452 assorted seedlings were issued to establish the above demo-orchards. Timely monitoring is carried out to collect data as per the IHPP guidelines.

Table 18 Number of demo-orchard established through IHPP

Dzongkhag	No. of orchard established	No. of fruit plants	Fruits plants
Wangdue	8	347	Pear, peach. persimmon, avocado, loquat, apple, dragon fruit
Tsirang	9	210	Pear peach, avocado, citrus, kiwi
Dagana	10	360	pear, persimmon, citrus, avocado, dragon fruit, kiwi
Punakha	10	320	pear, peach, plum, avocado, walnut, kiwi
Gasa	4	190	pear, peach. plum, walnut, apple
Total	41	1427	

v. Improvement of local cultivars through top working

During the FY 2020-21, the horticulture sector has conducted topworking on local fruits and nuts cultivars with promising varieties to rejuvenate the old trees as well as to improve the existing local cultivars in the farmers' field of Punakha and Tsirang Dzongkhags. In total 665 trees are top worked of 82 HHs within the two Dzongkhag. The figure 3. below shows the different fruit trees top worked.

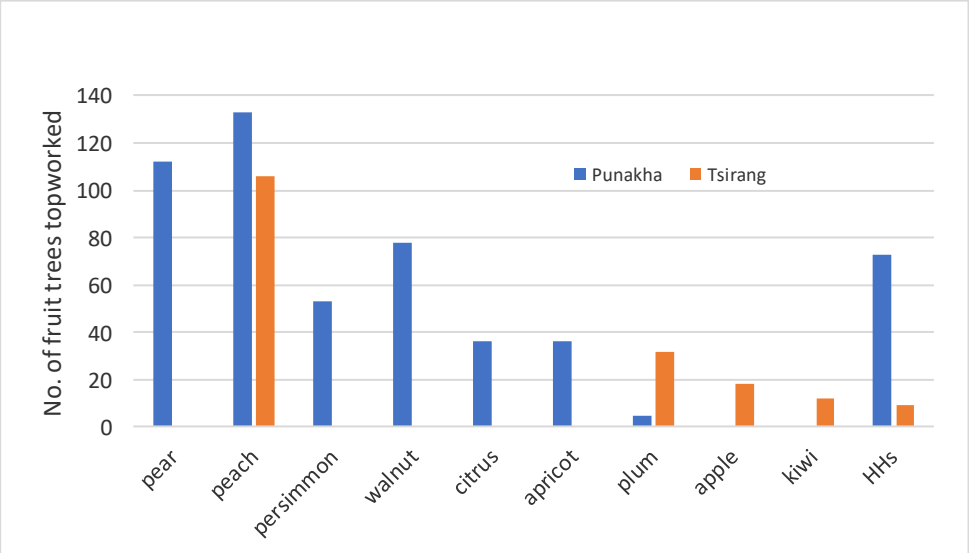


Figure 3 No. of different fruit plant top-worked

vi. Evaluate and maintain citrus germplasm

While progress on citrus research on production management are progressing, it is imperative that a system of nursery to marketing through production are further

explored and institutionalized to sustain increased production and yield especially when the whole world's citrus industries are getting streamline due to dreaded graft transmissible diseases (Huanglongbing (HLB) Citrus tristeza virus, citrus exocortis viroid, phytoplasmas).Therefore, this citrus repository is a corner stone for initiating and institutionalization of citrus nursery system in order to enable 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, 2020, NCR has been able to collect 110 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 the figure 4. The cultivars are collected from Australia, Japan, Nepal and locally from Bhutan.

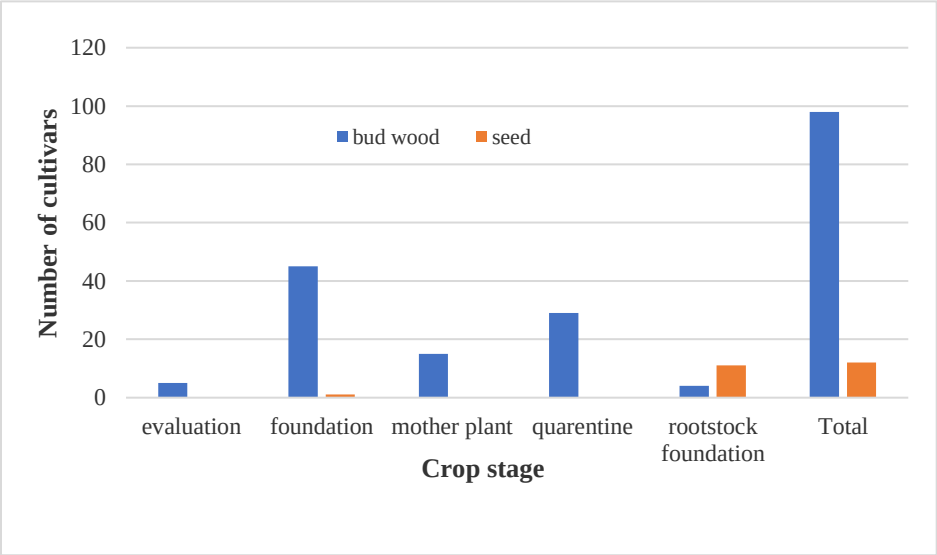


Figure 4 Crop stage of citrus germplasm at NCR

The National Citrus Repository has successfully achieved its annual target of 110 citrus germplasm collection in accordance to Annual Performance Agreement (APA), of which 64 and 46 citrus germplasms are collected locally and globally respectively (annexure attached). However, 29 collections are in quarantine house growing for Huanlongbing (HLB) test in the future. 9 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 next batch. Negatively tested plants will move to foundation house as germplasm through propagation. 8 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 for its performance evaluation research in multi environment of 500, 1000, 1500 and 2000 masl. 72 foundation plants are well maintained in an insect proof screen house as germplasm. 13 varieties are being developed for characterization in the repository for research and development purpose. Micro grafting (STG) is being initiated in 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 hardware for smart irrigation is

completed and software installation is in progress with due completion by end of June 2021. Standard protocol is well maintained in managing citrus repository.

vii. Promotion of quality fruits and nuts grafted seedlings

Amidst the COVID-19 Pandemic with repeated lockdown and remote working modality ARDC Bajo along with ARDSC Menchunna could produce more than 5000 improved grafted disease-free seedlings fruit plant seedlings for the region which will cover more than 40 acres of area. Out of which, 2584 are already planted in the field covering more than 19 ac area with technical support like layout, pit digging, pit filling and planting. This was done in close collaboration with the Dzongkhag Extensions and by providing systemic training to the farmers. The balance fruit stock especially the sub-tropical fruits plants like citrus and avocado will be distrusted to the farmers in the coming monsoon season soon.

Table 19 List of fruit plants distributed to farmers in West-Central Region

Fruit plants	Seedling quantity (Nos)			Planting distance (M2)	Area planted (ac)	Total area covered (Ac)
	Qty issued	Stock balance	Total			
Pear	290	550	840	30	2.15	6.23
Persimmon	220	0	220	30.25	1.64	1.64
Walnut	125	80	205	49	1.51	2.48
Avocado	300	300	600	36	2.67	5.34
Citrus	370	1500	1870	36	3.29	16.63
Kiwi	95	0	95	42	0.99	0.99
Peach	195	20	215	25	1.21	1.33
Plum	100	20	120	36	0.89	1.07
Apricot	120	0	120	25	0.74	0.74
Loquat	300	0	300	25	1.85	1.85
D. Fruit	200	0	200	16	0.79	0.79
ST apple	100	0	100	30	0.74	0.74
Grape	89	0	89	36	0.79	0.79
Total	**2584**	**2570**	**5134**		**19.26**	**40.62**

viii. 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 characters of respective varieties collected from other research Centre, farmer's field in Dagana, Tsirang and Sarpang. These varieties are maintained with the objective to identify and characterize based on the morphological characteristics and also to maintain germplasm for breeding works in future.

The two recently collected lots of varieties namely Barlangey and Seremna from farmer's field in Dagana and Tsirang respectively are maintained outside in open. However, the rest of the varieties in open field were recommended to be removed by the consultant from Nepal during his visit in the 2018 as he found it 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.

ix. Feasibility Study Orchard Establishment

During the FY 2020-21, the Horticulture sector carried out three feasibility study on orchard establishment in Punakha Dzongkhag based on the request made by the land owners. The feasibility study includes site visit, slope measurements, recording of latitude & aspect, area measurement, recommendation of planting materials and layout of orchard.

1. Dorji, Lungkha, Shagana

Name of proposed site:	Dobomoma
Forest type:	Pine
Aspect:	SW facing
Water source:	Shangana about 6 km away from the site. The proposed site is connected with water
Soil type:	Sandy loam
Elevation:	1540 masl
Size of the land:	2 acres
Feasible fruit crop:	Persimmon, avocado, lime and oranges

Expectation of the farmers: Seedlings and technical support from ARDC, Bajo; machine and fencing from the dzongkhag.

As per the findings from the site visit, the sector technically discourages the owner from taking up mango farming (as he is interested).

2. Talo Goenpa Shedra

Name of proposed site:	Talo Goenpa Shedra
Site topography:	Steep sloppy covered with forest trees
Aspect:	SW facing
Water source:	Available
Soil type:	Loam
Elevation:	2400 masl
Size of the land:	20 decimals
Feasible fruit crop:	Pear, peach, persimmon & loquat
Recommendation	Based pit should be filled up by wood bio-char about one foot followed by irrigation and filling up by soil mixture (>30 kg of compost)
Layout	Contour system followed

3. Ugyen Wangchuk, Thamji, Chubu

Name of proposed site:	Thamji
Forest type:	Broadleaf
Aspect:	NE facing
Water source:	Available
Soil type:	Loamy clay
Elevation:	1440 masl
Size of the land:	2 acres fellow
Feasible fruit crop:	Persimmon, avocado, pecannut, apricot, pear-Hosui
Expectation of the farmers:	Seedlings and technical support from ARDC, Bajo

x. Production and supply of spawn for mushroom cultivation

Mushroom cultivation in Bhutan has created employment opportunities, due to its high market value. However, lack of quality spawn supply in the market hindered from producing at commercial scale. Therefore, the Department of agriculture under ministry of agriculture and forests 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. Today, with the appointment of one trained mushroom staffs, laboratory facility has been improved, and production of quality Oyster and Shiitake mushroom initiated. In the FY 2020-21, a total of 3447 bottles of oyster spawn and 620 bottles of oyster mother spawn was produced and supported to farmers in mushroom cultivation.

The spawn was supplied to interested farmers of West-Central Region (table 20). 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 mushroom in Punakha and Tsirang region. The mother spawn will be used by them to further multiply and start mass production at village level. It will help in starting business and entrepreneurship and help in establishing small and cottage industries in rural area

Table 20 Quantity of spawn supported in the Region in the FY 2020-21

SN	Dzongkhag	Mushroom spawn supplied (bottles)		Mother spawn supplied (bottles)		Remarks
		Bottles	No. HH	Bottles	No. HH	
1	Wangduephodrang	959	28	0	0	
2	Gasa	180	6	0	0	
3	Tsirang	233	6	130	1	
4	Dagana	650	16	0	0	
5	Punakha	1125	20	170	1	
6	ARDC Bajo	300		320		250 mother spawns used at the Centre
Total		**3447**	**76**	**620**	**2**	

The spawn varieties for Shiitake mushroom were SM5, M290, A577 and Nepal variety. Materials used to produce spawn were wheat grains mixed with saw dust. Spawn from Nepal variety was produced from saw dust. The Shiitake mushroom cultivation technical support as farmer training was provided to Wangdue, Punakha, and Tsirang Dzongkhags based on the extension demand. Around 15 households were involved in shitake mushroom production. The unit caters its technical services to the five Dzongkhags of West Central regions.

Table 21 Shiitake mushroom cultivation in the FY 2020-21

SN	Dzongkhag	No. of HH	No. of billets
1	Wangduephodrang	13	6268
2	Punakha	1	1800
3	Tsirang	1	500
Total		**15**	**8568**

xi. Strengthen floriculture production

ARDC-Bajo started floriculture research and mass production since 2016. The Centre has developed floriculture on-station site with collection of assorted ornamental plants. During the FY 2020-2, the Centre has produced more than 18500 potted plants. The Centre has catered in supplying more than 8500 ornamental potted plants for beautification of various institutions within the region and outside (annexure…). At present the Centre has stock maintained more than 10000 plants in the nursery.

Table 22 Inventory of different type of ornamental plant in nursery June, 2021

SN	Flower plant	Quantity (nos)	Remarks
1	Ever green	4282	mixed variety
2	Annual flowers	6708	assorted
3	Deciduous flower	880	assorted
4	Orchid	1000	wild orchid collection
5	Medicinal herbs	4220	assorted
6	Miscellaneous	1500	mixed variety
Total		**18590**	

2) Vegetable research and development

i. Evaluation of Chili lines

With chili blight and many soils borne diseases affecting the crop, chili production still remains an issue. Resistant cultivars of chili lines from world vegetable centre, Taiwan are evaluation from 2021. These chili lines are tolerant varieties to many major diseases of chili plants such as mosaic virus, tobacco mosaic virus, leaf curl, bacterial wilt and etc. With seeds sourced by DoA, MoAF, it is nationally coordinated trial carried out throughout all research centres in Bhutan. In total thirty (30) lines are evaluated across all research centres, and ARDC Bajo is evaluating seven lines. Since, the seeds receipt was of very less (1g in each packet), this season, it is cultivated for seed multiplication purposes for the research in the following years.

Table 23 Resistant cultivars of chili from World Vegetable Center

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

Phenotypic characteristic studies of traditional chili varieties are also underway at on station farm field. Seven cultivars collected from various chili growing areas of Bhutan, especially from the west central and central parts of Bhutan is under study. Through this study, the germplasm of traditional lines will be maintained besides ascertaining its yield potential and other yield attributes.
Traditional chili varieties under evaluation at ARDC Bajo in FY 2020-21 are:

- Sha Ema
- Nubi Ema
- Khasadrapchu Ema
- Yangtsep Ema
- Tamchi Ema
- Kabji Ema

ii. Sweet potato varietal performance evaluation

On station adaptability and performance trial for three varieties of sweet potato (Gorojima, Orange flesh, and pink vein) were carried since 2019, and the findings already reported in the annual report of 2019-2020. In 2020, the trial was repeated again to ascertain the consistency in the performance of the cultivars with respect to yield and its adaptability with two check varieties. In order to find out its performance under different agro-ecological zones in Bhutan, similar varietal performance studies were carried out at two locations in farmer's field under farmer's management practice. Thimphu, at an altitude range of 2340masl, was identified site for the trial. From two years evaluation period at the station, it was found that there are no significant yield differences (P value: > 0.05). Even in the farmer's field, there was no significant yield differences observed within the varieties. The varieties will be put for release in June 2021.

Table 24 Sweet potato varietal performance

Variety Name	On station mean Yield(t/ac)	On-farm Mean Yield (t/ac) Thimphu(2340Masl)
Beni Azumi	10.51a	6.03a
Orange Flesh	13.81	6.88a
Gorojima	10.03a	6.18a
Local white	14.04a	7.1a
Local Pink	9.78a	6.5a
Mean yield	11.63	6.37a
P value	0.06	0.0721

iii. Radish varietal evaluation

Four radish varieties were evaluated using RCBD with four treatments (varieties) in 2020. The varieties are Gensuke, Akino Irodi, long foot and Shogoin which were introduced from Japan in close collaboration with IHPP-JICA in 2018.

Table 25 On farm and on station yield data for radish

Variety Name	On-station(1210masl) Mean Yield(t/ac)	On farm Mean Yield (t/ac)	
		Tsirang(1860masl)	Punakha(1200masl)
Akino Irodi	21.07abc	29.47	24.77
Gensuke	24.10a	30.30	15.80
Long foot	22.46ab	30.47	22.73
Shogoin	15.49 c	25.23	21.57
Minowase (Check variety)	17.56bc	21.47	29.47
Mean	20.14	27.39	20.96
F value	0.04	0.0794	0.3626

The performance of these cultivars was studied both at the station as well as at the farmer's field with the check variety Minowase to ascertain its adaptability and the yield potentiality for two consecutive years from 2019-2020. The plants were grown in 5m2 bed with the spacing of 20-25cm between the plants 40-50 cm between the rows. Data analysis was carried out with the help of ANNOVA of STAR 2.0.1. It was observed that all the varieties under evaluation at on station showed significant yield differences. However, in farmer's field, it was ascertained that there are no significant yield differences observed between the varieties under evaluation. Hence, the varieties will be registered for the variety release in June, 2021.

iv. Zucchini varietal evaluation trial

Yellow zucchini is under the varietal evaluation trial at ARDC Bajo with the check variety green Zucchini. These varieties were evaluated last year too at on station farm field. In 2020 it was evaluated at on station as well as in the farmer's field to find out its yield performance and adaptability under different agro-climatic Zones.

ANOVA TABLE
Response Variable: Plant yield(g)

Source	DF	Sum of Square	Mean Square	F Value	Pr(> F)
Rep	2	351347.8689	175673.9344	46.35	0.0211
trt	1	162379.0470	162379.0470	42.84	0.0226
Error	2	7579.9056	3789.9528		
Total	5	521306.8215			

Summary of the Result: Yield/Plant(g)

Trt	Means	N group
1	2098.84	3 a
2	1769.82	3 b

Means with the same letter are not significantly different.

v. Carrot varietal evaluation (*Daucus carota*)

Pure red variety of carrot introduced from Japan with the control variety New kuroda is under performance evaluation trial on station. The trial will be conducted for another one year and variety to be proposed for the next VRC.
Response Variable: Yield

Source	DF	Sum of Square	Mean Square	F Value	Pr(> F)
Rep	2	1.1152	0.5576	1.86	0.3492
Trt	1	5.1523	5.1523	17.22	0.0535
Error	2	0.5984	0.2992		
Total	5	6.8659			

Summary Statistics

CV(%)	Yield Mean
8.22	6.66

vi. Colocasia varietal trial

Four Colocasia varieties from Japan and two local varieties as check variety are under study at ARDC Farm field. These varieties are not yet evaluated at farmer's management practices in farmer's field. The varieties were found performing significantly well at the centre. It will be evaluated on-farm in the next season. Japan Green, Japan Red and Yuasa Red, local red and local white are under studies.

vii. Tomato varietal evaluation

Three hybrid varieties, and two open pollinated varieties sourced by Department of Agriculture, MoAF, is under evaluation at on station for its yield performance. Monalisa, the hybrid variety is under evaluation with check variety PS-61 and cosmic. All these varieties are under fast tract evaluation for release. King 180, Pontarosa and Thai variety, an open pollinated varieties are also under evaluation with check variety Roma and rattan. If the varieties are found performing significantly higher than the check varieties in terms of yield, and other yield parameters, it will be proposed for release next year. In 2020, Red Tommy Toe, An Australian variety, and master variety which were under evaluation for past two years was found very superior in fruit quality besides being high yielding varieties. Its Statistical data analysis using Annova of STAR 2.0.1 is as presented below table 26.

Table 26 Agronomic performance of tomato varietal evaluation

Varieties	Mean fruit weight(g)	Mean fruit length(cm)	Mean fruit diameter (cm)	Mean TSS (degree brix)	Yield (ton/ac)
Red Tommy Toe	25.00c	3.24c	3.58c	3.83a	13.27a
Master	189.80a	5.64a	7.16a	3.56b	11.57b
Rattan	101.00b	5.06b	5.53b	3.42c	7.52c
Mean	105.27	4.65	5.42	3.60	10.79
SD	74.02	1.12	1.63	0.56	5.02

viii. Pumpkin varietal trial

Kuri, pumpkin variety was introduced from Japan, and 1315, pumpkin lines from AVRDC were under performance evaluation since 2019. These varieties were evaluated using check variety, Ebisu (Wengkhar kakur). One more year is required to study this variety before proposing for the variety release. Hence, it will be evaluated one more season.

ix. Performance evaluation of Strawberry (*Frageria anansa*)

Red flesh and Camarosa varieties of strawberry which were introduced from Japan are under the varietal performance evaluation trial at the Centre, ARDC, Bajo. Data compilation for the one growing season was carried out and the trial however needs the yield data for another growing season for the variety to be put up for the varietal release committee.

x. Brinjal performance evaluation trial

Brinjal (Solanum melongena) belongs to Solanaceae or nightshade family grown for edible fruits which is botanically called berry. Pusa purple long, is only variety released and made available for cultivation in Bhutan until date. In order to diversify eggplant varieties in Bhutan, four varieties of Japanese eggplant were introduced at

ARDC-Bajo through Integrated Horticulture Promotion Project (IHPP). The performance evaluation of four Japanese eggplant varieties was carried out at ARDC-Bajo Horticulture farm field. The experiment was conducted in Randomized Complete Block Design with tree replicates. The one-year data shows that the average yield t/ac is maximum in Nagaoka and Manryo variety

Table 27 Agronomic performance of brinjal performance evaluation

SN	Variety	Yield (t/ac)	Fruit length Average (cm)	Fruit size Average(cm)	Weight/Fruit (gm)
1	Nagaoka	3.9	14.8	4.76	158.2
2	Manryo	3.2	16.8	5.34	158
3	Shin kurowase	2.7	16	5.92	186.5
4	Senryo	2.3	14.3	4.66	130.6
5	Pusa Purple Long(Check)	2.5	17.1	3.43	81.7

xi. Rice husk ridging and increase stalk length of Bunching onion

Kujo, a bunching onion variety is grown at ARDC farm field and it is used for evaluating the effects of rice husk ridging in its edible stalk length increase. Japanese bunching onion is a species of perennial plant, often considered to be a kind of scallion. Bunching onion is suitably cultivated under cool temperate condition, and can be propagated through seed as well as stem cuttings. Stem cuttings were transplanted in furrow spaced at 25-30 cm. Ridging is an important cultural operation to get good quality and longer edible stalk. Ridging of plants with rice husk and soil were studied to ascertain which methods would yield better quality and longer edible stalks of bunching onion. From the experiment, it was observed that rice husk treated bunching onion gave longer edible stalks than the soil. The trial will be conducted one more season to authenticate the data.

