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Bajothang, Wangduephodrang
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ROYAL GOVERNMENT OF BHUTAN

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Foreword

It is a pleasure to publish the 32th Annual Technical Report of ARDC Bajo for the financial year 2016-17. The report format follows the earlier format for standardized reporting across ARDCs.

The annual report synthesizes the research and development activities carried out within a year from July to June coinciding with the RGoB's financial year. It covers research carried out in field crops, horticulture, and engineering sector. The report also provides highlights of activities implemented at Chimipang Royal Project. Further, the report presents the human resources and visitors to the centre in addition to the technical findings.

Besides generating relevant and appropriate technologies, their usage and applicability in the field need to be tested, validated and then promoted. The centre thus accords high priority in testing and applying the generated technologies in the field in partnership with *Dzongkhag* extension colleagues. In some cases, we directly bring our best technologies and promote among farming communities as part of research outreach program. It is believed that showcasing and promoting of technologies is also our prime responsibility and this fits very well with the new and expanded mandate of research and development as a cyclical process. We continue to build and strengthened our linkages and partnerships with regional and international agricultural research organizations, other national centres, extension partners, farmers and more.

This report is intended to serve as a useful technical reference to all stakeholders involved in agricultural research and rural development to attain Gross National Happiness in Bhutan and beyond.

Trashi delek to all the readers.

Pema Chofil
Program Director

FROM THE EDITORS

The Ministry of Agriculture and Forests plays a crucial role in poverty alleviation and improvement in the livelihood of the Bhutanese people. This can only be achieved by enhancing the agricultural productivity by stimulating growth through technological innovations. The Research and Development centres are in the forefront in generation and dissemination of appropriate technologies.

This publication highlights the annual research and development work carried out from 1st July till 30th June of the financial year 2016-17. After Research Centres became Research and Development Centres, equal importance is given to promoting and disseminating proven technologies. Research component includes mainly varietal evaluation trials of field and horticulture crops. In addition, research activities on soil fertility management and pest (insect, disease, and weed) management and seed testing are important. This report includes work on optimum nutrient management of major crops like rice and wheat and pest management. The development section highlights activities mainly given in the form of support services, including engineering services that the sector provides not only to the Centre but also to a larger RNR family. It also includes provision of improved agricultural inputs such as seeds and seedlings of improved varieties, fertilizers, farming tools and mushroom production. In addition, farmers are empowered through transfer of skills, knowledge and farming technologies.

We hope this publication will serve as a useful information base and reference to our readers including academicians, development workers, students and field extension workers.

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50	Deo Raj Pradhan	Certificate in Driving	Driver- II
51	Dorji Choden	Certificate (X)	PABX Operator
52	Bago	Certificate (VI)	Messanger
53	Nedup	Certificate in Driving	Tractor Driver
54	Farm Attendants (Bajo)		25 numbers
55	Farm Attendants (ADTC)		44 numbers
56	Farm