Table 28 Agronomic performance of bunching onion in rice husk ridging

Treatment	Average stalk length (cm)	Average stalk weight(g)	Average stalk diameter (cm)
Rice Husk ridging	39.1cm	135.g	2.22cm
Ridging with Soil	19.8cm	100.g	3.01cm

xii. Growth of chili seedlings using improved potting mixes

Leaf mould and top soil are popularly used in raising vegetable seedlings before transplanting in the field. With this improved nursery technology, the use of leaf mould and topsoil could be reduced and the besides the use of fertile soil is not sustainable in long run. Hence, use of improved potting soil mixes prepared out of normal soil, biochar and sand which are supplemented with Bokashi and Suphala fertilizers These potting soil mixes is then filled in the plastic poly pots and then vegetable seedlings after 2 cotyledon leaf stage is potted which are kept until transplantable stage in main field. Begup ema is used for the study.

Treatment 1: Soil: sand: Biochar: Bokashi: compost (4:3:3;1: 0.5) 50g Suphala

Treatment 2: Soil: Biochar: Bokashi: compost (100:20:0.5:10) and 50 g Suphala.

Treatment 3: Leaf mould

Growth in nursery and yield effects from main field were studied between these three treatments. Randomized complete block design were used with three replication and three treatments. Growth data was collected during transplantable stage. From the study, it was found out that there is a significant difference in the growth. With highest obtained in treatment 1, followed by treatment 2 and 3. Similar findings were ascertained for stem girth of the plant. However, there were significant differences observed in leaves numbers.

Table 29 Agronomic performance of chili seedling using improved potting media

Treatment	Plant height (cm)	Stem girth(cm)	Leaves No
Treatment 1	6.47a	2.03a	5
Treatment 2	4.40b	1.30b	3
Treatment 3	3.53c	1.17b	3
Mean	4.8	1.5	3.63
P value	0.0001	0.0001	0.0015
CV	3.99	3.85	7.37

xiii. Evaluation and germplasm maintenance of traditional bean varieties

Nine traditional pole bean cultivars from DoA are grown this season. All these varieties are on observation this season, and from next season, its yield and other yield attributes will be evaluated. The germplasm of these varieties will be maintained at the station. They are:

- White bean
- Brown local
- Pink local
- Chaskharpa shepey
- Punakha local
- Kengkharpa
- Muka orey
- Kalo bori
- Black bean

xiv. Watermelon varietal evaluation trial

Water melon performance trial with two varieties (Black Ball and Kabuki) was carried out on-station with sugar baby as check. The objective of this trial was to evaluate the performances of these varieties for variety release since these varieties were evaluated with good yield and taste traits.

Table 30 Agronomic performance watermelon varietal evaluation

Varieties	Average fruit weight(kg)	Average fruit length(cm)	Average fruit diameter(cm)	Average TSS (%)
Black Ball	7.5a	24.15a	22.83b	11.24b
Sugar Baby	4.68c	20.77c	20.80c	10.27c
Kabuki	6.75b	23.14b	23.02a	11.42a
Mean	6.16	22.69	22.22	10.98
SD	1.48	2.03	1.7	1.11
p.value	0.804	0.297	0.951	0.919

xv. Vegetable breeder seed production and multiplication

As ARDCs are mandated to maintain the breeder seeds of various vegetables released from their Centres and make it available whenever National Seed Center (NSC) require. During the FY 2020-21 the Centre could produce more than 77 kg of assorted vegetables seeds as mentioned in the table 31. The Centre also issued five kg pole bean (Prime Green) which is recently released variety to NSC and 23.75 kg to the farmers in West-Central Region. The balance breeder seeds are maintained at the Centre which will be used in the coming season.

Table 31 Breeder seeds produced, maintained and issued 2020-21

SN	Crop variety	Quantity produced (kg)	Quantity issued to (kg)	
			NSC	Other agencies
1	Bean- Borloto	10	0	
2	Bean- Pusa Parvati	12	0	
3	Bean- Top Crop	7	0	
4	Bean- Rajma	11	0	
5	Bean- Prime Green	30	5	23. 75 kg to 5 dzongkhags
6	Brinjal- Pusa Purple Long	.5	0	
7	Broccoli- Desico	.5	0	
8	Cauliflower- White Top	.5	0	
9	Carrot- Early Nantes	1	0	
10	Radish- Bajo Laphu 1	2	0	
11	Spinach- All Green	2	0	
12	Tomato- Roma	.3	0	
13	Tomato- Cherry Tomato	.3	0	
14	Tomato- Bajo Lambenda 1	.3	0	
15	Watermelon- Sugar Baby	.2	0	
Total		77.6	5	

xvi. Promotion of improved vegetables for commercial production

Through the support from IHPP-JICA, the horticulture sector has initiated commercial vegetable production program within the region by producing improved seeds on-station and promotion by providing improved seeds, technical assistance and human resources development through systematic training program. During the FY 2020-21, the sector issued more than 56 kg of varieties of seeds which is calculated to cover more than 44.37 ac of areas.

Table 32 Vegetable seed promotion in West-Central Region in FY 2020-21

	Vegetable seed supplied (Kg)							
Dzongkhag	Pole bean	Pumpkin/ Zucchini	Carrot	Radish	Cole crops	Tomato	Leafy green	HHs covered
Gasa	3.00	0.20	0.38	1.63	0.72	0.04	0.35	18
Dagana	4.50	0.70	0.68	1.93	0.87	0.12	0.70	25
Wangdue	4.50	0.70	0.60	1.80	1.16	0.05	0.55	24
Punakha	4.50	0.70	0.70	1.83	1.16	0.09	0.70	30
Tsirang	7.25	0.14	0.38	13.00	0.65	0.10	0.00	12
Total	23.75	2.30	2.73	20.19	4.56	0.39	2.30	109
Area (ac)	1.98	2.30	5.81	7.21	22.80	1.97	2.30	44.37

The Centre also distributed seedling of high value vegetable crops like straw raised on-station in the poly pots especially straw berry and water melon for commercial production in Punakha-Wangdue valley at Tsirang Dzongkhag;

- Wangdue-Punakha valley: straw berry 500and watermelon 400 pots
- Tsirang Dzongkhag: straw berry 350 (7 HHs) and water melon 6330 (6 HHs)

xvii. Promotion of improved MAP crops

Turmeric cultivation is gaining popular 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 with 2.5acres in Saleri village under Barshong gewog and 0.5ac at Lower Tshokona, Tsholingkhar gewog. The main objective is to find out the feasibility of mass cultivation of turmeric in different location with different physio-climatic condition. it was cultivated in the same location at lower Tshokhana which is located at an altitude of 1200mals with total area of 0.5acres and. The crop was planted in March, 2020 on a raised bed with plant to plant and row to row distance of 25 cm. It was mulched with dead grass as turmeric requires thick mulching. Weeding was carried out once till now. The average yield was just about 1000kg per acre that is comparatively low.
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.

3) IHPP systematic training

As per the IHPP-JICA program, the sector has imparted systematic training to fruits and nuts and vegetable growers' farmers covering on improved nurseries technologies, management aspect, improved new potting media. protected cultivation and pest/diseases control.

Table 33 Farmer's training on improved technologies through IHPP

SN	Dzongkhag	No. of HHs			Remarks
		Male	Female	Total	
1	Dagana	7	1	8	IHPP systematic training
2	Gasa	3	1	4	
3	Punakha	4	1	5	
4	Tsirang	7	2	9	
5	Wangdue	1	6	7	
Total		**22**	**11**	**33**	

4) Hydroponic Research

With the establishment of Hydroponic structure through support from FSAP Project, the Centre has ventured into hydroponic farming research. Presently, the Centre has initiated research with celery and lettuce crop using different media like oasis cube, rice husk, pink bark power and pebbles. There have been five harvests as of June, 2021. In the FY 2020-21, the Centre facilitated in DeSuung Skilling Program where 31 Dessups are trained on hydroponic farming.

C. ENGINEERING SERVICES

Overview

Engineering Sector comprising of five engineers provided engineering services for implementation of 36 activities estimated value of Nu880.099million (M) for 13 agencies including six Dzongkhags in 2020-21 financial year. Amongst the agencies, the highest of nine activities were implemented for ARDC Bajo worth Nu7.770M, followed by RP Chimipang of five activities worth Nu6.045M, four activities each for RNR Agencies and Wangdue Dzongkhag. In terms of value of the work the highest was for Wangdue Dzongkhag of Nu Nu526.740M followed by Zhemgang Dzongkhag of Nu212.496M.

The maximum 11 activities corresponding to 30.6% of the activities implemented by Engineering Sector was implemented by TGT worth Nu748.961M (85.1%) and the second highest of 10 activities (27.8%) implemented by IBR worth Nu7.382M (0.84%) and the lowest of three activities (8.3%) worth Nu3.00M was implemented by TGL. In terms of estimated value of the work the highest was implemented by TGT with estimated value of Nu748.961M (85.1%) followed by PC worth Nu105.36M (11.97%) for seven activities and the least of Nu3.000M by TGL. As TGL is nearing retirement only a limited work was assigned.

On average each engineers implemented 7.2 activities worth Nu176.02M in 2020-21 financial year. The average value of an activity stands at Nu24.447M. The summary of activities implemented by the sector is presented in Table 34 while the subsequent section presents detail profile of activities implemented by each engineer under the sector. Although the activities are listed against each individual engineers who took the lead responsibilities but most of the activities were jointly implemented among the engineers the sector as well as the support of other the other sector in ARDC Bajo, ARDSC Tsirang, RP Chimipang and concerned client agencies.

Table 34 Profile of engineering services provided by site engineer, agencies and cost

SN	Agency	No of activities							Cost	
		TGL	PC	NW	IBR	TGT	Total	(%)	(NuM)	(%)
1	ARDC Bajo	2	1	-	4	2	9	25.0	7.770	0.88
2	ARDSC Tsirang	-	-	-	2	-	2	5.6	0.105	0.01
3	RP Chimmipang	-	-	2	3	-	5	13.9	6.045	0.69
4	NSC Bajo	1	-	-	-	-	1	2.8	0.400	0.05
5	RNR Agencies	-	2	2	-	-	4	11.1	35.902	4.08
6	GCF Project	-	-	-	-	1	1	2.8	0.028	0.00
7	De-suung Program	-	-	-	-	2	2	5.6	0.136	0.02
8	Dagana Dz	-	2	-	-	-	2	5.6	34.550	3.93
9	Punakha Dz	-	1	-	-	1	2	5.6	19.200	2.18
10	Trongsa Dz	-	-	-	-	1	1	2.8	12.197	1.39
11	Tsirang Dz	-	1	-	-	-	1	2.8	24.530	2.79
12	Wangdue Dz	-	-	1	-	3	4	11.1	526.740	59.85
13	Zhemgang Dz	-	-	-	1	1	2	5.6	212.496	24.14
Total- NoA		3	7	5	10	11	36	-	880.099	100
Total- (%)		8.3	19.4	13.9	27.8	30.6	-	100.0	-	-
Total- Cost (NuM)		3.000	105.36	15.396	7.382	748.961	-	-	880.099	-
Total- (%)		0.34	11.97	1.75	0.84	85.10	-	-	-	100

i. Engineering Services provided by Thinley Gyeltshen

In addition to many other small activities Mr. Thinley Gyeltshen (Principal Engineer) prepared drawings and estimated for three engineering activities with an estimated value of Nu3.0M. Out of three activities only two are implemented departmentally through labour contract. Due to the lack of budget at ARDC Bajo the third activity was directly implemented by DeSuung Program. Table 35 provides the summary of the activities while overview is presented in subsequent sections.

Table 35 Engineering Services provided by Mr. Thinley Gyeltshen in 2020-21

SN	Activity	Qty/ Unit	Amount (NuM)				Remark
			Estimated	DE	Contract	Actual	
1	Const. of Farm Manure Pit- ARDC Bajo	1 No	0.300	0.300	-	0.300	C
2	Const. of Farm Manure Pit- NSC Bajo	1 No	0.400	0.400	-	0.400	C
3	Const. of Desuup Toilet- ARDC Bajo	6 Unit	2.300	-	-	-	No budget
Total			3.000	0.700	-	3.000	

LEGEND: DE = Departmental Execution, TS = Technical Support, OG = On-going, C = Completed

Construction of Farm Manure Pit at ARDC Bajo

Base on the direction from ARDC Bajo Management, drawings and estimate was prepared for the construction of Farm Manure Pit at ARDC Bajo farm area for the Field Crops Sector. The cost was estimated at Nu 300,000 only. The work was implemented departmentally through labour contract. The work was completed on scheduled time and handed over to the management.

Construction of Farm Manure Pit at NSC Bajo

Drawings and estimates were prepared for the construction of Farm Manure Pit at NSC Bajo farm area based on the request from NSC Bajo Farm Manager. The cost of the construction was estimated at Nu400,000 only. The work was implemented departmentally and completed on time.

Construction of Desuup Toilet at ARDC Bajo

Drawings, estimate and BoQ were prepared for the construction of Toilet & Bathroom to be used during the specialized Desuung Training at ARDC Bajo in accordance to the direction of ARDC Bajo Management. The cost of construction of six-unit toilet was estimated at Nu2.3M based on 2020 BSR Thimphu rate. Owing to the lack of budget at ARDC Bajo the work was directly implemented by Desuung Program.

ii. Engineering Services provided by Puran Chhetri

This section presents engineering service provided by Mr. Puran Chhetri (Assistant Engineer). Total of seven activities were carried out during 2020-21 fiscal year. The task for the activities included surveying, designing, drawings, estimation, tendering and implementation. From a total of seven activities three activities are completed, while four other activities are on-going at the time of this reporting. The total value of

work done was Nu105.36M. Table 36 provides summary of the activities and overview are presented in subsequent sections.

Table 36 Engineering Services provided by Mr. Puran Chhetri in 2020-21

SN	Activity	Qty/Unit	Amount (MNu)				Remark
			Estimated	DE	Contract	Actual	
1	Const. of Lumina-Habisa IS at Guma Geog, Punakha	2.6 km	14.400	-		-	TS
2	Const. of Dangreygang IWS Pilot Project at Semjong, Tsirang	9.5 km	24.530	24.530		-	TS
3	Const. of Tsaimzigosa IS at Lhamoizingkha, Dagana	3.0 km	12.250	-			TS
4	Const. of Kanakha IS at Kana, Dagana	4.6 km	22.300	-			TS
5	Const. of Targaythang Fishery Pond WS, Punakha	1.0 No	24.630	-	1.780	1.996	C
6	Reno. of Rabuna Fish Pond, Wangdue	1.0 No	2.450	-	2.170	2.500	C
7	Const. of Khawajara SWPS at Toedwang, Punakha	1.0 No	4.800	4.800	-	-	DE, C
Total			105.360	29.330	3.950	4.496	

LEGEND: FS = Feasibility Study, DE = Departmental Execution, TS = Technical Support, IS = Irrigation Scheme, WS = Integrated Water Supply, WS = Water Supply, SWPS = Solar Water Pumping System, OG = On-going, C = Completed

Renovation of Lumina-Habisa Irrigation Scheme at Guma Geog, Punakha

The major renovation of Lumina-Habisa Irrigation Scheme is continuation of previous financial year activity. This activity was initiated with the direction from the DoA to conduct assessment for the renovation of the scheme towards.

Accordingly, the Engineering Sector along with Tshogpa visited the site for the assessing the problems of the Lumina-Hebisa Irrigation Scheme. The conveyance length and command area of the scheme was determined to be about 2.75km and 76 acres respectively. The scheme traps water from Lumina perennial stream located on the right bank of Mochu and conveys to the major command area located on the left bank. The conveyance system is a combination of (1.75km) open earthen channel and GI pipe siphon (1.0km). A cable suspended GI pipe aqueduct (180m multi-span) is used to cross Mochu. As per the Tshogpa this structure was reconstructed in 2018-19 fiscal year following the damage by the flood.

During the visit it was observed that water is trapped from the source using a temporary boulder diversion structure without any control gates. No sediment removable structures were seen either. During the tracking along the cannel from intake to delivery few stretches of the open channel were observed to be lined with cement masonry (less than 10% of the open channel), HDPE pipe were used for conveying water across unstable areas at two sites. About 100m downstream of the intake 30m length of channel was completely collapsed due the land slide rendering

the channel un-functional during the previous rainfall season. A sediment removal chamber was observed towards the last quarter of the open channel length. A steel gate for flushing out sediment was observed to be functional. The structure was constructed to prevent sediments entry into the siphon pipe conveyance line. However, the siphon pipe intake was located about 270m downstream of this structure with high possibilities of local sediment entry. This open channel between sediment removal structure and pipe intake structure was mostly filled with sediments.

The siphon pipe intake chamber is located on the ridge without any provisions of spillways for removal of excess water or discharge water safely in case of blockage of pipeline. Pipe inlet trash screen and ball vale were found to be in good condition. From this intake till final delivery tank 150mm GI pipe is used which are generally laid on the ground surface without much props with exception to few stretches. Rusting of GI pipes were observed in many stretches where pipe either enter or emerges from the ground. In some case pipe walls have become thin and small holes were seen on pipe. As per one of the ladies residing nearby pipeline stated that when the water flow in the pipe loud nice can be heard from the leakage of pipe which poses huge risk. As per the Tshogpa this pipeline was constructed about 20 to 30 years ago which has completed its designed life span.

In the first year based on the site observation two recommendations were proposed. First was a temporary restoration work intended to supply irrigation water for the coming rice season. The work included providing HDPE pipe for conveying water across landslip area and replace GI pipe only in few critical locations. The cost was estimated at Nu0.42M. The work was awarded to contractor through limited bidding form implementation. However, the beneficiaries expressed that it will be wastage of resources for a temporary solution so they are will to wait for one year for a more permanent solution. So, the temporary work was stop and material brought to site was handed over to the beneficiary group to be used in the future.

The second recommendation was for major renovation of the scheme. The work included carrying out detail survey, design, drawing, estimation, tendering and implementation which would not only require time but also substantial amount of budget. A very quick and rough design was prepared for budgeting purpose. The cost was estimated at Nu6.80M.

In 2020-21 a survey, design, drawing, and estimation was done as per the plan. The cost was estimate at Nu14.40M. Department of Agriculture and Punakha Dzongkhag agreed on 50-50% budgeting for the project. The open tendering was done by Dzongkhag but all the bidders who quoted within the budget range disqualified due to some minor error on the part of the bidders. Re-tendering is been done at the time of this reporting by Punakha Dzongkhag Administration.

Construction of Dangreygang Integrated Water Supply at Semjong, Tsirang

Based on the Royal Command, ARDC-Bajo and WSD-MoWHS entrusted to lead the construction of Dangreygang Integrated Water Supply Scheme (IWSS) in Semjong Geog under Tsirang Dzongkhag. The project was expected to benefit 70 households in Dangreygang village not only in terms of improved access to drinking but also for irrigation of 124 acres of dryland crops.

The main objectives of the project included:

- To enhance access to water by rural communities through development of appropriate water management infrastructures,
- To integrate drinking and irrigation water supply infrastructure development in the country to minimized capital and operation cost,
- To engage unemployed youth in nation building process through the spirits of camaraderie, volunteerism, and cooperation under DeSuung Program,
- To pilot new modality of project implementation- multi-sectoral engagement (Desuung Program, MoWHS, MoAF, Dzongkha and Geog Administration, Beneficiary farmers etc.) for an integrated project goal (drinking and irrigation).

The overall conceptualization and planning of the project was done by Desuung Program. The identification of project site was done jointly by Desuung Program and local governments. Tsirang Dzongkhag Administration conducted physical survey and technical supervision during the implementation. ARDC Bajo prepared overall design of the scheme which includes (1) hydraulic design of main conveyance pipeline, (2) diversion weir, (3) sand trap chamber, (4) silt exclusion cum pipe inlet chamber, and (5) distribution network. ARDC Wengkhar provided technical support for distribution control network. MoWHS prepared design, drawing, and estimate for the construction of RCC water storage (500 cu.m) tank.

Initially the cost of the project was estimated at Nu6.0M with implementation period of three months. However, due to increase in scope of the project and frequent lockdown of border towns due to COVID-19 the revised estimated to cost Nu24.53M with total implementation of nine months.

Construction of Tsaimzigosa Irrigation Scheme at Lhamoizingkha, Dagana

Based on the direction of Agriculture Engineering Division (AED) ARDC Bajo provided technical assistance in surveying, designing, drawing, and estimation for the renovation of Tsaimgisa Irrigation Scheme at Lhamoizingkha under Dagana Dzongkhag. The Green Climate Fund (GCF) funded the project. The length of scheme was determined to be 3.0km which commands 224 acres of wetland owned by 64 households. The cost of the renovation work was estimated at Nu12.25M only.

Construction of Kanakha Irrigation Scheme at Kana, Dagana

Based on verbal request from Dzongkhag Agriculture Officer of Dagana Dzongkhag, technical assistance was provided to Engineer of Kana Geog for designing, drawing and estimation for construction of Kanakha Irrigation Scheme in Kana Geog under Dagana Dzongkhag. The total length of channel was 4.80km which will irrigate 160 acres of wetland belonging to 60 households in the village. HDPE pipe was recommended to be used as main conveyance line.

Construction of Water Supply System at Targaythang Fish Pond, Punakha

Engineering services was provided to NRDCR&LF Haa under Department of Livestock for construction of Fish Pond Water Supply System at Targaythang in Punakha. The overall survey, design, drawing, and estimation for infrastructure renovation and development were done in previous financial year. Since only a limited amount of the budget secured, the management in consultation with ES Bajo prioritized to spend the budget on the construction of Fish Pond Water Supply System only. The scope of the work included construction of gabion diversion walls, sand and silt removal chambers with manual geared control DI gates and spillways, link

channel between diversion structure and sediment removal structures. The drawing and estimate reflecting the revised scope was prepared and submitted to the management for tendering. The work was awarded to Ms. Thruendel D Construction at the contract price of Nu1.78M only. Engineering services for site supervision and passing of bill were provided by the ES. The work was handed over to the management which was completed within the contract price and scheduled time.

Renovation of Rabuna Fish Pond, Wangdue

Similarly, engineering services were provided to NRDCR&LF Haa under Department of Livestock for renovation of Rabuna Fish Pond in Wangdue. The overall survey, design, drawing, and estimation for infrastructure renovation and development were done in previous FY. Since only a limited amount of the budget was secured, it was prioritized to be utilized for major renovation of Fish Pond. The work included construction of RCC lined pond with manual geared control DI gates, spillways, flush out-cum-excess water drain out channels and link channels between ponds. The drawing and estimate representing the revised scope was prepared and submitted to the management for tendering. The work was awarded to Ms. Pema Dungtshe Construction at the contract price of Nu2.45M only. Engineering services for site supervision and passing of bill were provided ES. The work was handed over to the management which was completed within the contract price and scheduled time.

Construction of Khawajara Solar Pumping System at Toedwang, Punakha

ARDC Bajo in consultation with GCF Project Management identified Khawajara village under Toedwang Geog in Punakha Dzongkhag as the most appropriate site for the construction of Solar Pumping System. The village has 55 acres of wetland belonging to 14 household.

The rational for selecting this site is that despite the village being located on the bank of Phochu the village is facing severe irrigation water shortage problem. The village a small irrigation channel which conveys water from a small perennial source. This source is also used by two other adjacent villages. This irrigation water sources shared though rotation among the tree villages. Within Khawajara water is shared among the 14 households on rotation basis. Within one day two farmers will share the water from the channel. On a good day water share from the channel is sufficient to transplant about one acre paddy but on dry day water from channel is not even sufficient to transplant one langdo (1/3 of an acre). Absolute water rotation duration is 22 days which is three times more than the average of 7 days generally observed in other parts of Bhutan. If a farmer owns 3 acres of paddy field it will take 43 days to complete paddy transplantation on good days while it will take 129 days on dry day rate. On the other hand, farmer does not have the luxury to wait was the paddy needs to be transplanted on time to avoid late maturity. Traditionally the last date to paddy transplantation is 4th day of 6th Bhutanese Calendar (Lunar). As per the farmers paddy grains will be empty if transplanted after this date. Hence, this village was selected to address some of the irrigation water shortage problem.

Accordingly, physical survey using TS was conducted for proper designing of the solar pumping system. The hydraulic design of the pumping pipeline was carried out to suit pre-procured pump of 20HP. From procurement of pipe a duty point was established at 46m of operating head with corresponding flow rate of 12 lps for selected conveyance pipe size of 200mm OD (HDPE) and adopted operation period of

20 hours. In Punakha average sunshine is 5.1 hours while remaining needs to be supplemented through grid electricity power. With this duty point about 7.1 acres of paddy transplantation can be completed per day. Solar alone would be only 1.8 acres (25.5% of 7.1 acres).

After the procurement of the pipe, pump performance curves were received from the pump supplier. The duty points as per the information at the maximum efficiency point of 53% was 85m of operation head and discharge rate of 12 lps. This did not match with the initially selected system duty point. Hence, the actual duty point will be 17 lps at operation head of 60 m which will operate at 45% efficiency.

This pumping system will pump water from Phochu to the existing irrigation channel on situated on the upper part of the village though 580m HDPE pipeline (200mm OD, PN6). Entire length of the pipe will be laid in trench and backfilled.

An open well submersible vertical pump of 20 HP will be used. The control house and solar panels are under construction on the left bank of Phochu. Backup grid electricity will be connected to control house. The control panel will consist of auto switching between solar and grid electricity input which can also be manually operated.

Procurement of pump (20HP), solar panels and accessories were done through the initially allocated budget of Nu2.0M by GCF Project. Additional budget of Nu3.291M is required for covering the cost of procurement and construction of sump, control house, delivery chamber, fencing, grid electricity supply, HDP pipe and pipe fitting.

iii. Engineering Services provided by Nima Wanghchuk

The services included surveying, designing, drawing, estimation, tendering, and implementation in general. A total of five major activities were implemented with an estimated value of Nu12.331M only. From a total of five activities, two are completed with final value of work done of Nu7.706M, two worth Nu4.882M is ongoing stage and one worth Nu0.970M is in proposal stage. Table 37 provides the summary of the activities while overview is presented in subsequent sections.

Table 37 Engineering Services provided by Mr. Nima Wangchuk in 2020-21

SN	Activity	Qty/ Unit	Amount (Nu)				Remark
			Estimated	DE	Contract	Actual	
1	Construction of ESP Quarter at RP Chimipang	2 Blocks	3,064,730.70	-	2,393,458.42	-	OG
2	Maintenance of Old ESP Quarter at RPC	8 Blocks	2,539,038.96	-	2,489,312.00	-	OG
3	Const. of Division Forest Office Building at Dagapela, Dagana	1 Blocks	6,555,924.25	-	6,069,198.41	5,947,780.02	C
4	Const. of Site Development works at DFO Dagapela	1 No	2,266,115.62	-	2,075,825.00	1,758,910.00	C
5	Renovation of Water Tank at Rubesa, Wangdue	1 No	970,232.18	-	-	-	P
Total			12,331,311	-	10,634,335	7,706,690	

LEGEND: DE = Departmental Execution, P = Proposal stage, OG = Ongoing, C = Completed, DFO = Division Forest Office

Construction of ESP Quarter (2 Block - 4 Units) at RPC

The engineering services were provided for the construction of two block (double units) ESP quarters at RPC based the request of the farm manager. Drawings and estimate were prepared as per the past designs and specifications. The cost of construction was estimated at Nu 3.065M based on BSR 2020 (Thimphu) rates. The work was awarded to Ms. Uma Rikay Phunsum Construction (CDB#7622) for implementation through open tendering at contract price of Nu2,393,458.42 and project period of 120 days. The works stand at 50% completed at the time of reporting while scheduled duration of completion was 21 May 2021. As per the contractor the delay is attributed to COVID-19 restrictions on labour and material availability.

Maintenance of Old ESP Quarter (8 Blocks - 16 Units) at RPC

Based on the direction from Royal Project Coordination Office (RPCO) and Farm Manager (CRP) the estimates and BoQ were prepared for the maintenance of 8 Blocks (2 units per block) old ESP Quarters at Royal Project Chimipang. These eight blocks were the first lot of ESP quarters constructed during the initial project establishment period. Design specifications were provided by RPCO which focused on used of local material and low-cost concept. Accordingly, Engineering Sector at ARDC Bajo prepared designs, drawing and estimate for two types of structure. Mud block and cement block walls, timber doors and windows with double pitched CGI roofing without ceiling. Both options were rejected due high cost. Later the engineer was shown a sample structure constructed at Dechenling in Thimphu. Based on the sample structure specification were developed for the first 8 block of ESP Quarter construction at RPC.

The specification adopted consisted of double unit block with each unit comprised of one bed room, one sitting room, one kitchen and detached toilet. The structure shall be PCC floor, single layer loose bamboo walls on timber frames, timber doors and windows, CGI roofing on timber frames without ceiling and basic electrical wiring & fittings. After few years of construction, the feedback from the occupant included (1) the dust enters into the room through the single layer bamboo walls very easily, (2) poor wall insulation, (3) drifted rain drops inter through the walls into the room, and (4) lack of privacy owing low noise insulation and semi-transparency of bamboo mat.

Owing to the above problems subsequent ESP quarter construction the wall materials were upgraded to ekra walls and with inclusion of ceilings. The recent ones also include attached toilet, cooking platform and wash sinks in the kitchen. But for the first 8 blocks constructed it was decided to improve the walls through major renovation. Accordingly cost estimate of Nu2,539,038.96 were prepared and submitted to RPCO at Thimphu. The work was awarded to Ms. KST Construction through limited tender by RPCO at contract price of Nu2,489,312 with and implementation period of 75 days. The engineering supervision was provided by ARDC Bajo. The work is under construction.

Construction of Division Forest Office Building at Dagapela, Dagana

Engineering services were provided to Division Forest Office (DFO) at Dagapela based on the direction from DoA. In accordance to the general specification provided by DFO a design, drawings and estimated were prepared for the construction of two-storey office building at Dagapela. The cost was estimated at Nu 6,555,924.25 based on BSR 2019 Gelephu rate. The implementation of the work was awarded to Ms. Druk Phuensum Construction (CDB#1361) through open tender at contract price of

Nu 6,069,198.41 with an implementation period of 10 months. Although the work was scheduled to be completed by 12 December 2020 got delayed due COVID pandemic situation as the material and skilled labours were not available. The final value of the work done stands at Nu 5,947,780.02 only.

Site development works for DFO at Dagapela

Similarly, engineering services were also provided to DFO Dagapela for office building site development work. Based on the direction from DFD office, the estimates and BoQ were prepared by ARDC Bajo Engineering Sector. The major works included construction of approach road black topping and compound lighting system. The cost was estimated at Nu 2,266,115.62 based on BSR 2019 Gelephu rates. The work was awarded to Ms. Tsheyang Construction (CDB# 7121) for the contract price of Nu 2,075,825 with an implementation period of 3 months. The work was completed on 14 April 2021 and the final amount was Nu 1,758,910 was verified and passed for the payment.

Renovation of Water Reservoir Tank at Rubesa- Wangdue

Based on the direction of ARDC Bajo Management drawings, estimate and BoQ for the renovation of water reservoir at Rubesa under Wangdue Dzongkhag were prepared. The cost was estimated at Nu970,232.18 and storage capacity of the reservoir is 668cu.m.

iv. Engineering Services provided by Indra Bdr Raika

General electrical and plumbing engineering services were provided by Mr. Indra Bdr Raika (Sr Tech-III). A total of 10 activities with an estimated value of Nu7.382M were implemented in 2020-21 financial year. The activities included maintenance of electrical components of pumping system, maintenance of electrical and plumbing systems at three RNR Offices, preparation of electrical drawings and estimate for all civil construction works, technical support for departmental execution for the construction of Tama Drylang IS, and installations of Dutch Bucket Hydroponic System and all other electrical equipment installations. Table 38 provides details of the activities and overview are presented in subsequent sections.

Table 38 Engineering Services provided by Mr. Indra Bdr Raika in 2020-21

SN	Activity	Qty/Unit		Amount (Nu)m				Remark
				Estimated	DE	Contract	Actual	
1	Maint. of Water Pumps- Bajo	5	Nos	50,000	-	-	50,000	C
2	Maint. of Electrical Systems- Bajo	30	days	150,000	-	-	150,000	C
3	Maint. of Electrical Systems- Tsirang	15	days	75,000	-	-	75,000	C
4	Maint. of Electrical Systems- RPC	15	days	75,000	-	-	75,000	C
5	Maint. of Plumbing System- Bajo	20	days	60,000	-	-	60,000	C
6	Maint. of Plumbing System- Tsirang	10	days	30,000	-	-	30,000	C
7	Maint. of Plumbing System- RPC	10	days	30,000	-	-	30,000	C
8	Electrification of ESP Quarter- RPC	4	Unit	336,422	-	283,752	283,752	OG
9	TS on construction of Tama Dryland IS Zhemgang	7.6	km	6,495,535	-	6,495,535	6,495,535	C
10	Installation of Dutch Bucket Hydroponic System	2	No	80,000	-	-	86,000	C
Total				7,381,957	0	6,779,287	7,335,287	

LEGEND: TS = Technical Support, IS = Irrigation Scheme, DE = Departmental Execution, P = Proposal stage, OG = Ongoing, C = Completed, RPC =Royal Project Chimipang.

Electrification of ESP Quarter at RP Chimipang, Punakha
The electrical drawings and estimate for the construction of two blocks of ESP Quarter (2 block- 4 unit) at RPC were prepared. The cost was estimated at Nu 336,422 based on BSR 2020 with 10% cost index over Thimphu rates. The engineering services for monitoring and passing of bills for all electrical works were also provided.

Maintenance of water pumps at ARDC Bajo
Engineering services were provided for the regular maintenance of river pumping system at ARDC Bajo. The services included checking the electrical components and troubleshooting before the start of pumps.

Maintenance of electrical system
Electrical Engineering services were provided for routine operation and maintenance of electrical systems at ARDC Bajo, ARDSC Tsirang, and RP Chimipang.

Maintenance of Plumbing works
Engineering services were provided for regular maintenance of office water supply pipelines at ARDC Bajo, ARDSC Tsirang, and RP Chimipang. The services include repair of leakages.

Construction of Tama Dry Land Irrigation Scheme at Zhemgang
The Engineering Sector conducted survey and prepared design & drawing for the construction of Tama Dry Land Irrigation Scheme in Tama Village under Zhemgang Dzongkhag. The work was initiated by Program Director with the funding from DoA. The project was design to be implemented on cost sharing basis, the management will provide all the required materials and while beneficiaries will contribute the labours for the work. The works includes the construction of intake structure, sedimentation tank, HDPE pipeline conveyance of 7.0km, reservoir tank and fencing. The total cost was estimated at Nu6,111,783 only. For a design flow of 12lps with corresponding HDPE pipe size of 90mm was adopted. Since, the village faces acute shortage of irrigation water the project also supported in construction of earthen reservoir with storage capacity of 59.9 cu.m to enhance water availability during the dry season. The revised cost is estimated at Nu6,495,535.09 including some other additional works.

Installation of Dutch bucket hydroponic system at ARDC, Bajo
In accordance to the direction of ARDC Bajo Management, Engineering Sector provided technical services to install the Dutch bucket hydroponic system at Horticulture block in Poly house for the hands-on training for the Desuup. The work is completed within one week**.**

v. Engineering Services provided by Thinley Gyamtsho

In addition to functioning as Sector Head for the Engineering Sector, Mr. Thinley Gyamtsho also provided engineering services for 11 major activities in financial year 2020-21. The major task included (a) participation in meetings and workshop required preparation of paper or report, preparation of presentation slides and presentation, (b) served a resource person (RP) for providing training on irrigation engineering and water management, and (c) providing technical support for irrigation infrastructure planning and development. The overall value of these activities is estimated

Nu748.961M. Table 39 provides summary of the activities and overview are presented in subsequent sections.

Table 39 Engineering Services provided by Mr. Thinley Gyamtsho in 2020-21

SN	Activity	Qty/Unit		Amount (NuM)				Remark
				EC	DE	CC	AC	
1	Participated in GCF Project Annual Review & Planning Meeting	5	Days	0.010	-	-	0.010	C
2	Participated in AWM Options in Sustainable crop production meeting	10	Days	0.020	-	-	0.020	C
3	RP for Irrigation Training-cum-Design Workshop	14	Days	0.028	-	-	0.028	C
4	RP for Irrigation Training for 42nd De-suung Batch	27	Days	0.054	-	-	0.054	C
5	RP for Irrigation Training for 43nd De-suung Batch	41	Days	0.082	-	-	0.082	C
6	TS for Khawajara SPS works	1	No	4.800	-	-	0.480	OG
7	TS for Dangreygang IWSS at Semjong	1	No	24.530	-	-	2.453	OG
8	TS for IID in Wangdue Dzongkhag	5	No	500.000	-	-	50.000	OG
9	TS for Installation of DIS at Kamichu Orchard	1	No	1.240	-	-	0.124	C
10	TS for Const., of Wangdigang IS, Trong Geog	18.6	km	206.000	-	-	20.600	OG
11	TS for Restoration of Wangling IS, Langthel	2	No	12.197	-	-	1.220	OG
Total				748.961	0	0	75.071	

LEGEND: TS = Technical Support, IS = Irrigation Scheme, EC = Estimated Cost, DE = Departmental Execution Cost, CC = Contract Cost, AC = Actual Cost, P = Proposal stage, OG = Ongoing, C = Completed, GCF = Green Climate Fund, AWM = Advance Water Management, RP = Resource Person, SPS = Solar Pumping System, IWSS = Integrated Water Supply Scheme, IID = Irrigation Infrastructure Development, DIS = Drip Irrigation System.

Participated in GCF Project Annual Review & Planning Meeting

The Engineering Sector Head (ESH) participated in GCF Project Annual Review & Planning Meeting held in Paro Drukchen Hotel from 05 to 10 July 2021 on behalf of ARDC Bajo-GCF focal person who was engaged in other important meeting. An updated on the progress of Solar Pumping System construction in Toedwang Geog was made. It was reported that Engineering Sector conducted survey for the proposed project towards the end of 2019-20 fiscal year. It was planned to irrigation 5 acres of dryland located on the left bank of Phochu. The farmer has leased-in this land from Dratshang for a period of 30 years just two years before. Besides the land being dryland, it was also located at tail-end part of the village irrigation scheme with severe irrigation water shortage problem. Besides lacking access right to irrigation water, the framer lacks access right even to the village drinking water supply system. Hence, providing support for construction of Solar Pumping System (SPS) will not only provide access to drinking water but also enable to irrigate the dryland which will immensely improve his livelihood.

Some of the participants remarked that it was not fair that project was benefiting only one household despite fund supported by GCF was fairly large of Nu1.9M. The response provided was that SPS is new technology and being promoted for the first time in Bhutan it is not possible to say how many acres can be irrigated with Nu1.9M budget. If this SPS can pump more water than what is required for 5 acres, the farmer is ready to shared irrigation water with adjacent farmer who are in dire need. Both area and numbers of farmers can be increase. But false promise without knowing the scope of the project will not be comfortable way forward.

Participated in AWM Options for Sustainable Crop Production Meeting

The ESH participated in the regional consultation virtual meeting on Advanced Water Management (AWM) Options for Sustainable Crop Production in South Asia organized by SAARC Agriculture Centre, Dhaka- Bangladesh from 05 to 06 April 2021. A country status report on Advance Water Management Options for Sustainable Crop Production in Bhutan was prepared and presented during the meeting jointly with Dr Tshering Penjor (Precision Agriculture Specialist) of ARDC Wengkhar. The report was prepared based on the outlines provided by SAARC Agriculture Centre.

The meeting provided good opportunities to share and learn the advance water management technologies that have generated immense benefit for sustainable crop production in South Asian nations. SAARC Agriculture Centre will share the proceedings later.

RP for Irrigation Engineering Training-cum-Design Workshop

ESH also served as resources person for Training-cum-Design Workshop for Irrigation Scheme planning, designing, drawing, estimation, and preparation of specification which was conducted at Drukchen Hotel, Paro from 09 to 22 July 2021. The training was provided to engineers who will be engaged in irrigation scheme construction under GCF project. The participants included Dzongkhag Engineers from Wangdue, Trongsa, Tsirang and Sarpang, and Engineers from ARDC Bajo and DoA.The objective of the project was:

- To enhance capacity on overall planning and design of irrigation scheme
- To enhance skills on hydraulic design of irrigation structures (diversion, sediment exclusion, aqueduct, siphon, drop structures, drainage crossing, and road crossing)
- To enhance skills on hydraulic design of water pipe conveyance system (ARV, NRV, BPT, PRV, Flash out chamber/valves).

The immediate outcome of the workshop was preliminary design, drawings and estimate of the proposed irrigation schemes in their respective Dzongkhags. The long term expected outcomes was engineers enabled to properly plan, design and construct sustainable irrigation schemes generating continuous benefit to famers.

RP for Irrigation Water Management Training for 42 De-suung Batch

In accordance to the direction of DoA the ARDC Bajo Engineering Sector with support from AED developed training materials for the “Specialized De-suung Training Program” on irrigation water resources management. Through this training participants are expected to (a) know current status of water resources in Bhutan, (b) gain basic understanding of irrigation systems, (c) gain basic principles of hydraulic design of irrigation system, (d) interpret construction drawings and specifications, (e) identify relevant tools, machines, equipment and material for construction, and (f) understand concepts of operation and maintenance of irrigation scheme.

The draft training materials were improved through many rounds of presentations made to Engineers at Agriculture Engineering Division (AED). The reviewed and critical feedback sessions which usually started late in the afternoon would many times fail to end by even 8pm. In many occasions the core team even works on weeks to complete the work within time.

During the 42nd De-suung Batch Specialized Irrigation Water Resources Management training was provided to 1000 participants under four centres as detailed in the following table 40.

Table 40 Profile of irrigation training provided to 42nd De-suung Batch

			Trainees		
Training Centre	**Trainers**		**Male**	**Female**	**Total**
Wing XI, Gelephu	Thinley Gyamtsho	ARDC Bajo	219	81	300
	Meena Dhungyel	AED			
RBPTI, Jigmeling	Sonam Gyeltshen	AED	126	74	200
	Dorji Tshering	AED			
CDO Wing, Paro	Khando Tshering	AED	90	160	250
	Nima Wangchuk	ARDC Bajo			
MTC, Wangdue	Kezang Tenzin	AED	50	200	250
	Puran Chhetri	ARDC Bajo			
Total			**485**	**515**	**1000**

For the entire month of October 2020, three engineers from ARDC Bajo were engaged for preparation of training materials, production of training manual, and providing a week-long training.

RP for Irrigation Water Management Training for 43 De-suung Batch

ARDC Bajo Engineers were also engaged in imparting a week-long Specialized Irrigation Water Management Training to 43rd De-suung Batch starting from 03 November till 13 December 2020. The task included major modification of training materials based on the feedback from 42nd Batch, and providing the training itself. During the 43rd De-suung Batch, the irrigation specialized water management training was provided at three training centres including Wing-I in Tendruk, SRPF in Trashigatshel, and Wing-V at Tshichhoeling.

ARDC Bajo engineers covered only two centres as detailed in the following table:

Table 41 Profile of irrigation training provided to 43nd De-suung Batch

			Trainees		
Training Centre	**Trainers**		**Male**	**Female**	**Total**
Wing I Tendruk	Thinley Gyamtsho Meena Dhungyel	ARDC Bajo AED	100	231	331
SRPF Trashigatshel	Puran Chhetri Nima Wangchuk	ARDC Bajo ARDC Bajo	-	-	200
Wing V Tshichhoeling	Sonam Gyeltshen	AED AED	-	-	-
Total			**100**	**231**	**-**

Construction of Dangreygang Integrated Water Supply at Semjong, Tsirang

The overall engineering service for the construction of Dangreygang Integrated Water Supply Scheme (IWSS) in Semjong Geog under Tsirang Dzongkhag was provided by Mr. Puran which is detailed in Section 0.

The specific engineering services provided by ESH includes (a) hydraulic design of main conveyance pipeline, (b) intake weir hydraulic design, drawing, and 3D model

in SketchUp, (c) sand trap chamber hydraulic design, drawing, and 3D model in SketchUp, (d) Silt trap-cum-pipe inlet chamber hydraulic design, drawing, and 3D model in SketchUp, and (e) served as resources person for one day training of Desuung on overall all irrigation water management and irrigation water application system at the project site.

TS for Irrigation Infrastructure Development in Wangdue Dzongkhag

The ARDC Bajo Engineering Sector provided technical services for irrigation infrastructure development in Wangdue Dzongkhag which amongst the many includes:

- Finalization of planning and design of major development of Samtengang Irrigation Scheme,
- Finalization of plan and design for the construction of Khotokha-Rubesa Irrigation Scheme benefiting both Bjena and Rubesa Gewogs,
- Technical guidance on planning for the construction of Gaselo Irrigation Scheme which will benefit both Gasetshogom and Gasetshowom Gewogs,
- Provided technical guidance on planning for the construction of Baychu Irrigation Scheme. Based on the preliminary survey the scheme is expected to be 34km long and irrigation about 1000 acres of wetland under Phangyul and Kazhi Gewogs. Although this scheme was planned and budgeted to be constructed during the first democratically elected government, but construction got delayed owing to the social clearance. At present all the social problems are resolved. GCF Project is ready to fund the project but conveyance system needs to be changed from initially plan open channel to pipe conveyance system which require detail survey and resign. The Department of Agriculture, Wangdue Dzongkhag Administration and GCF Project decided that the project will be implemented under SDBOH (Survey, Design, Built, Operation and Hand over) mode. Currently the DoA is preparing terms and conditions of SDBOH.
- Served as recourse person for the field visit of Wangdue Dzongkhag Engineers to Phendey Irrigation Scheme under Punakha Dzongkhag on 01 March 2021. Participants were not only had the opportunity to see the intake structure, sediment exclusion chamber, stream crossing pipe aqueduct, and Air Release Vale & chamber but also got opportunity to observed the real time functions of the structures. This provided good understanding of the need to do proper survey and design of irrigation infrastructure development.

TS for Installation of Drip Irrigation System at Kamichu Orchard

Design, drawing, estimate and BoQ were prepared and submitted to the officer in charge of the Orchard.

TS for Construction of Wangdigang Irrigation Scheme at Zhemgang

ESH provided irrigation engineering services starting from conducting feasibility study, survey, design, drawing, and estimation were provided for the construction of Wangdigang Irrigation Scheme under Trong Geog in Zhemgang Dzongkhag in financial year 2019-20. Capacity development training on irrigation scheme design focusing on pipe conveyance system was provided to Dzongkhag Engineers through a training-cum-design workshop for duration of three weeks at Zhemgang. The immediate outcome of the workshop was preliminary design, drawings and estimate for proposed Wangdigang Integrated Water Supply Scheme (IWSS).

The scheme was designed to convey 251 lps water from Wangdigang stream which is situated at 18.6km away from Zhemgang Town through 630mm diameter HDPE Pipe (PN6) using 33m of gravity energy. The peak design flow for irrigation was established at 222 lps which will irrigation 230 acres of paddy field against a gross command area of 833 acres while for drinking was 29 lps which will be sufficient for future population of about 40,000 which is 10 time more than the current population of about 4,000. No future provision increased in demand for irrigation water was considered owing to limited capital resources; however, improvement in irrigation water used efficiency provided ample scope future expansion of irrigated area. As such the cost of construction of this scheme was estimated at Nu220.0M which was much higher than the allocated of Nu75.0M only.

As the budget availability within the Water Flagship Programme was limited the government decided to fund the project though ADB Loan. To access the fund ADB require a proposal which satisfy formalities. Accordingly, Zhemgang Dzongkha sought the technical support of ARDC Bajo to be one of the counterparts for ADB proposal development team. Due to COVID-19 situation the proposal development team regularly (average 2 hours per week) meet and discuss through virtual meeting since January 2021. The proposal is about 70% completed at the time of this reporting. This will probably become the proposal modal for accessing ADB Loan for fund other large irrigation schemes in future. On the other hand, Zhemgang Dzongkhag has already awarded the work for 18.6km of pipeline alignment formation cutting work to contractor through open tendering at a contract price of Nu48.0M and with implementation duration of 8 months. At the time of this reporting about 8.0km length is already completed starting from tail end towards source.

TS for Restoration of Wangling Irrigation Scheme under Langthel Geog

ESH also provided engineering services for conducting feasibility study for restoration of Wangling Irrigation Scheme in Langthel Geog under Trongsa Dzongkhag in accordance to the direction of DoA. A team comprised of Mangmi, Tshogpa, Engineer & Agriculture Extension Officer of Langthel Geog, an Engineer from ARDC Bajo and four beneficiary farmer representatives visited the Wangling Irrigation Channel damaged by land slip. The site visit was made on 17 March 2021 which is located about 1.5 km from the village centre. The objective of the visit was to make assessment of problem and identify options for restoration of the scheme.

Wangling is a small village under Langthel Geog in Trongsa. It is located on the upper slope on right bank of Mangdi-chu. The village is connected to the Geog Centre by a 10.5 km long farm road. The village has total arable land of about 180 acres of which 80 acres are paddy field. Irrigation water is trapped from a nearby stream and conveyed to command area through two open earthen irrigation channels known upper and lower channels. The length of the upper channel is about 3.0km while the lower is about 1.5km. Each channel irrigates about 40 acres of paddy field. Over the last few FYPs earthen channels passing through difficult terrain has been replaced by at HDPE pipes (225mm OD/PN6).

As per the farmers the land slip started in March 2017. The slip process started from the valley base. Over the years land slips size increased. During the site visit the length, width and depth was roughly estimated at 370m, 80m and 5m respectively. The average slope of the land slip along length was estimated at 43%. In the past as

the size of the land slip was fairly small it was within their capacity to implement some temporary restoration works, but farmers expressed that the situation becoming worse by each passing year and now it has become beyond means to cope. They are looking forward for support of permanent solution from the government. Based on the field observations and discussion with the farmers four options area identified as listed below:

Option-A: Deep trenching of pipelines within the landslip area,
Option-B: Construction of temporary cable supported pipe aqueduct,
Option-C: Construction of permanent cable supported pipe aqueduct and
Option-D: Construction of by-pass inverted siphon pipe conveyance line.

The details of in terms of advantages, disadvantages, reliability, preliminary design & drawings, specification and cost of implementing each option are submitted to concerned agencies as field visit report titles as "Wangling Irrigation Scheme- An assessment of land slip damage to the channel and mitigation options".

vi. Rectification of Karmaling Dryland Irrigation System

Karmaling Dryland Irrigation System was constructed in 2018 with the financial support from Remote Rural Community Development Project (RRCDP). The scheme benefits 98 households. Accordingly, it was handed over to the beneficiary in same year. The completed irrigation system consists of two reservoirs connected by incoming 120 mm HDPE pipe. However, during operation, it was observed that outlet pipe (32mm) connected to 90mm HDPE out flow pipe was too small to make smooth flow. Though, project handed over the scheme to the users, however, beneficiaries could not make full utilization because of slide error in outlet construction.

However, with the technical and budgetary supports from ARDC, Bajo through Food Security and Agriculture Productivity Project (FSAPP), rectification works were successfully completed in in FY 2020-21.

Rectification works includes following additional activities:

- Replacing of 32mm HDPE pipe with 90mm HDPE pipe.
- Construction of two additional controlling chambers.
- Repairing of two reservoir tanks
- Fitting and drenching of 225mm pipe from main reservoir till nearby paddy fields (300m)
- Replacement of twelve numbers of controlling valve.

With the completion of rectifications works, scheme had become fully operational. In past the years, due to defect with outlet, scheme could not benefit wetland. However, replacement of outlet valve had resolved defects and benefited additional 33 households for paddy cultivation this year. Further, this rectification works supported additional benefits for sufficient delivery of irrigation water for winter vegetables and other fruit crops during dry season. Following table depicts the common areas benefited by the scheme.

Table 42 Common areas benefited by the dryland irrigation rectification

SN	Crops	Common area (ac)	Total HHs	Remarks
1	Paddy	23	33	The activity is supported by FSAPP project and excecated by Extension through technical support
2	Winter Vegetables	12	67	
3	Fruits and nuts	132	89	
	Total	167		

D. SUPPORT SERVICES RESEARCH AND DEVELOPMENT PROGRAM

5) Integrated Pest Management

i. Occurrence of the important horticultural pests at Bajo and Tsirang-surveillance

A significant portion of crop is lost to pests and diseases aggravating the already insufficient production in the country. further, climate change aggravates the condition favouring the pest outbreaks that cause huge crop losses and results food insecurity. Insect pests are a major challenge for food security and food self-sufficiency and horticulture where the insect pest outbreaks can cause huge losses to crops, threatening the livelihoods of vulnerable farmers and the food and nutrition security of millions at a time.

Pest management has been an issue for agriculture although not given due importance, with very weak pest surveillance system in the country. Generally, insecticides are best effective when applied when the insect larvae are small. However, current practice is that Bhutanese farmers apply insecticides only when the larvae are mature and crop damage is noticeable fairly. Sprays are applied but mostly when least effective and reports major damage to crops. These may be due to the dearth of information necessary for the effective control/management.

To prepare effective management methods of insect pests, information on first emergence, peak flight activity and relative population density of the target insect is necessary. Sex pheromone traps were used to gather these information due to their efficiency and specificity (Weinzier et al., 2011), which reduces labour and minimalize the error. So, to gather the firsthand information using pheromone traps, population change (moths) of four different insect pests which were common were studied at Tsirang (26°59'45.4"N 90°07'24.6"E) and (27°29'32.6"N 89°54'03.9"E). Pheromones (lures) manufactured by Pheromone Chemicals (India) were used for the study. Funnel type traps were used with lures placed at 1.5m height. The lures were changed at 14 days interval. For a site, two sets of traps were installed.

Moths of the first trap catches were identified at laboratory based on their descriptors in different literatures wto further minimize the error of counting non-target insect pest. Data collection was carried out in 14 days interval. Polyethylene bags were labelled and used for trapped insect transfer for data collection at laboratory.

In current study, we observed that moth activities were high in May month for Common cutworm and Cotton bollworm (Chilli pod borer). However, Cabbage lopper moth population peaked in July, January, May, September. For beetworm, highest moth population was observed in November (2020) month. Detailed report will be published after the completion of the study.

ii. Fall armyworm moth population change & beneficial insects associated with FAW infested cornfields-survey and surveillance

Fall armyworm (*Spodoptera frugiperda*), an invasive pest native to Americas was observed infesting maize crops in certain parts of the country starting 2016. The fall armyworm (FAW) was recorded from Dagana (Tashiding), Tsirang (Kilkorthang), Wangdue (Thedtsho) and Punakha (Guma, and Kabesa) in the recent years. In

collaboration with National Plant Protection Center, we are studying the moth population change using sex pheromone trap. Moth population reached peak in December (2020) with 79 mean trap catches at Tsirang and 99 catches at Bajo. However, peak moth population was in January (2021) with 99 catches while second peak was in April (2021) with 330 catches.

Plant Protection Unit of ARDC Bajo is studying the biology of FAW at Bajo, and further documenting its natural enemies. The natural enemies are under 17 different families under 4 orders.

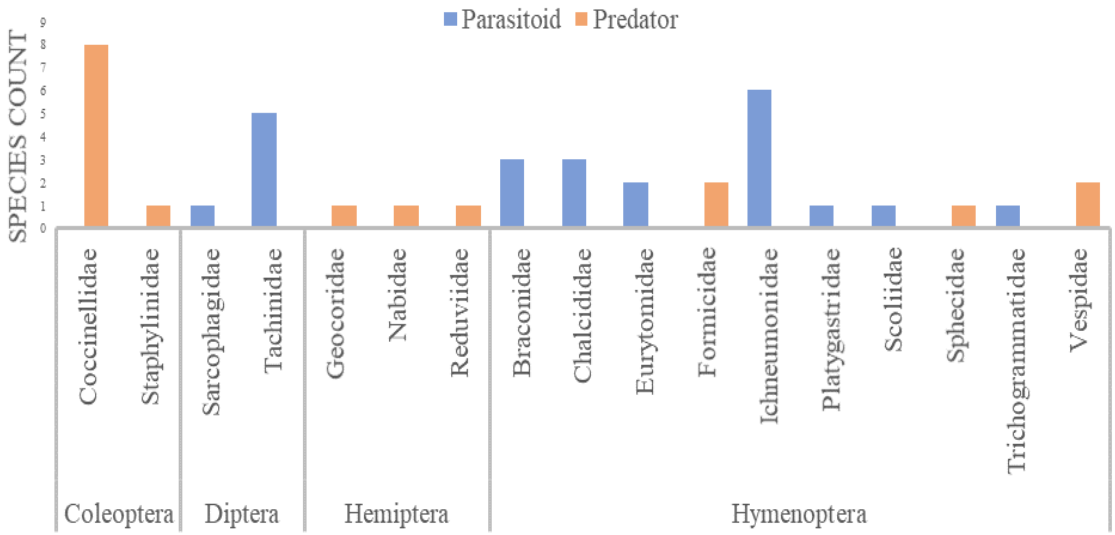


Figure 5 Natural enemies in different families & orders

iii. Agriculture uses of wood vinegar (Pyroligneous Acids)

Two separate specially designed ovens for the wood vinegar production are built with the fund support from Integrated Horticulture Promotion Project (IHPP) and Organic Flagship Programme. Wood vinegar also known as Pyroligneous Acid (PA) is a highly acidic liquid, obtained by pyrolysis of lignocellulose or as a by-product of charcoal. Major components of the PA are acetic acid, phenols and organic matters. For Bhutan's Organic Agriculture, PA with wide agriculture uses can be an important input, specifically for plant protection use as sustainable alternative to chemicals. For this, the wood and bamboo waste materials from the Research Fields (of ARDC Bajo) are being used as raw materials. Wood and bamboo wastes are common in most of the Bhutanese farms. Modern agriculture uses PA as fungicides, insecticides, termicide, growth regulators, and other similar agronomic uses. Currently, ARDC Bajo is testing the effects and efficacies of different PAs on insects, weeds and fungal diseases at our research field.

Activities are:

- Insecticidal properties on;
  - Cabbage aphids
  - Large cabbage white butterfly
- Fungicidal effect on mustard green (against powdery mildew)
- Herbicidal effect on weeds under greenhouse condition.

Preliminary results shows that cabbage aphids can be controlled using the bamboo vinegar (@ 0.1 and 0.5% conc.). Similarly, cabbage white butterfly larvae are found susceptible to the PAs (@0.1 and 0.5% conc.) under lab conditions. Herbicidal effect on different weed species under greenhouse condition was also observed. Further, researches are planned and will be carried out in the appropriate coming crop seasons.

iv. Light Repellent System for Nocturnal Moths-research and development

Light affects insect behaviour and development in a variety of ways; such as attraction [i.e., positive phototaxis, moving toward a light source where the response can be used to trap pests, but the effective wavelengths and intensities have been reported to vary among species], repulsion [i.e., negative phototaxis, moving away from light which can be used to prevent pests from entering a cultivation area by presenting light at wavelengths and intensities that repel them] , light adaptation [flight and mating are inhibited in nocturnal moths upon exposure to bright light at night], circadian rhythms/phase shift [exposure of insects to certain period of light at night shifts the timing of diurnal and nocturnal behaviours of insects], photoperiodicity [physiological response of insects to light schedule], light toxicity [UV and blue light damages the compound eye retina], blocking vision [UV blocking films in greenhouses where insects can't see], and, dorsal light reaction [normal orientation of insect flight is disturbed by dorsal light, which is perceived as sun].

Of the different phototaxis, suppression of insect activities by yellow light and blue light was demonstrated with the support from Integrated Horticulture Promotion Project, ARDC Bajo.The light system is to manage the nocturnal moths infesting Tomato, Chilli, Pear and Persimmon. Chilli pod borer (*Helicoverpa armigera*), Common cutworm (*Spodoptera litura*) and different fruit piercing moths are target pests for the current activity.

Data on the effects on insects are collected based on the simple experiments currently under process in greenhouse condition (tomato), and field condition [(a) Vegetables; chilli and tomato(b) Fruits; Persimmon and pear]. Initial results show that yellow light system is more effective than the green light against Chilli pod borer. The study will be continued in the current and next seasons.

v. Inventory of Wheat Insect Pests at Bajo-Research/survey

The increased global demand for wheat due to changes in population, dietary preferences, and socioeconomic conditions (Mondal et al., 2016) is challenged by a number of factors (including severe insect infestation). Insect pests is one of the factors that impede wheat production by damaging crops directly affecting agricultural food products. There are studies examined for Bhutan's wheat production constraints and strategies to improve but no information on wheat pest is limited. This study enlists vvarious insect pests in wheat during the vegetative and generative stages in at Bajo, Bhutan.

The study was conducted in the field of ARDC, Bajo, Wangdue (27° 29' 21.16" N, 89° 53' 53.95" E) during spring wheat cultivation season of 2021 with an area of 2.41 hectares. It was for a duration of 3 months from February till the end of April, 2021. Further examination and identification were carried out at Plant Protection Laboratory, ARDC Bajo,

A total of 54 insect pest species were recorded. The species recorded belonged to 5 orders, 24 families and 36 subfamilies. The pests were categorized either as major or minor pest based on their frequencies during samplings (Annex 1).

The insect pests recorded were of Hemiptera (27.8 %), lepidoptera (27.8%), Orthoptera (25.9%), Diptera (11.1%) and Coleoptera (7.4%) orders. These insect pests were classified as major, minor or occasional pest. There were 2 major, 33 minor and 19 occasional pest species in spring wheat at Bajo. Maximum pest species i.e., 27.8 % was in Hemiptera whereas minimum number was in Coleoptera (7.4 %). During the heading and anthesis stages, Indian grain aphid was the major pest while armyworm was found as major pest during the anthesis and maturity stages.

The minor pest species were found occurring throughout the study period. Highest number of insect pest species were from Hemiptera (27.8%) and Lepidoptera (27.8%) orders with 15 species each under 7 and 10 families respectively. The species under orthoptera was 25.9 % of the pests recorded i.e., 14 species under families Tettigoniidae, Acrididae, Gryllidae and Acrididae. Lepidoptera had 15 pest species (27.8 %) from which 1 major, 4 minors, and 10 were seen to be occasional pest under 10 families (Figure 3). We found six dipteran (11.6% of the total) pest species under two families (Tephritidae and Diopsidae) but were all occasional pests (Annex 1). The Coleoptera was only 7.4 % with all 4 species falling under Chrysomelid family.

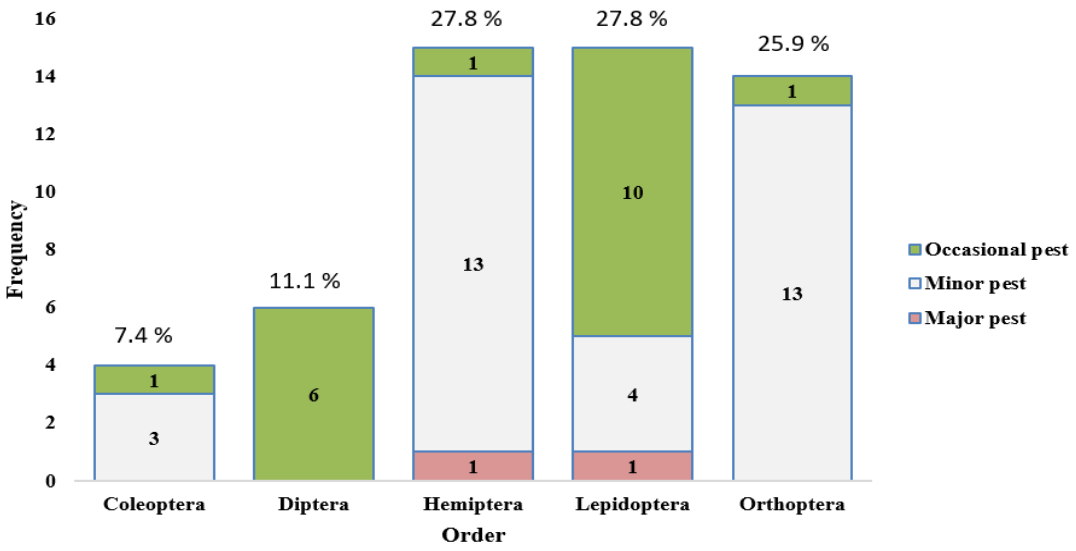


Figure 6 Distribution of insect pest diversity in different orders

A total of 24 different family of insect pests were observed in the spring wheat at Bajo. Maximum of the insect pest recorded were under Tettigoniidae and Pentatomidae with 6 species each followed by Acrididae and Tephritidae, 5 species each. The Coleoptera family Chrysomelidae had 4 pest species while the Lepidopteran families had only 1 to 2 species recorded in the study. Among different orders, the maximum pest family were in Lepidoptera, followed by Hemiptera, Orthoptera, Diptera and Coleoptera respectively. Most of these pests are responsible for huge losses in wheat yields and various strategies are developed against them.

vi. Beneficial Insect Species associated with Spring Wheat at Wangdue

Natural enemies, predators, parasitoids and spiders can be found in large numbers in many wheat fields subjected to their insect pest. They are naturally occurring biological control agents providing excellent pest control (El-Wakeil & Volkmar, 2013). Natural enemies play an important role in managing arthropod pest populations in agro-ecosystems (Ali et al., 2018). Biological control strategies that capitalize on biological interactions between insect pests and natural enemies in the ecosystems represents an integrated pest management options for reducing pesticide use (Xie, 2015). It is critical to formulate successful pest management tactics in light of the increasing demand and yield losses in grain and fodder. This research could aid farmers in aligning wheat production with the diagnosis, identification and documentation of various natural enemies.

The study was conducted in the research fields of Agriculture Research and Development Center (ARDC), Bajo for 3 months starting 1st February till end of April, 2021. Further examination and identification were carried out at Plant Protection Laboratory, ARDC Bajo. Insect collection was made using sweep net and pitfall traps from selected wheat fields at ARDC, Bajo. Sweeping was done from the plant canopy level including the interspaces between plants as well as close to basal region of the plants as far as possible (Bakar, & Khan, 2016). In each field, 20 complete sweeps were made to collect the natural enemies at each date of sampling at 2 days intervals. Sampling was done at maximum tillering and panicle initiation stages. Sampling was done during morning hours (9-12) at all study fields on all sampling dates. The samples were sorted and identified under light microscope, magnifying glass and run through the keys collected from various publications.

A total of 42 beneficial insect species were recorded to be associated with spring wheat crop (Annex 2). These beneficial insects belonged to 6 orders and 13 families. They were categorized as Predators, Parasitoids and Pollinators in reference to their mode of attack on the insect pests and to wheat crop. Some 33% of the beneficial insects recorded were Coleopteran with 14 species under family Coccinellidae, Carabidae, and Scymninae. Dipterans comprised 23% of the beneficial insects with 10 species recorded from family Tachinidae and Syrphidae. Ichneumonidae and Vespidae were the hymenopterans that comprised 25% of the beneficial insects with 9 species recorded. Neuroptera comprised of 7% beneficial insects with 3 numbers of species from family Mantispidae and Chrysopidae. Hemiptera revealed 2 species under family Pentatomidae and Nabidae with 5% recorded beneficial insect and Odonata under family Libellulidae comprised of 5% beneficial insects with 2 species were recorded.

From these species, 31 were classified as predators, 9 parasitoid and 2 considered as the beneficial insect. It was recorded that the predators were prominent beneficial insects found in associated with wheat pest followed by the parasitoid and pollinators. Among different orders the Coleoptera has maximum number of predators followed by Diptera, Neuroptera, Odonata, Hemiptera respectively and least number was found in Hymenoptera. Order Diptera and Hymenoptera comprises of both predators and parasitoid species but Hymenoptera was only the order with maximum number of parasitoid species associated with predators and pollinators.

From the current investigation, we confirm there is good diversity of natural enemies associated with spring wheat largely under orders of Coleoptera, Diptera, Hemiptera, Hymenoptera, Neuroptera, Odonata and Orthoptera. Predators, parasitoid and pollinators were the groups of beneficial insects associated with the wheat farming. Besides the Apidae, other families were all naturally occurring biological agent for the pest control in the wheat field.

vii. Research on chili wilt management

The production of chili which is considered as major vegetable is affected by biotic factors such as phytophthora wilt, verticillium wilt, and pod borer insects. The production season usually coincides with the summer rains resulting to major crop losses to soil born fungal diseases. Biological control is one of the key methods of IPM. For the biological control of the wilts, we experimented using commercial *Trichoderma harzianum and T. viride* fungicides multiplied using water and *bokashi.* The results of the experiments are discussed as below.

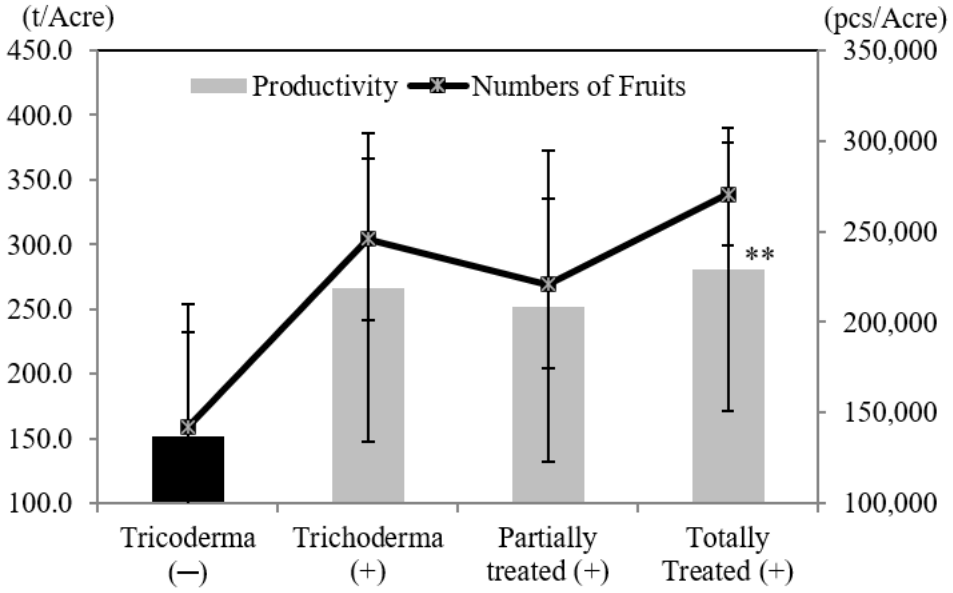


Figure 7 Productivity and fruit number differences

The *Trichoderma spp.* application enhanced the yield of chilli. As high as 186% yield increase was found. Productivity of the plants was also enhanced yielding more numbers of fruits and more yield.

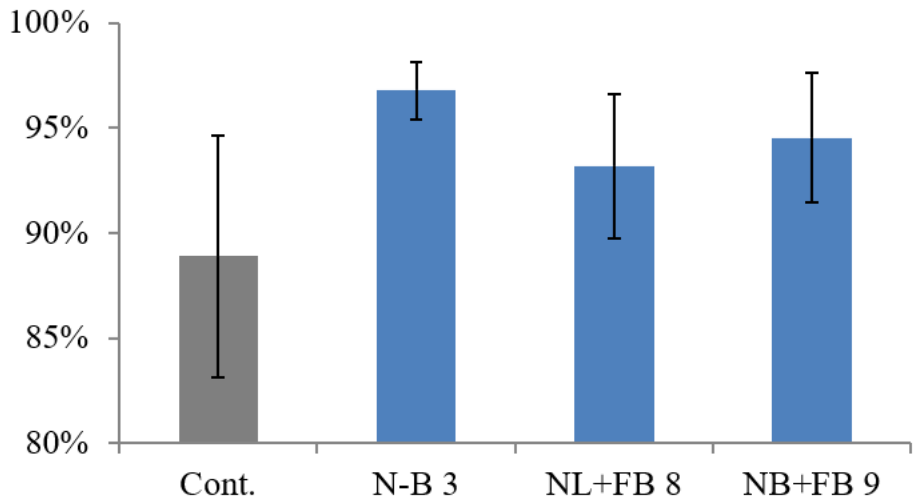


Figure 8 Average survival rate in different treatments

The application of *Trichoderma spp.* and *bokashi* enhanced the survival rate of the plants. For higher efficacy, application from nursery to field is recommended.

viii. 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. For fall armyworm, a filed a Dzomlingthang was used. For other pests, demonstrations were carried out in ARDC Bajo and ARDSC Menchhuna. As high as 1000 moths were trapped per trap during peak seasons which ultimately reduces the subsequent pest populations.

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 are 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 the 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 to which otherwise might serve as bridge for the weevils. Other methods include the pesticide application and mound preparation. Mound preparation reduces the weevil's attacks on the tubers.

IPM on chilli pests and diseases management

Verticillium wilt and chili pod borers are the major biotic factors that affect the chili production. Aphids also cause serious damage resulting from viral transmission by the aphids. Aphid control using wood vinegar and neem oil were demonstrated. For wilt control/management; soil solarization, bokashi application and *Trichoderma spp.* applications were demonstrated.

Fruit bagging against birds and insects

Most of the fruits are attacked by birds and insects when near ripe. To protect the fruits from the pests, wrapping of fruits/ fruit bunches were covered using bags made from different materials. Fruit wrapping/bagging is the best method of fruit protection from birds and insects. However, costs of materials and labour may hinder to adopt the technology if for larger area.

ix. Diagnostic and recommendation services

Pest and disease identification services were provided for about 75HHs during the FY 2020-2021. Pests/diseases and the crops infested were as in the table 43.

Table 43 List of Pest diagnostic services

Dzongkhag	Gewog	Locality	Pest/Disease	Crops	HHs
Dagana	Drujaygang	Patala	*Thysanoplusia orichalsia*	Maize	5
Dagana	Drujaygang	Menchhuna	*Thysanoplusia orichalsia*	Maize	4
Dagana	Drujaygang	Khebisa	*Thysanoplusia orichalsia*	Maize	1
Punakha	Guma	Changyul_LoongsilgangTashijong	*Helicoverpa armigera*	chilli, beans, eggplant	6
Punakha	Kabisa		*Helicoverpa armigera*	chilli, beans, eggplant	5
Punakha	Chubu		*Helicoverpa armigera*	chilli, beans, eggplant	5
Punakha	Kabisa		*Thysanoplusia orichalsia*	cabbage	2
Punakha	Guma	Dzomlingthang	*Helicoverpa armigera*	chilli, beans, eggplant	2
Punakha	Toepisa	Menchhuna	Rice blast	Maachum (Red)	3
Wangdue	Gangtey	Gorgoena	Spodoptera sp.	Radish & turnip	10
Tsirang	Serithang		Phytophthora blight	Chilli and tomato	8
Wangdue	Nisho	Ritsawa	Rust	Garlic	2
Wangdue	Rubesa	Ruichikha	Phytophthora blight	Chili	3
Punakha	Guma	Dzomlingthang palace	Spodoptera frugiperda	Maize	1
Punakha	Barp	Gamakha	Rice blast	IR64	2
Punakha	Barp	Tshogkorna	Rice blast	Ngabja zuema	1
Punakha	Kabisa	Heyloog_ Tongzhoognang	Rice blast	Tan Tsheri	2
Punakha	Kabisa	Heyloog_ Tongzhoognang	Rice blast	Maachum (Red) local	2
Punakha	Guma	Baymenang Wangwakha	Rice blast	Gemjaa	2
Punakha	Guma	Changyul_Loongsilgang_ Tashijong	Rice blast	Jamjaa	1
Punakha	Talog	Loongnangkha	Rice blast	Tan Tsheri	1
Punakha	Talog	Loongnangkha	Rice blast	Ngabja	1
Punakha	Dzomi	Goobji_Tseykha	Rice blast	IR64	3
Wangdue	Nahi		Early blight	Desiree	5
Total HHs					**75**

6) Soil and Land Management Unit

i. Response of rice to different nitrogen application rate

Trial was conducted at Bajo in collaboration with National Soil Services Centre with the objective of the study is to evaluate the efficiency of different nitrogen levels on rice growth, productivity and nitrogen use efficiency of HYV Three different paddy varieties were treated with five different treatments of nitrogen fertilizer. The pre and post soil samples were collected and crop cut was done at the end. The first- and second-year data was collected and submitted to NSSC. The trial will be continued for another one year and reports will be generated at the termination of the study.

The design of the experiment would be split plot design with a 6X3factorial of two factors. Main plot treatments will have 6 levels of N (P & K to remain same) and the sub plots treatments will have 3 varieties. There will be 3 replicates. Each of the 6 levels of nitrogen will be tested 3 times and each of the 3 varieties will be tested 18 times. The size of the main plot will be 3 (varieties) times the subplot. The area of each subplot will be 5m X 2m ($10m^2$) with bunds around and the size of the main plot will be 6 X $10m^2$. Each subplot should have at least100 plants, one plant per hill. To control the competition effect, the plants from the two outermost rows will be discarded.

NPK application rate:

- (NPK)1 – 40-20-12 kg ha-1
- (NPK)2- 80-20-12 kg ha^{-1}
- (NPK)3- 120-20-12 kg ha^{-1}
- (NPK)4- 160-20-12 kg ha^{-1}
- (NPK)5- 200-20-12 kg ha^{-1}
- (NPK)6- 240-20-12 kg ha^{-1}

Mean comparisons for 2019

Nrate	N	Bajo Kaap 1	Bajo Kaap 2	IR64 group
n1	3	6.0333 a	6.8600 a	4.2267 b
n2	3	5.2367 a	5.2000 a	6.1233 ab
n3	3	6.5000 a	6.6500 a	5.4600 ab
n4	3	5.5100 a	5.6933 a	7.4767 a
n5	3	5.7067 a	5.9100 a	6.0533 ab
n6	3	5.5700 a	4.7667 a	5.8400 ab

Mean comparison for 2020

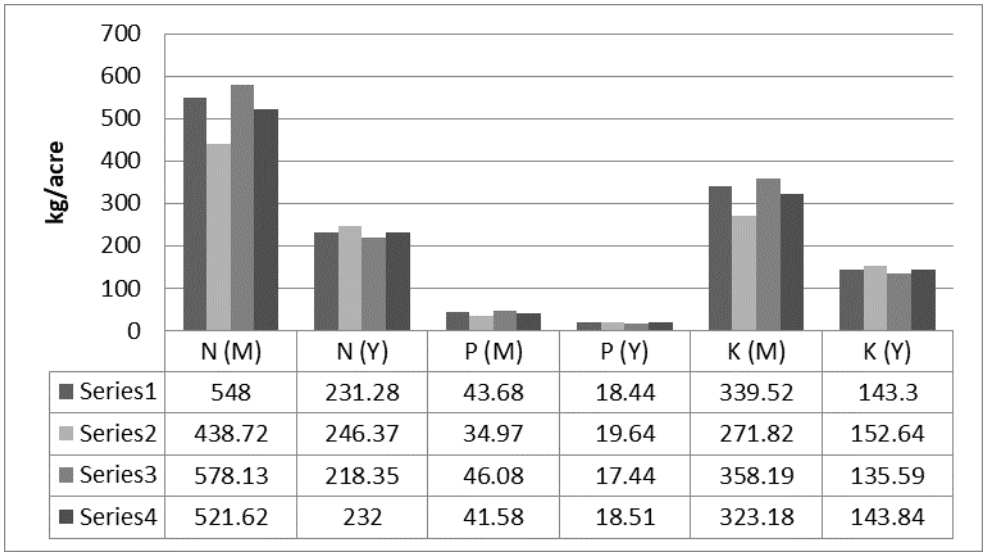
NPK rate	N	Bajo Kaap 1	Bajo Kaap 2	IR64
n1	3	6.1000 a	6.8667 a	4.3333 b
n2	3	5.4333 a	5.4333 a	6.0667 ab
n3	3	6.6000 a	6.5667 a	5.6667 ab
n4	3	5.6000 a	5.8000 a	7.4000 a
n5	3	5.8000 a	6.0667 a	6.0333 ab
n6	3	5.6267 a	4.9000 a	5.8333 ab

Means with the same letter are not significantly different

For both the seasons, there are no significant differences in the yields of Bajo Kaap 1 and Bajo Kaap 2 for all the different NPK rates. But, n4 gives the best yield, followed by n2, n3, n5 and n6. Of all the different rates, n1 gives least yield in IR64.

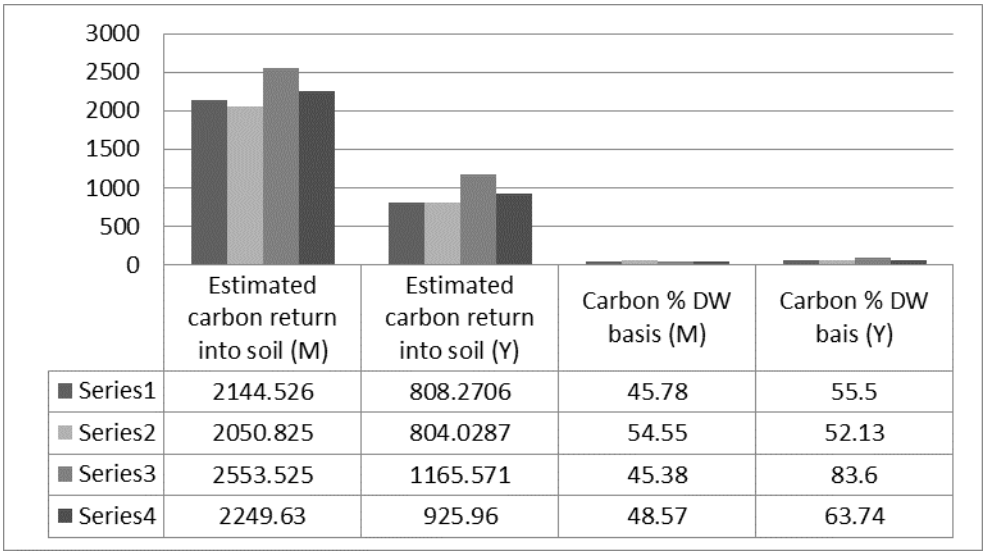
ii. Sequestration of carbon into soil using Dhaincha

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 addition of organic matter into soil. Its cultivation must be done 60-70 days before main crop. The seeds are broadcasted in fields at the rate 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 soil is new in Bhutan. The use of Dhaincha as a biochar, which can add carbon into the soil was studied. An experiment was conducted to determine the development stage of plants at which it must be converted into biochar and applied into soil. Two plots each measuring 100m^2 were used. The seed rate (30kg/acre) was maintained in both plots. The sowing time differs by 20 days between 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 flowering stage. Whereas the young Dhaincha block was 40 days old and was at vegetative stage. Biochar was prepared from the two different samples using the same method of barrel and cone system. The comparison of carbon percent of the biochar prepared from the dried biomass was done. The biochar prepared from the young Dhaincha block was found to have significantly higher content of carbon percent 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 will be carried out for the third year.



	N (M)	N (Y)	P (M)	P (Y)	K (M)	K (Y)
Series1	548	231.28	43.68	18.44	339.52	143.3
Series2	438.72	246.37	34.97	19.64	271.82	152.64
Series3	578.13	218.35	46.08	17.44	358.19	135.59
Series4	521.62	232	41.58	18.51	323.18	143.84

Figure 9 Comparison of N-P-K supply [matured(M) vs. young(Y)]



	Estimated carbon return into soil (M)	Estimated carbon return into soil (Y)	Carbon % DW basis (M)	Carbon % DW bais (Y)
Series1	2144.526	808.2706	45.78	55.5
Series2	2050.825	804.0287	54.55	52.13
Series3	2553.525	1165.571	45.38	83.6
Series4	2249.63	925.96	48.57	63.74

Figure 10 Carbon sequestration

iii. Effect of aqua-biota supplementation on growth and yield of rice

Excessive and inappropriate use of chemical fertilizers can lead to soil impoverishment caused by nitrogen leaching, soil compaction, reduction in soil organic matter and loss of soil carbon. It also affects waterways through the leaching of chemicals. The import and use of chemical fertilizers are expected to be reduced by 50% within the next few years through production and promotion of organic and bio fertilizers in the country under National Organic Flagship Program (NOFP).

Therefore, there is an increasing need to explore organic alternatives to chemical fertilizers to improve soil fertility and increase rice production. Use of aqua-biota could be one organic option in rice production system. The aqua-biota is a complex of micro-biota selected amongst 200 strains for their properties to benefits plant growth and development. Studies have shown that the use of aqua-biota improved soil fertility, reduced diseases and pest, increased crop yield, reduced the need of chemical fertilizers and increased the concentration of bio-actives in the rice. The present study aims to assess use of aqua-biota on the growth and yield of rice in Bhutan. The experiment will be conducted in collaboration with Agriculture Research & Development Center Bajo (ARDC Bajo) at Royal Project Chimipang (RPC). The trial has been set up in 2020 season and will be continued in the coming season.

iv. Fermented rice bran in vegetable cultivation

1000 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 chilli, tomato and cabbage. Its shows potential in yield improvement by 20 %, soil borne disease suppression by 30 % and also resulted in quality produce of vegetables.

v. Trenching in Fruit Blocks on-station

This system of manuring was effective in fruits. Between December and January month, around 250 fruit plants at the Centre were given fertilizer and irrigation through this method. It also serves demonstration purpose to visitors.

vi. Potting technology

This technology is promoted for their ability to ensure almost 100 percent seedlings survival in field condition after transplanting. The potential of this technology is now being promoted in the farmers' field. Around 2000 polypots were used in the past year for vegetables and fruit cultivation.

vii. Mulching technology

Mulches are promoted as it helps in adding organic matter into soil. It also suppresses weed growth and retains moisture in soil. The technology is widely practiced at the Centre.

viii. Soil nutrients production for research use and demonstration

The table 44 summarize the different types of nutrients produced during the FY 2020-21 by the Soil and Land management Unit at the Centre. The nutrients produced is for research purpose, and to demonstrate to the visitors visiting the Centre.

Table 44 Soil nutrients produced in the FY 2020-21

SN	Nutrient	Quantity produced	Purpose	Remarks
1	Vermicompost production for soil fertility management	1050 kg	To improve potting mix for research & demonstration. 100kg will be utilized for aqua-biota trial to check its efficacy	1 kg of active worms supported by NSSC to enhance and promote vermi composting
2	Bio-char	1000	alternative media to be use in potting mix and as a soil amendment.	On-farm demonstration and farmers training were also done.
3	Compost	20 MT	produced for their organic matter content to be used in integrated nutrient management	The raw materials were organic residues available in field, chicken manure, saw dust, farm yard manure, rice brans and stalks, etc.
4	EM	1000	Cater services to various clients of West Central Bhutan	The mother plant was established with support from IHPP
5	Dhaincha seed	100 kg	On-station and on-farm green manuring	10 kg seed issued to Lhamoizingkha gewog
6	Azolla Nursery	1200 kg	For seed production, rice trial and promotion	Eight nurseries, mother block and production block
7	Fermented rice bran fertilizers	1000	Research, promotion and demonstration	demonstrated on-farm together with biochar technology

ix. Establishment of regional soil and plant analytical laboratory

The regional soil and plant analytical laboratory have been established at ARDC-Bajo with technical support from National Soil Services Centre and financial support from RGoB and FAO. The soil parameters like pH, EC, N, P, K, Ca, Mg, Na, Soil moisture and bulk density can now be analyzed at the regional laboratory.

x. Establishment of Bhutan Agri-microbial Solution (EM) plant

Effective microorganisms (EM) contribute to soil enrichment, by harmonizing and diversifying native microorganisms. With support from IHPP, the Centre has setup 500 liters and 300 liters capacity plant has been established at ARDC Bajo and ARDSC Menchhuna respectively. Another 500 liters capacity plant was also established at NSSC Semtokha. With establishment of these three plants, we do not have to import EM from outside. This has been named as Bhutan Agri-microbial Solution (BAMS). In total 1500 litres of BAMS from Bajo, 600 litres from Menchhuna and 500 litres from Semtokha was produced in a year. The produced BAMS are utilized for on-station usages and distribution to farmers and schools.

xi. Demonstration and promotion of climate smart technologies

During the FY 2020-21, the Centre has demonstrated six main climate smart agriculture namely bio-char, bokashi, azolla, improved method of potting media, composting and mulching and in the WC Region. Rice husk biochar, fermented rice bran fertilizer, Bhutan Agri-microbial solution, Gelatin solution, starch solution, wood and bamboo vinegar, azolla, water harvesting technology are promoted in every farmer training in districts The demonstration was conducted mainly through hand-on training to farmers with the objective to promote the climate smart technologies which will help farmers/youth/agriculture entrepreneur in practicing organic agriculture. The technologies were demonstrated through financial support from RGoB and project namely NOFP, FSAPP, GCF and RDCAP. The table 45 summarize the demonstration conducted through in multi locations.

Table 45 Demonstration of climate smart agriculture technologies in WC Region

SN	Dzongkhag	Gewog	No. of farmers	Remarks
1	Dagana	Namlaythang	37	Through NOFP
2	Dagana	Gayerserling	30	
3	Dagana		9	through systematic training
4	Punakha	Kabisa	11	
5	Punakha		5	through systematic training
6	Punakha	Oathbar (Goenshari)	50	youth
7	Gasa	Khamoed	20	
8	Gasa	Laya	6	
9	Tsirang		9	through systematic training
10	Wangdue	Kazhi (Lull)	18	Through NOFP
11	Wangdue		7	through systematic training
12	Trongsa	FMCL	80	
13	Dessups	De-Suung Skilling Program	31	At ARDC Bajo
Total			**233**	

Besides the farmers from WC Region, the Centre has also demonstrated the technologies to FMCL Trongsa youth (80), Thimphu Jimena 15, 13 Agriculture Extensions Punakha and 18 extensions from six dzongkhags under GCF project were trained in the FY 2020-21.

xii. Setup and demonstration of multi-tier integrated azolla production system with vegetable nursery beds

ARDC-Bajo has ventured into new technology of multi-tier integrated azolla production system with vegetable nursery beds in protected cultivation. The technology has been promoted in collaboration with FMCL. Promotion of azolla technology is important for Climate Resilient Agriculture and enhancing sustainability. Azolla plays critical role in agriculture as bio-fertilizer. It provides crucial nutrient nitrogen which is necessary for healthy plant growth especially in paddy farming. Azolla can be used as substitute for chemical fertilizer in paddy farming thereby minimize leaching of nutrients into water bodies. It also plays important role for nitrogen fixation which increases the fertility of the soil which in turn increases the yield. Therefore ARDC-Bajo maintains on-station mother block of azolla and distribute to the client Dzongkhag farmers. In order to maintain quality azolla mother culture, construction of shed with M/s frame is necessary. The setting up of metal frame along with plywood set and covering with plastic of 300 gsm is used. The plastic is tied firmly in all the sides to protect from strong wind. The integrated system set up inside protected structures can be used for off season vegetable and seedling production. The lower and upper space can be utilized for azolla production.

Table 46 Demonstration of multi-tier integrates azolla production system

SN	Dzongkhag	Gewog	No. of set	No. farmers trained	Remarks
1	Dagana	Kana	1	11	Through FSAPP
2	Dagana	Drujegang	1		Through FSAPP
3	Dagana	Karmaling	1		Through FSAPP
4	Dagana	Lhamoizingkha	1		Through FSAPP
5	Dagana	Nichula	1		Through FSAPP
6	Dagana	Goshi	1		
7	Punakha	CRP	1	4 ESP	
8	Wangdue	Gangtey	5	20 monk body	GEF-LDCF
Total			**12**	**183**	

xiii. Progress as per signed Organic Flagship Performance Agreement

As per the APA 2020-21 agreement with NOFP, the Centre carried out Organic research and promotion of organic technologies within the region. Various research study conducted. Dhaincha seed production for green manure purpose was also carried out. The production technology on wood and bamboo vinegar is also established and perfected at the centre. With support from NOFP 1000kg rice husk biochar, 1000kg fermented rice bran bio-fertilizers and 500kg vermicompost and 20 MT compost was produced. Timely monitoring and submission of monthly progress report by 25th of every month was done to NOFP office.

E. POLICY, REGULATION AND COORDINATION PROGRAMME

1) Release of improved varieties and improved technologies

As ARDCs are mandated to release Climate smart technologies new varieties and improved technologies to be adopted by the clients, the Centre has targeted to release 11 technologies in during the 12FYP. During the FY 2020-21, the Centre has released 11 varieties of six crop and one climate smart improved technology through Variety Release Committee (VRC) and Technology Release Committee (TRC) respectively as listed in the table 47. These technologies will be disseminated to farmers and other clients for adoption.

Table 47 New varieties and technologies release in FY 2020-21

SN	Variety/Technology release	No of varieties	Varieties released new name	Traits
1	Radish • Akino Irodi • Gensuke • Long foot	3	BajoLhapu II Bajo Lhapu III Bajo Lhapu IV	High yielding (20-22T/AC)
2	Tomato • Red TommyToe • Master	2	Bajo Lambenda II Bajo Lambenda III	High yielding (8T/AC) optimum size, juicy
3	Zucchini • Yellow Zucchini	1	Zucchini Yellow	Early variety, resistance to pest/diseases
4	Watermelon Blackball, Kabuki	2	Bajo kharbuja I, Bajo kharbuja II	Taste & bigger size
5	Sweet potato • Beni azumi, • orange flesh	2	Bajo kawa I Bajo kawa II	No variety released before, market preference, varietal diversity
6	Rice (TME80518)	1	Bajo Kaap 3	Mid altitude varieties, higher yield performances
7	Rice bran bokashi	1	Rice bran bokashi	Soil organic nutrient, potting mix, bio-pesticide
Total		**12**		

2) Information management, publications and extension material

i. Publication of scientific journal papers

As a Research Centre, it is mandatory to publish journal papers every year. During the FY 2020-21 the Centre published a series of technical journal papers in both international and in Bhutan Journal of Agriculture (BJA). The seven international journals papers were published by officers who are currently undergoing PhD studies of the Centre. While ARDC-Bajo came up with three technical papers and submitted to be published in BJA only one paper got published. Table 48 provides the list of technical publication with details.

Table 48 Technical journal papers produced by the Centre, 2020-21

Journal Publication Title	Author	Publisher (in)	Date
Nitrogen and potassium fertilization influences growth, rhizosphere carboxylate exudation and mycorrhizal colonization in temperate perennial pasture grasses	**Tshewang, S**., Rengel, Z., Siddique, K. H. M. & Solaiman Z. M	https://doi.org/10.3390/agronomy10121878 *Agronomy*. 10 (12) 1878.	2020
Growth, rhizosphere carboxylate exudation and arbuscular mycorrhizal colonisation in temperate perennial pasture grasses varied with phosphorus application	**Tshewang, S**., Rengel, Z., Siddique, K. H. M. and Solaiman Z. M	https://doi.org/10.3390/agronomy10122017 Agronomy. 10 (12) 2017.	2020
Growth and nutrient uptake of temperate perennial pastures are influenced by grass species and fertilization with a microbial consortium inoculant	**Tshewang, S**., Rengel, Z., Siddique, K. H. M. and Solaiman Z. M	https://doi.org/10.1002/jpln.202000146 *Journal of Plant Nutrition and Soil Science.*	2020
Spatio-temporal landscape changes and the impacts of climate change in mountainous Bhutan: A case of Punatsang Chhu Basin.	**Chhogyel, N,** Kumar L, Bajgai Y	http://www.elsevier.com/locate/rsase *Journal of Remote Sensing Applications: Society & Environment*	2020
Consequences of Climate Change Impacts and Incidences of Extreme Weather Events in Relation to Crop Production in Bhutan	**Chhogyel, N,** Kumar L, Bajgai Y	https://www.mdpi.com/journal/sustainability	2020
Prediction of Bhutan's ecological distribution of rice (Oryza sativa L.) under the impact of climate change through maximum entropy modelling.	**Chhogyel, N**, Kumar L, Bajgai Y, Sadeeka Jayasinghe L	https://doi.org/10.1017/S0021859620000350 The Journal of Agricultural Science 158, 25–37.	2020
Invasion status and impacts of parthenium weed (Parthenium hysterophorus) in West-Central region of Bhutan	**Chhogyel, N**, Kumar L, Bajgai Y	https://doi.org/10.1007/s10530-021-02534-3 *Biol Invasions*	2021
High yielding Indeterminate Bean Varieties to Diversify Bean Farming	**Wangmo, D, Dorji U, Dema T, Etal**	Bhutan Journal of Agriculture (BJA)	2020

ii. Frameworks/Guidelines/Standards developed

During the FY 2020-21, with support from IHPP-JICA, the Centre has developed technical extension package for fruits as "Fruit Growers Training" ROP Implementation Guidebook. The publication is circulated to relevant stakeholders in the country. Through support of IHPP_JICA the Centre has developed series of pamphlets on technologies. These are compiled in table 49.

In accordance to the direction of DoA the ARDC Bajo Engineering Sector with support from AED developed training materials for the "Specialized De-suung Training Program" on irrigation water resources management. Through this training participants are expected to (a) know current status of water resources in Bhutan, (b) gain basic understanding of irrigation systems, (c) gain basic principles of hydraulic design of irrigation system, (d) interpret construction drawings and specifications, (e)

identify relevant tools, machines, equipment and material for construction, and (f) understand concepts of operation and maintenance of irrigation scheme.

Table 49 List of pamphlets published 2020-2021

Type of publication	Name of Publication	Contact person	Remarks
Pamphlet	Carrot	Tshering Dema	Starter guide
Pamphlet	Straw berry	Tshering Dema & Karma Dema	Starter guide
Pamphlet	Cabbage	Tashi Dorji	Starter guide
Pamphlet	Cauliflower	Arjun Kumar Ghallay	Starter guide
Pamphlet	Broccoli	Tshering Dema	Starter guide
Pamphlet	Andey	Sonam Chophel	Starter guide
Pamphlet	Grapes	Sonam Chophel	Starter guide
Pamphlet	Pecan nuts	Tashi Phuntsho	New variety release
Pamphlet	Eggshell calcium extraction using vinegar	Ugyen Dorji & Dorji Khandu	Pests & Diseases Reference guide
Pamphlet	Chilli pod borer management	Ugyen Dorji & Dorji Khandu	
Pamphlet	Large Cabbage White Butterfly Management	Ugyen Dorji & Dorji Khandu	
Pamphlet	Sweet potato weevil	Ugyen Dorji	
Pamphlet	Red melon beetle management	Ugyen Dorji & Dorji Khandu	
Pamphlet	Cabbage aphid management	Ugyen Dorji & Dorji Khandu	
Pamphlet	Fruit nursery management Theme 1 “Work calendar for Temperate fruits nursery”	Gyeltshen Tshering	Step-up guide
Pamphlet	Fruit nursery management Theme 2 “Fruit bagging”	Sonam Chophel, Tashi Phuntsho, Ugyen Dorji & Gyeltshen Tshering	Starter guide
Pamphlet	Vegetable cultivation Theme 2 “Soil pH & EC	Kinley Tshering, Arjun Kr. Ghallay, Duptho Wangmo, Tshering Dema, Tashi Dorji & Karma Dema	Step-up guide

Besides these publications IHPP-JICA has developed 10 audio-video clips on the new technologies in National language and made available in YouTube channel. The video clip link has been shared with relevant stakeholders.

1. Bokashi Bran https://youtu.be/sIQtSm17VmQ
2. Biochar https://youtu.be/V66OpfCholw
3. Nursery Raising of Vegetables https://youtu.be/IZfhGgYjyz0
4. Planting of Nursery Fruit Treeshttps://youtu.be/N9--UPoLwBg
5. Grafting of Nursery Fruit Trees https://youtu.be/Y_6Is3_i6ds
6. Polyhouse construction https://youtu.be/i8izu3PmQRE
7. Top working https://youtu.be/WWdBhheUvic
8. Pruning and training 1-2 years old tree https://youtu.be/pAJElfP1_zU
9. Vegetable Seedling Transplanting https://youtu.be/TxW_-s3bDTI
10. Compost making https://youtu.be/raZcwWJdnq4

3) Regional Agriculture Database

ARDC Bajo has been maintaining regional database of the West-Central Region and made it available whenever required. From this FY, the Centre has generated online database for the five Dzongkhags of West-Central Region viz., Gasa, Punakha, Wangdue Phodrang, Dagana and Tsirang. The following data has been updated and made online at the Centre webpage www. rcbajo.gov.bt under the subheading "West Central Region Database"

- Extension Staff information
- Crop cut data
- Household information
- Land use data
- Crop Production Data
- Electric Fencing
- Farm Road
- Irrigation
- Protected cultivation
- Farm machineries

Besides these data, the Centre has also uploaded collaborative activities of the West Centre Region.

4) Visitors' information

Unlike in the previous in the fiscal years, this year there were limited number of visitors visiting the Centre due to COVI2-19 pandemic. In total 29 various groups of visitors comprising of farmers, students, youths, trainees, delegates from various organizations and agencies visited ARDC-Bajo. The visits were made on study tour 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 technologies available or adopted in the Centre.

5) 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 percent, physical purity percent, and moisture percent of seeds. Th clients include ARDCs, BAFRA, NSC, farmers and private seed companies. The seed parameters to be tested depend on interests of clients and the capacity of the laboratory to perform tests. The seed samples submitted through BAFRA are tested for germination percent, purity percent and moisture percent whereas seed samples from farmers are usually tested for germination and purity percent only. The results and recommendations are then provided the beneficiaries The seed samples collected are usually from vegetables and cereals crop annexure…..

The figure 11 indicates that the mean of germination and purity percentage rate of 21 crops seed samples test conducted in the FY 2020-21. Although the germination rate varies zero (bitter gourd) to 99 (pumpkin), the purity percentage is high 98 to 100 percentage.

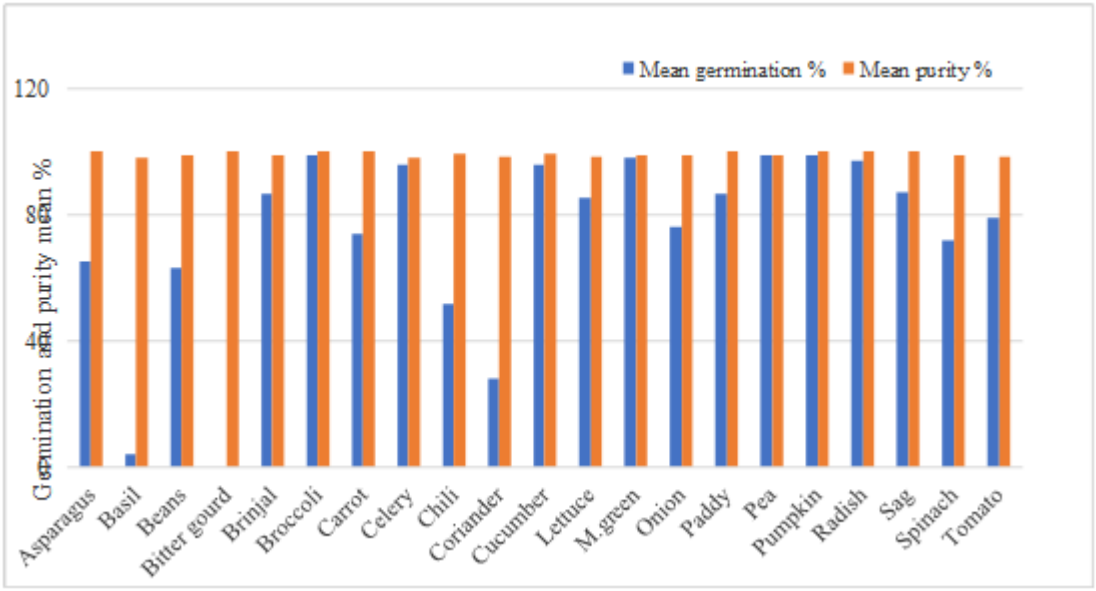


Figure 11 Germination and purity mean of crop seed sample tested

6) Social and impact studies conducted

i. Impacts of Integrated Horticulture Promotion Project-brief report

Integrate Horticulture Promotion Project (IHPP) and Agriculture Research and Development Center (ARDC) Bajo promoted 'Fruit Growers Training Programme' as the 'Research Outreach Program (ROP)' since 2016, targeted five Dzongkhags in the west-central region. The project baseline and monitoring surveys had been conducted since 2016, and the survey data suggested suitable approaches and the importance of basic management for improving current horticultural production. Bhutan has high potentials to cope with climate change because of the various geographical locations under subtropical highland on the averagely small cultivation size. However, low agricultural productivity is a big challenge from commonly observed poor nursery management, less input and insufficient soil fertility. For instance, there is a huge difference in the national average for Tomato and green Chili productivities (Figure 12).

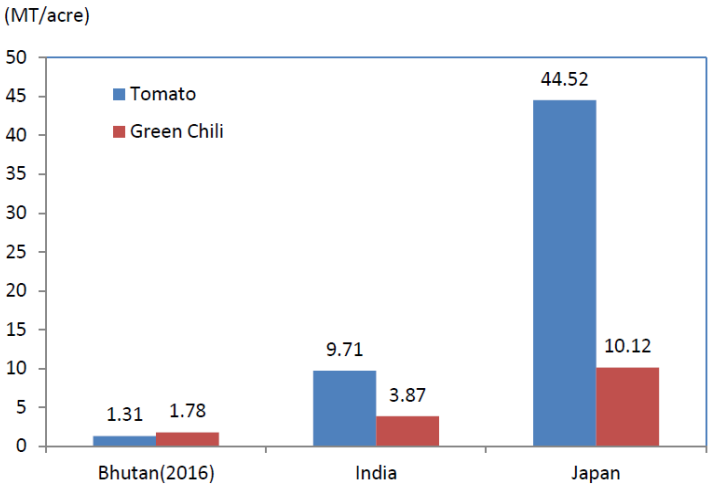


Figure 12 Comparison of Tomato and green Chilli productivity (National average)

This average yield comparison data suggested that if farmers improve their field and nursery management, provide appropriate fertilisers inputs, and choose appropriate cultivars, the horticultural crop productivity could be double or more. The project successfully provided several key technologies to improve horticultural production, and the surveys point that 0.2 acres per household (HH) as the adequate promotion size (Table 50). This size is also estimated enough to achieve the overall project goal of 25% of income gain.

Table 50 The estimated potential of each horticultural cultivation size

No	Item description	Set value for the estimation	For 0.2 acre	For 0.6 acre[3]
1	Necessary work hours (Hrs)[4]	800 hrs/ acre	200	500
2	Planting numbers	100 saplings/ acre	20	60
3	Necessary work force	4 persons (one HH)	Family only	Family only
4	Input cost (Nu.)	NPK 50kg/acre (Suphala50kg@1800 Nu.) FYM 10t/acre (self) Tools: 2500Nu./HH	4,500	10,000
5	Marketing Cost (Nu.) Middleman charge	20% of total sales Yield x @100Nu/kg	12,000	28,800
6	Other Cost (Nu.) Harvest loss	15% of total sales	9,000	21,600
7	Productivity (kg)	Target yield 3,000kg/acre (1/4 of Japanese average)	600	1,800
		Total income (Nu.)	60,000	180,000
		Annual Input Cost (Nu.)	4,500	10,000
		Expected harvest loss/handling charge (Nu.)	21,000	50,400
		Estimated net income (Nu./year)	**53,400**	**119,600**

For further horticultural promotion, a system of cooperative group production is suggested. Group production with a feasible size and items combined in a manageable sized cooperative should be more profitable and suitable for the current farming style and systems.

Table 51 An example of the corporative group facility required

Items required for Coop	Functions/Purpose	Minimum Unit
Human resource	Management, procurement/distribution	1 person
Cool chamber(s)	Temporary storage, pre-cooling	1 -2 unit (3m3) price apx. @500,000 INR
Processing facility	Loss reduction and extra income generation	1 unit(rental member facility)
Warehouse	Sorting/packing, storage and processing	1 unit(rental member yard)
Vehicle(s)	Transportation/delivery	1 -2 unit (rental members car)

Two of the project target Dzongkhags (Gasa and Dagana) are organic Dzongkhags. The continental climate and range of altitude support the high potential of organic production in Bhutan. However, the current cultivation they call "organic" is almost equal to naturally-grown cultivation with less input and minimum management. Horticultural crops always require enough input for a quality harvest and the complete incorporation of cultivar characteristics, especially in cross-bred and hybrid varieties. The biggest challenge in organic cultivation is disease and pest control, strongly related to climate change and the conditions. Management methods for some of the important pests and diseases are suggested (Table 52).

Table 52 High risk pest/disease in organic areas, and their management

Common Name	Target crop	Infection source	Non-Chemical Countermeasures
Verticillium wilt	Chili, Tomato Brinjal, Potato	Compost Soil	Seed sterilisation Biological soil sterilisation, Crop rotation Mustard Green manure usage Antagonistic microbes
White roo rot	All temperate Fruit-tree	Compost Soil Saplings	Sterilisation sapling roots Hot water treatment (nursery) Removal /burn out affected trees
Sweetpotato weevil	Sweetpotato (Japanese varieties)	Transplants Left-over tubers Morning glories	Host morning glories removal Outline drench making Fence planting/mixed planting Weevil free transplants production
Armyworms	Grain and vegetables	Other affected crops	Drench trapping Fence planting
Fruit Borer Night moth	Pear Persimmon Peach Chili Tomato	Solanum weed and crops	Trapping Yellow/green light repellent, Bagging, netting

As indicated in the detailed Impact report, 1) improvement horticultural crop productivity, 2) detailed-plan-based promotion on fruit-tree production, from nursery production to post-harvest and marketing and 3) annual cycle of the programme implementation for the next five years with by proper assessment and monitoring should be continued for upscaling and improving the horticultural activities.

ii. Assessment on the adoption of low-cost water harvesting technology in Barshong Gewog, Tsirang

Irrigation water shortage is one of the main constraints in crop production in Barshong gewog. Although the gewog receives abundant rainfall in the summer, rainwater and runoff water go untapped in absence of suitable water harvesting technology. Therefore, low-cost plastic lined water harvesting pond technology with plastic sheet (300GSM) was promoted and supported to store water which can be used

during dry or lean season for agricultural as well as household purposes by Himalica' pilot project.

Although the project period has closed, farmers of Barshong gewog has adopted the water harvesting technologies and it is proven success story. The technology has been modified and released as technology by ARDC Bajo and promoted to other locations. To assess the adaptability and its continuity by farmers as water harvesting technology and its impact, a quick social study was conducted from 29 beneficiaries with semi-structured questionnaires by the Centre. The data collected was analysed using SPSS Version 25.0 and MS Excel to generate graphs.

Table 53 Land under Agriculture farming

Land Types	N	Minimum	Maximum	Mean	*SD*
Wetland	13	.47	6.00	2.16	1.57
Dryland	29	1.00	8.00	3.12	1.65
Orchard	9	.40	4.00	1.14	1.15
Vegetable	28	.10	3.00	.51	.59
Cardamom	15	.10	3.00	.59	.83

From the 29 households with water harvesting pond, the structures in 23 households (79%) were functional and the structures in 6 households (21%) were defunct due to rodent damage, water seepage, soil erosion and completely removed from the areas (Table 2). The farmers reported that they will relocate in an appropriate site soon.

Table 54 Number of functional and non-functional pond

Water pond still in use	No. of respondents
Yes	23
No	6
Total	**29**

Sources of water for harvesting

In order to generate information on the sources of water tapped for water harvesting and off-season use, the respondents view on the water sources were collected. It was revealed that 72% (*N*=29) of the respondent harvest water from tap water supply and rain water. Similarly, 10% each informed that they harvest from rainwater and stream and rain respectively. The remaining 7% harvest the water from both the stream and tap as presented in Figure 13.

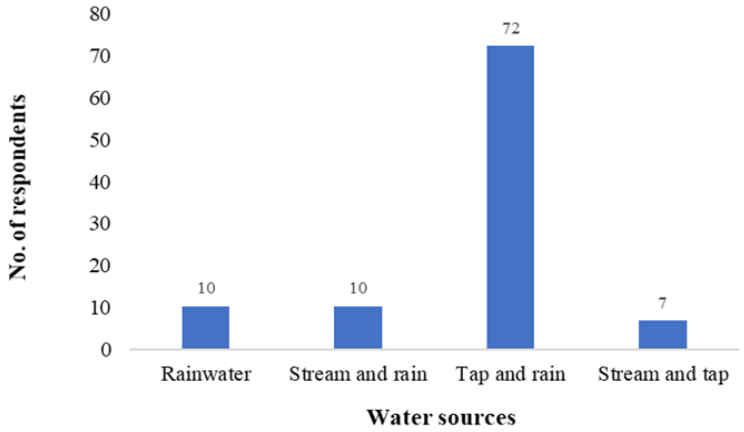


Figure 13 Source of water for harvesting

Subsequently, it was found that the maximum 69% (20 farmers) of the respondents use the tapped water for vegetable cultivation, followed by 21% (6 farmers) use it for vegetable cultivation and for livestock keeping. The remaining minimum 7% (2 farmers) and 3% (1 farmer) respectively use the water harvest for vegetable and orchard and for vegetable and rice production respectively (Table 3).

Table 55 Respondent views on the purpose of water harvesting

	Purpose of water harvest				
	Vegetable production	***Vegetable and rice production***	***Vegetable and orchard***	***Vegetable and livestock rearing***	***Total***
No. of respondents	20	1	2	6	**29**

Knowledge source and practices

Since the technology on low-cost water harvesting was introduced to the farmers of Barshong gewog recently, information on the source of knowledge on the technology provided to the farmers were collected. It was found that 93% (*N*=29) of the respondents revealed that they got the knowledge and skills through the agriculture extension services in the gewog and through developmental support projects in the gewog (Figure 3). Some portion of the respondents (7%) mentioned that they got the knowledge through farmers-to-farmers extension, this section of the farmers learned to adopt the technology by learning from their neighbourhood.

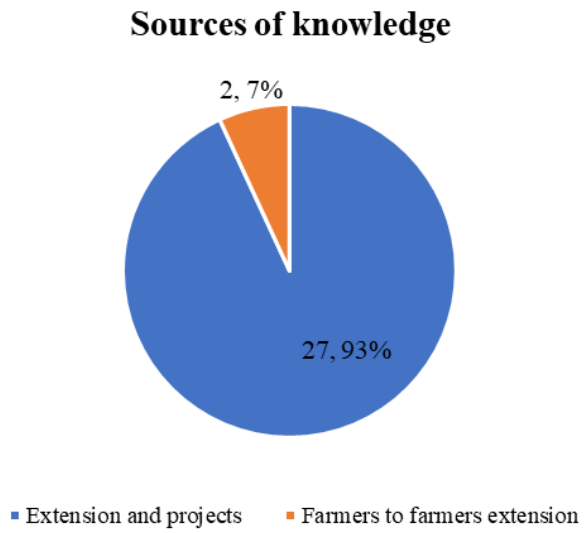


Figure 14 Respondents view on the source of knowledge on the technology

Similarly, almost all the respondents (97%) have some basic knowledge on global warming and its impact of agriculture practices. The respondents could relate the impact of global warming on the current farming scenarios such as incessant rainfall, drought, flash floods, increase in temperature, occurrence of pest and diseases incidences, etc.

Realizing the importance of water and water harvesting for agriculture, 96% (*N*=28) revealed that there is need to expand the water harvesting practices in the community. Such technology will contribute to agriculture production especially during the dry spell season in winter.

Benefits of water harvesting

The respondents reported the water from the ponds were used for agriculture and livestock purposes. The technology helped to increase the cultivation area and its production with mean increase 73% and 76% respectively.

Problem and threats in water harvesting

Some of the problems and threats involved for the technology were seepage, drainage, erosion, tarpaulin durability (damage by mice), and seasonal water sources. Seepage caused by mice damage was the major constraints for the technology.

Other issues associated were mosquito breeding and dangers for trapping animals. Fencing and manual rocking of the water may be suggested for the solutions.

iii. Assessment on Electric fencing using HDPE at Pungshi, Kana, Dagana

Human wildlife conflict in the form of crop losses and livestock predation is a biggest challenge Bhutan is facing in addressing food security and conservation successes. A range of wildlife species are responsible for crop damage. The main vertebrate pests in Pungshi are deer, bear, monkey, and wild boar.

Farmers traditionally use a range of methods for managing vertebrate pests. These include shouting, banging cans, using scarecrows and night guarding. These techniques can be very time consuming to implement, and are of varying

effectiveness. The latest emergence in the country is the use of electrified fencing, which so far has proved very effective. However, sustainability of the technology is questioned due to the wooden post that needs to be replaced often. Options to reduce the negative effects on environment are HDPE posts, PE posts and Facilitated Wood Replacement through renewable forests. With the support from FSAPP, ARDC Bajo established electric fence using HDPE posts at Pungshi, benefitting 11 households. The efficacy and impacts of the electric fence are discussed.

Crop diversification

Maize, Paddy, Citrus, and leafy vegetables were the crops grown before the fences. After the establishment of electric fence, new crops such as potato, beans, spices, and cole crops are grown.

Cultivation area and production

Cultivation area has increased for 63% the farmers for the old crops and while 82% of them reported total increase in cultivation of new crops. Production increase with mean percentile of 62 and as high as 80 were reported for the old crops.

Costs and preference

All the farmers previously used wooden post electric fence. When asked about the preference, all the farmers preferred HDPE post electric fence due to durability and low maintenance cost.

Efficacy of the fence

Monkey was the most difficult animal to control. While electric fences used wooden posts, the monkeys used the wooden posts to climb and cross the fences to reach the crops. But the monkeys avoid the slippery HDPE posts. No monkey damage is reported after the HDPE used electric fence system. Further, it is found effective to other vertebrate pests as well.

Conclusion and way forward

The study indicates the Human Wildlife Conflict for Pungshi is solved. The fence system also increased cultivation area and the production. The durability and low maintenance costs were the key points as advantage of the HDPE posts. However, the high initial costs may affect the adoption rate. Farmers expressed their interests in establishing more fences with the support of different government projects. Continuous evaluation of the fence system in contrast to wooden posts and other materials should be done.

F. ANNEXURES

1) Financial Report as of June 30, 2021

Title source	Approved budget (Nu. M)	Expenditure (Nu. M)	Balance (Nu. M)
RGoB	59.538	58.499	0.986
Enhancing Sustainability and Climate Resilience	1.95	1.949	0.001
RDCCRP	2	1.999	0.001
Green Climate Fund	6.841	3.486	3.355
FASP Project	3.215	3.113	0.155
Deposit work	7.458	7.458	0
Total	**81.002**	**76.504**	**4.498**

2) Agronomic traits of Azolla trial 2020-21

Replication	Treatment	Avg. No. tillers/hill	Avg. plant height(cm)	Avg. panicle length(cm)	Avg. yield kg/acre
Rep I	1	18	82	21	1010
	2	14.3	86.6	22.6	2233
	3	9	92.3	22.3	2010
	4	13.3	103.3	23	2100
Rep II	1	10	88.3	23.3	1100
	2	11.6	87.6	18.6	2267
	3	13.3	79	21.6	1033
	4	12.3	86.3	19.6	1980
Rep III	1	15.3	89	25	1022
	2	10.3	90	22	2020
	3	8.3	91.3	23.3	1900
	4	14	85.6	21.3	1900

3) Phenotypic Characterization of Traditional Land Races of rice

Treatments	Tillers/ hill	P. height (cm)	Maturity days	Panicle length (cm)	MC %	Yield kg/acre
Punakha						
R1V1	8	145.2	156.00	22.6	12.3	2513.53
R2V1	12	149.2	156.00	25.3	9.2	3026.60
R3V1	13	140	156.00	24	12.3	2715.30
R1V2	12	83.8	150.00	22.4	13.7	3041.90
R2V2	15	79.8	150.00	24	11.7	1574.30
R3V2	11	81.4	150.00	22	13.2	1749.40
R1V3	10	81.20	160.00	22.48	14.90	2638.70
R2V3	12	87.20	160.00	24.00	12.90	2903.30
R3V3	16	101.40	160.00	20.80	14.30	2125.80
R1V4	17	160.2	155.00	27.5	15.3	2823.30
R2V4	14	160.2	155.00	27.5	15.3	2823.30
R3V4	13	174.2	155.00	25.4	12.7	2706.90

R1V5	11	146.2	155.00	25.08	12.7	2300.90
R2V5	9	153	155.00	24.5	14.7	3107.80
R3V5	12	141.4	155.00	23.6	11.1	2894.40
R1V6	15	130.6	160.00	22.8	11.3	2887.90
R2V6	18	137.5	160.00	22.2	15.2	3089.60
R3V6	7	132.2	160.00	21.2	12.5	2577.50
R1V7	16	126.80	155.00	24.30	12.20	2926.60
R2V7	12	145.80	155.00	26.20	11.70	3217.10
R3V7	9	133.20	155.00	24.90	13.20	1682.10
Tsirang						
R1V 1	11	142.60	165.00	25.50	13.20	1370.00
R2V 1	10	128.20	165.00	22.80	13.90	1378.00
R3V 1	10	138.80	165.00	22.40	12.80	1678.00
R1V 2	9	146.40	165.00	25.00	13.20	1468.00
R2V 2	9	143.40	165.00	25.80	13.40	1328.00
R3V 2	10	137.80	165.00	25.20	13.10	1294.00
R1V 3	10	148.00	172.00	25.00	14.10	1049.00
R2V 3	9	132.60	172.00	23.40	13.60	1275.00
R3V 3	12	144.40	172.00	22.80	13.70	1322.00
R1V 4	10	85.50	144.00	25.50	13.80	598.00
R2V 4	10	112.40	144.00	25.60	13.30	624.00
R3V 4	13	93.00	144.00	25.50	13.30	755.00
R1V 5	10	78.70	144.00	22.40	12.20	535.00
R2V 5	11	95.40	144.00	22.60	13.30	612.00
R3V 5	11	67.20	144.00	21.60	13.50	800.00
R1Mixture	13	129.40	165.00	22.20	13.20	1123.00
R2Mixture	9	129.20	165.00	23.20	13.40	1182.00
R3Mixture	12	144.00	165.00	22.60	12.60	1036.00

4) Phenotypic characterization of traditional land races of rice, ARDC- Bajo

Accession No	Average plant height (cm)	Average no. tiller/till	Average panicle length (cm)	Average yield kg/ac	*SD*
240	152.00	15.60	23.20	914.60	84.21
1482	156.60	16.00	21.40	873.80	311.44
347	142.40	12.60	24.40	859.40	108.13
1011	133.80	13.40	24.60	779.80	200.14
1481	141.60	12.00	20.40	932.20	159.56
62154	108.00	9.80	22.80	830.20	242.47
677	140.60	13.80	26.80	825.20	192.18
1036	153.40	12.40	22.80	560.40	71.97
346	169.00	19.40	23.00	867.80	58.45
1445	128.20	14.40	19.60	696.00	302.46
1104	152.00	10.00	24.80	773.80	192.26
1103	146.20	13.60	21.00	726.40	295.27
1012	147.40	16.40	22.40	856.60	87.84
1506	153.00	15.40	20.60	812.80	199.90

676	147.00	16.40	25.00	783.60	165.98
1444	147.00	14.80	21.40	751.60	384.51

5) Phenotypic characterization of traditional land races of rice, ARDSC-Menchhuna

Accession No	Mean plant height(cm)	Mean tiller/till	Mean panicle length(cm)	Mean yield kg/ac	Remarks
273	126	12	28	3	
340	125	13	25	1.7	
342	118.25	11	24.24	0.972	
179	damaged by blast				
269	78.25	10	21	2.1	
310	101	12	23	3.1	
322	115	11	24.2	2.7	
64878	120.25	9	25	0.36	Chaffey grain
413	112	12	24	2.5	
236	109	13	25	3	
414	110	11	23	2.3	
232	44	12	25.2	4.2	
296	118	12	23	4.2	
32392	106.6	11	25.3	1.81	
339	124	14	26	3.4	
281	damaged by blast				
334	119	11	26	0.5	
331	damaged by blast				
239	122	11	26	4.1	
34	116.3	9	24	3.07	
234	133	15	24	2.5	
169	88	14	23.3	2.5	
263	damaged by blast				
86867	98	14	19	0.9	
64918	99	10	23	0.8	
274	106	11	26	3.1	
411	128	13	24	2.1	Chaffey grain
238	99	11	22	1.1	
171	Fail to emerge panicle				

6) NCR Citrus germplasm details as of 30-06-2021

Species	Cultivar name	Origin	Precise location	Year	Biological status	crop stage
Sinensis	Cara Cara	Australia	Dareton, NSW	2013	bud wood	evaluation
Reticulata	Othsu	Japan	ARDC, Wengkhar	2012	bud wood	evaluation
Reticulata	Okitsu wase	Japan	ARDC, Wengkhar	2012	bud wood	evaluation
Reticulata	Yushida Ponkan	Japan	ARDC, Wengkhar	2012	bud wood	evaluation

Reticulata	otsu 4	Japan	ARDC, Wengkhar	2012	bud wood	evaluation
Reticulata	Amigo mandarin	Australia	Dareton, NSW	2013	bud wood	foundation
reticulata	Cafein Clementine	Australia	Dareton, NSW	2013	bud wood	foundation
Medica	Fingered citron	Australia	Dareton, NSW	2013	bud wood	foundation
sinensis	Mc Mohan	Australia	Dareton, NSW	2013	bud wood	foundation
sinensis	Ryan	Australia	Dareton, NSW	2013	bud wood	foundation
sinensis	Salustiana	Australia	Dareton, NSW	2013	bud wood	foundation
maxima	Starrubby	Australia	Dareton, NSW	2013	bud wood	foundation
sinensis	Torracco Ippolite	Australia	Dareton, NSW	2013	bud wood	foundation
sinensis	Benyenda Valencia	Australia	Dareton, NSW	2013	bud wood	foundation
sinensis	hamlin	Australia	Dareton, NSW	2016	bud wood	foundation
sinensis	person brown	Australia	Dareton, NSW	2016	bud wood	foundation
reticulata	afourer	Australia	Dareton, NSW	2016	bud wood	foundation
sinensis	navel benyenoal	Australia	Dareton, NSW	2016	bud wood	foundation
Poncirus	p. rubidoux	Australia	Dareton, NSW	2016	seed	foundation
sinensis	Berri Valencia	Australia	Dareton, NSW	2016	bud wood	foundation
sinensis	valencia reena	Australia	Dareton, NSW	2016	bud wood	foundation
sinensis	Navaline/local	Australia	Dareton, NSW	2016	bud wood	foundation
sinensis	Valencia	Australia	Dareton, NSW	2016	bud wood	foundation
medica	Citron-berti	Bhutan	Berti, Z/gang	2013	bud wood	foundation
medica	Citron-Tshanglajong	Bhutan	tshanglajong	2014	bud wood	foundation
medica	Citron-zurphey	Bhutan	zurphey	2013	bud wood	foundation
medica	Humpang-goling	Bhutan	goling	2013	bud wood	foundation
aurantifolia	lime-berti	Bhutan	berti	2013	bud wood	foundation
aurantifolia	lime-trongpam	Bhutan	trongpam	2013	bud wood	foundation
reticulata	Local-chukha	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-dagana	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-dorokha	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-kengkhar	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-narang	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-p/gatshel	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-s/jongkhar	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-samtse	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-sarpang	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-shumar	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-trongsa	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-tsirang	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Local-yadi	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
maxima	Pummelo-berti	Bhutan	Berti, Z/gang	2013	bud wood	foundation
maxima	Pummelo-goling	Bhutan	Goling, Z/gang	2012	bud wood	foundation

aurantifolia	Bearslime	Bhutan	Tsirangtoe, Tsirang		bud wood	foundation
medica	Citron trong pam lime	Bhutan	trong pam	2013	bud wood	foundation
medica	Citron	Bhutan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Dekoponkan/local	Japan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	encore/local	Japan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Hayaka	Japan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	sasaki/local	Japan	ARDC, Wengkhar	2012	bud wood	foundation
reticulata	Dorokha local	Bhutan	Dorokha		bud wood	mother plant
aurantifolia	lime Shemjong (SS)	Bhutan	Shemjong		bud wood	mother plant
aurantifolia	lime Tsirang toe(TT)	Bhutan	Tsirangtoe, Tsirang		bud wood	mother plant
reticulata	local 27/28 (shumar)	Bhutan	Shumar, P/gatshal		bud wood	mother plant
reticulata	Local T-13	Bhutan	Tsirangtoe, Tsirang	2012	bud wood	mother plant
aurantifolia	maxican lime	Bhutan	ARDC, Wengkhar	2012	bud wood	mother plant
medica	etrog	Bhutan	ARDC, Wengkhar	2012	bud wood	mother plant
tangelo	orlando tangelo	Bhutan	ARDC, Wengkhar	2012	bud wood	mother plant
aurantifolia	rangpur lime	Bhutan	ARDC, Wengkhar	2012	bud wood	mother plant
limon	rough lemom	Bhutan	ARDC, Wengkhar	2012	bud wood	mother plant
Japonica	Kumquat	Japan	ARDC, Wengkhar	2012	bud wood	mother plant
reticulata	Otha Ponkan	Japan	ARDC, Wengkhar	2012	bud wood	mother plant
reticulata	Teshiu Ponkan	Japan	ARDC, Wengkhar	2012	bud wood	mother plant
reticulata	Tarku	Nepal	ARDC, Wengkhar	2012	bud wood	mother plant
aurantifolia	Bears lime-tsirang	Unknown	Tsirangtoe, Tsirang	2012	bud wood	mother plant
reticulata	41-42/local (Khengkhar)	Bhutan	Mongar, Kengkhar		bud wood	quarantine
reticulata	47-48/local	Bhutan	Mongar		bud wood	quarantine
reticulata	51-52/local	Bhutan	Mongar		bud wood	quarantine
reticulata	57-58/local (khengkhar)	Bhutan	Mongar, Kengkhar		bud wood	quarantine
reticulata	AREP 2/local	Bhutan	ARDC, Wengkhar	2012	bud wood	quarantine
reticulata	AREP1/local	Bhutan	ARDC, Wengkhar	2012	bud wood	quarantine
reticulata	clementine	Bhutan	ARDC, Wengkhar	2012	bud wood	quarantine
sinensis	junar	Nepal	ARDC, Wengkhar	2012	bud wood	quarantine
sinensis	kiyomi	Japan	ARDC, Wengkhar	2012	bud wood	quarantine
sinensis	sweet spring	Japan	ARDC, Wengkhar	2012	bud wood	quarantine
aurantifolia	lime	Bhutan	Jechhu, Chucha	2019	bud wood	quarantine
sinensis	Pummelo	Bhutan	Pemaling, Samtse	2019	bud wood	quarantine

maxima	pummelo	Bhutan	Norbugang, P/Gatshal	2019	bud wood	quarantine
reticulata	mandarin	Bhutan	Chubu, Punakha	2019	bud wood	quarantine
maxima	pummelo	Bhutan	Gozhi, Dagana	2018	bud wood	quarantine
reticulata	mandarin	Bhutan	Pemaling, Samtse	2019	bud wood	quarantine
limon	frost ureka	Bhutan	ARDC, Bajo	2019	bud wood	quarantine
sinensis	sweet orange	Bhutan	Namchala, Tashiding	2018	bud wood	quarantine
reticulata	mandarin	Bhutan	Tama, Z/gang	2019	bud wood	quarantine
aurantifolia	lime	Bhutan	Norbugang, P/Gatshal	2019	bud wood	quarantine
reticulata	mandarin	Bhutan	Norbugang, P/Gatshal	2019	bud wood	quarantine
sinensis	sweet orange	Bhutan	Pelrithang, Sarpang	2000	bud wood	quarantine
maxima	pumelo	Bhutan	Norbugang, P/Gatshal	2019	bud wood	quarantine
reticulata	mandarin	Bhutan	Pelrithang, Sarpang	2019	bud wood	quarantine
reticulata	mandarin	Bhutan	Norbugang, P/Gatshal	2019	bud wood	quarantine
maxima	pumelo	Bhutan	Gozhi, Dagana	2019	bud wood	quarantine
bergamia	bigamate	Australia	Dareton, NSW	2013	seed	root stock
volkameria na	citrus volka meria	Australia	Dareton, NSW	2013	seed	root stock
sinensis	pera limeria	Australia	Dareton, NSW	2016	bud wood	root stock
trifoliata	poncirus pomeroy 2x	Australia	Dareton, NSW	2016	seed	root stock
trifoliata	poncirus pomeroy 4x	Australia	Dareton, NSW	2016	seed	root stock
trifoliata	scarlett mandaria trifoliate	Australia	Dareton, NSW	2016	seed	root stock
trifoliata	Poncirus pomerory 2x 0110081-10	Australia	Dareton, NSW	2016	seed	root stock
trifoliata	Poncirus rubudoux 4x	Australia	Dareton, NSW	2016	seed	root stock
volkameria na	Volkameria 4x SRA 1079-10	Australia	Dareton, NSW		seed	root stock
trifoliate	tri 22	Australia	Dareton, NSW	2017	seed	root stock
swingle	swingle	Australia	Dareton, NSW	2017	seed	root stock
C35 citrange	C 35	Australia	Dareton, NSW	2017	seed	root stock
c.ichangens is	Ichang papeda	Bhutan	ARDC, Wengkhar	2012	bud wood	root stock
citrus/poncirus trifoliata	Trifoliate	Bhutan	ARDC, Wengkhar	2012	bud wood	root stock
sinensis	Troyer	Bhutan	ARDC, Wengkhar	2012	bud wood	root stock
sinensis	washington navel	Bhutan	varietal trial field, ARDSC	2021	bud wood	quarantine
reticulata	mandarin	Bhutan	Paro	2021	bud wood	quarantine
reticulata	mandarin	Bhutan	Paro	2021	bud wood	quarantine

7) Potted plants issued to various organization as of 30th June, 2021

SN	Address	Qty (Nos)	Remarks
1	ARDSC Menchunna	300	
2	Municipal & chorten, Wangdue	900	Flower & herbs
3	Beatification Punakha	1922	
4	CNR, Lobesa	550	
5	DOA	1500	
6	Goen Shari Extension	30	
7	Gyelsung site Khotakha	300	
8	Kazhi Lhakhang	213	
9	Phangyul Extension	90	Flower & herbs
10	PHPA 1	405	
11	RBP Wangdue	169	
12	Rinchengang Lhakhang	50	
13	RLDC & Wind mill, Rubesia	140	
14	Royal Orchard Richa, Punakha	255	Flower & herbs
15	Tencholing Primary School	100	
16	Thimphu	350	
17	Tarathang Gelephu	60	
18	Wangdue Hospital	80	
19	RBA, Tencholing Wangdue	105	Flower & herbs
20	YERE Project Thimphu	70	Flower & herbs
21	Bumthang	320	
22	Aduit Tsirang	47	
23	Talo Lhakhang	75	
24	ARDC Bajo	476	
25	Bajo High School	200	
26	Tsirang Dzongkhang	75	Flower & herbs
Total		8582	

8) Seed samples tested in FY 2020-21

Beneficiary	Location	Crop	Variety	Germn %	MC %	Purity %
Tashi Wangmo	Logodama, Punakha	Beans	Local	93%	6%	100%
		Sag	Local	87%	6%	100%
		Onion		79%	7%	99%
		Broccoli		99%	7%	100%
		Tomato	Ratan	69%	7%	98%
		Asparagus		65%	8%	100%
		Tomato	ratan	89%	6%	99%
		Sag	Local	87%	6%	100%
		Onion		79%	7%	99%
		Broccoli		99%	7%	100%
		Tomato	Ratan	69%	7%	98%
		Asparagus		65%	8%	100%
Kinley	Nahi,	Tomato	ratan	89%	6%	99%

Wangchuk,	Wangdue	Sag	Local	87%	6%	100%
		Onion		79%	7%	99%
		bean	broloto	95%	70%	98%
		Chili	Local	51%	8%	99%
		Brinjal	Pplong	87%	8%	99%
		Bean	local	18%	8%	99%
		Bean	local	24%	8%	99%
		Cucumber	s.gunchu	97%	9%	99%
		cucumber	S.gunchu	93%	8%	100%
		Bean	broloto	99%	8%	100%
		Radish	local	96%	8%	100%
		M.green	local	99%	7%	98%
		Bean	broloto	95%	7%	98%
		Chili	Local	51%	8%	99%
		Brinjal	Pplong	87%	8%	99%
		Bean	local	18%	8%	99%
		Coriander	Local	nil	8%	98%
		Lettuce	Local	87%	7%	98%
Tashi Dema,	Hebisa, Wangdue	Brinjal	local	97%	8%	99%
		Bean	local	36%	8%	100%
		Bean	local	23%	8%	99%
		Bean	broloto	98%	8%	97%
		Bean	broloto	93%	7%	99%
		Bean	local	98%	8%	100%
		Brinjal	local	87%	8%	98%
		Chili	local	30%	8%	99%
		Radish	local	98%	9%	100%
Dorji Bidha,	Hebisa, Wangdue	Bean	broloto	95%	7%	98%
		Chili	Local	51%	8%	99%
		Brinjal	Pplong	87%	8%	99%
		Bean	local	18%	8%	99%
		Bean	local	24%	8%	99%
		Cucumber	s.gunchu	97%	9%	99%
		Coriander	Local	nil	8%	98%
Dawa, Changkha,	Gasatshogom, Wangdue	Lettuce	Local	87%	7%	98%
		Brinjal	local	97%	8%	99%
		Bean	local	36%	8%	100%
		Brinjal	local	87%	8%	98%
		Chili	local	30%	8%	99%
		Radish	local	98%	9%	100%
		Bean	broloto	95%	7%	98%
		Chili	Local	51%	8%	99%
		Brinjal	Pplong	87%	8%	99%
		Bean	local	18%	8%	99%
		Bean	local	24%	8%	99%
		Cucumber	s.gunchu	97%	9%	99%

Phub Gyem,	Daga, Wangdue	Cucumber	S.gunchu	93%	8%	100%
		Bean	broloto	99%	8%	100%
		Radish	local	96%	8%	100%
		M.green	local	99%	7%	98%
		Chili	local	97%	8%	100%
Tashi Mo	Daga, Wangdue	M.green	local	97%	8%	99%
		Bean	broloto	99%	8%	100%
		Pea	usui	99%	8%	99%
		Coriander	local	95%	8%	99%
		M.green	local	98%	8%	100%
		Pumpkin	local	99%	8%	100%
		Lettuce	sunny	93%	8%	100%
		Spinach	All green	72%	8%	99%
		Coriander	local	17%	10%	99%
Passang Wangmo,	Daga, Wangdue	Paddy	Bajo Kaap II,	91%	14%	100%
		Paddy	Bajo Maap II	92%	14%	100%
		Paddy	IR-20913	68%	13%	100%
Dorji, Wangmo, Drabesa, Daga	Daga, Wangdue	Paddy	Bajo Kaap II,	91%	14%	100%
		Paddy	Bajo Maap II	92%	14%	100%
		Carrot	E.nantes	74%	8%	100%
		Basil		4%	7%	98%
		Celery		96%	8%	98%
		Brinjal	Pplong	63%	7%	99%
		Green leave		99%	8%	99%
		Lettuce	Grate lake	74%	7%	98%
		Bitter gourd			8%	100%
Kinley Pem,	Daga, Wangdue	Onion		79%	7%	99%
		Broccoli		99%	7%	100%
		Tomato	Ratan	69%	7%	98%
		Asparagus		65%	8%	100%
		Tomato	ratan	89%	6%	99%
		Bean	rajma	90%	7%	100%
		0nion		65%	6%	98%

9) Biodiversity of insect pest associated with spring wheat

Scientific name	**Order**	**Family**	**Subfamily**	**Role**
Monolepta signata Olivier, 1808	Coleoptera	Chrysomelidae	Galerucinae	Minor pest
Altica sp. Geoffroy, 1762	Coleoptera	Chrysomelidae	Galerucinae	Minor pest
Aulacophora indica Gmelin, 1790	Coleoptera	Chrysomelidae	Galerucinae	Minor pest
Bruchidius mendosus Gyllenhal, 1839	Coleoptera	Chrysomelidae	Bruchinae	Occasional pest
Procecidochares atra Loew,	Diptera	Tephritidae	Tephritinae	Occasional

1862				pest
Dioxyna sororcula Wiedemann, 1830	Diptera	Tephritidae	Tephritinae	Occasional pest
Campiglossa sp. Rondani, 1870	Diptera	Tephritidae	Tephritinae	Occasional pest
Ensina sonchi Linnaeus 1767	Diptera	Tephritidae	Tephritinae	Occasional pest
Metasphenisca reinhardi Wiedemann, 1824	Diptera	Tephritidae	Tephritinae	Occasional pest
Teleopsis sp. Rondani, 1875	Diptera	Diopsidae	Diopsinae	Occasional pest
Cletus punctiger Dallus,1852	Hemiptera	Coreidae	Coreinae	Minor pest
Plautia sp. Stal, 1867	Hemiptera	Pentatomidae	Pentatominae	Minor pest
Nezara viridula Linnaeus, 1758	Hemiptera	Pentatomidae	Pentatominae	Minor pest
Menida formosa Westwood,1837	Hemiptera	Pentatomidae	Pentatominae	Minor pest
Sitobion miscanthi Takahashi, 1921	Hemiptera	Aphididae	Aphidinae	Major pest
Spilostethus hospes Fabricius, 1794	Hemiptera	Lygaeidae	Lygaeinae	Occasional pest
Eysarcoris ventralis Westwood, 1837	Hemiptera	Pentatomidae	Pentatominae	Minor pest
Camptopus sp. Amyot & Audinet serville, 1843	Hemiptera	Alydidae	Alydinae	Minor pest
Eurydema pulchrum Linnaeus, 1758	Hemiptera	Pentatomidae	Pentatominae	Minor pest
Exitianus sp. Ball, 1929	Hemiptera	Cicadellidae	Deltocephalinae	Minor pest
Cofana unimaculata Signoret, 1854	Hemiptera	Cicadellidae	Cicadellinae	Minor pest
Poophilus sp.	Hemiptera	Aphrophoridae	Aphrophorinae	Minor pest
Nezara viridula f. viridula Linnaeus	Hemiptera	Pentatomidae	Pentatominae	Minor pest
Leptocorisa acuta Thunberg, 1783	Hemiptera	Alydidae	Micrelytrinae	Minor pest
Graptostethus incertus Walker, 1872	Hemiptera	Lygaeidae	Lygaeinae	Minor pest
Plutella xylostella Linnaeus, 1758	Lepidoptera	Plutellidae	Plutellinae	Occasional pest
Syntomoides imaon Cramer, 1780	Lepidoptera	Erebidae	Arctiinae	Occasional pest
Danaus chrysippus Linnaeus, 1758	Lepidoptera	Nymphalidae	Danainae	Occasional pest
Lampides boeticus Linnaeus, 1767	Lepidoptera	Lycaenidae	Polyommatinae	Occasional pest
Colias eurytheme Boisduval, 1852	Lepidoptera	Pieridae	Coliadinae	Occasional pest
Helicoverpa armigera Hübner, 1808	Lepidoptera	Noctuidae	Heliothinae	Minor pest
Mythimna separata Walker, 1865	Lepidoptera	Noctuidae	Hadeninae	Major pest
Maruca vitrata Fabricius, 1787	Lepidoptera	Crambidae	Pyraustinae	Occasional pest
Potanthus dara Kollar,	Lepidoptera	Hesperiidae	Hesperiinae	Occasional

1842				pest
Aglaomorpha plagiata Walker, 1855	Lepidoptera	Erebidae	Arctiinae	Occasional pest
Vanessa cardui Linnaeus, 1758	Lepidoptera	Nymphalidae	Nymphalinae	Minor pest
Artona zebraica Butler, 1876	Lepidoptera	Zygaenidae	Procridinae	Occasional pest
Nomophila noctuella Denis & Schiffermüller, 1785	Lepidoptera	Crambidae	Spilomelinae	Minor pest
Crombrugghia distans Zeller, 1847	Lepidoptera	Pterophoridae	Pterophorinae	Occasional pest
Scirpophaga incertulas Walker, 1863	Lepidoptera	Crambidae	Schoenobiinae	Minor pest
Atractomorpha acutipennis Guérin-Méneville, 1844	Orthoptera	Pyrgomorphidae	Pyrgomorphinae	Minor pest
Oxya velox Fabricius, 1787	Orthoptera	Acrididae	Oxyinae	Minor pest
Phaeroptera spinosa Bei-Bienko 1954	Orthoptera	Tettigoniidae	Phaneropterinae	Occasional pest
Euconocephalus sp.	Orthoptera	Tettigoniidae	Conocephalinae	Minor pest
Patanga succincta Johannson, 1763	Orthoptera	Acrididae	Crytacanthacridinae	Minor pest
Pyrgomorpha sp.	Orthoptera	Pyrgomorphidae	Pyrgomorphinae	Minor pest
Trilophidia annulata Thunberg, 1815	Orthoptera	Acrididae	Oedipodinae	Minor pest
Oecanthus indicas Saussure, 1878	Orthoptera	Gryllidae	Oecanthinae	Minor pest
Phaneroptera roseata Walker 1869	Orthoptera	Tettigoniidae	Phaneropterinae	Minor pest
Aiolopus thalassinus Fabricius, 1781	Orthoptera	Acrididae	Oedipodinae	Minor pest
Acrida exaltata Walker, 1859	Orthoptera	Acrididae	Acridinae	Minor pest
Eupholidoptera sp.	Orthoptera	Tettigoniidae	Tettigoniinae	Minor pest
Conocephalus sp.	Orthoptera	Tettigoniidae	Conocephalinae	Minor pest
Conocephalus fuscus Fabricius, 1793	Orthoptera	Tettigoniidae	Conocephalinae	Minor pest

10) Biodiversity of Natural enemies associated with spring wheat crop.

Scientific name	**Order**	**Family**	**Sub family**	**Role**
Coccinella septumpunctata Linnaeus, 1758	Coleoptera	Coccinellidae	Coccinellinae	Predator
Oenopia dissecta	Coleoptera	Coccinellidae	Coccinellinae	Predator
Cheilomenes sexmaculata	Coleoptera	Coccinellidae	Coccinellinae	Predator
Oenopia sauzeti Mulsant, 1866	Coleoptera	Coccinellidae	Coccinellinae	Predator
Micraspis univittata	Coleoptera	Coccinellidae	Coccinellinae	Predator
Cryptogonous quadriguttatus Weise, 1895	Coleoptera	Coccinellidae	Coccinellinae	Predator
Coccinella transversalis Fabricius, 1781	Coleoptera	Coccinellidae	Coccinellinae	Predator
Coelophora bissellata Mulsant, 1850	Coleoptera	Coccinellidae	Coccinellinae	Predator
Harmonia sedecimnotata	Coleoptera	Coccinellidae	Coccinellinae	Predator

Fabricius, 1801				
Harmonia eucharis Mulsant, 1853	Coleoptera	Coccinellidae	Coccinellinae	Predator
Harmonia octamaculata Fabricius, 1781	Coleoptera	Coccinellidae	Coccinellinae	Predator
Propylea luteopustalata	Coleoptera	Coccinellidae	Coccinellinae	Predator
Scymnus (*Scymnus*) *nubilus* Mulsant, 1850	Coleoptera	Coccinellidae	Scymninae	Predator
Euthera fascipennis Loew, 1854	Diptera	Tachinidae	Phasiinae	Parasitoid
Winthemia trinitatis Thompson, 1963	Diptera	Tachinidae	Exsoristinae	Parasitoid
Eupeodes corollae Fabricius, 1794	Diptera	Syrphidae	Syrphinae	Predator
Platycheirus scutatus Meigen, 1822	Diptera	Syrphidae	Syrphinae	Predator
Microdon analis Macquart, 1842	Diptera	Syrphidae	Syrphinae	Predator
Syrphus ribesii Linnaeus, 1758	Diptera	Syrphidae	Syrphinae	Predator
Episyrphus balteatus De Geer, 1776	Diptera	Syrphidae	Syrphinae	Predator
Sphaerophoria Lepeletier and Serville, 1828	Diptera	Syrphidae	Syrphinae	Predator
Episyrphus viridaureus Wiedemann, 1824	Diptera	Syrphidae	Syrphinae	Predator
Andrallus spinidens Fabricius, 1787	Hemiptera	Pentatomidae	Asopinae	Predator
Vilius melanopterus Stal, 1863	Hemiptera	Reduviidae	Ectrichodiinae	Predator
Nabis capsiformis Germar, 1838	Hemiptera	Nabidae	Nabinae	Predator
Pimpla pedalis Cresson, 1865	Hymenoptera	Ichneumonidae	Ichneumonidae	Parasitoid
Pimpla sp. Fabricius, 1804	Hymenoptera	Ichneumonidae	Ichneumonidae	Parasitoid
Metopius sp. Panzer, 1806	Hymenoptera	Ichneumonidae	Ichneumonidae	Parasitoid
Gotra sp.	Hymenoptera	Ichneumonidae	Ichneumonidae	Parasitoid
Delta campiniforme campaniforme Fabricius, 1775	Hymenoptera	Ichneumonidae	Ichneumonidae	Parasitoid
Agrypon sp.	Hymenoptera	Ichneumonidae	Ichneumonidae	Parasitoid
Apis mellifera mellifera	Hymenoptera	Apidae	Apinae	Pollinator
Apis cera Fabricius, 1793	Hymenoptera	Apidae	Apinae	Pollinator
Ischnojoppa luteator Fabricius, 1798	Hymenoptera	Ichneumonidae	Ichneumonidae	Parasitoid
Polistes sp. Latreille, 1802	Hymenoptera	Vespidae	Vespidae	Predator
Mantispa sp. Illiger, 1798,	Neuroptera	Mantispidae	Mantispinae	Predator
Chrysoperla sp.	Neuroptera	Chrysopidae	Chrysopinae	Predator
Hemerobius sp.	Neuroptera	Chrysopidae	Chrysopinae	Predator
Pentala flavescens Fabricius, 1798	Odonata	Libellulidae		Predator
Conocephalus maculatus Le Guillou, 1841	Orthoptera	Tettigoniidae	Conocephalinae	Predator
Palpopleura sexmaculata Fabricius, 1787	Odonata	Libellulidae		Predator

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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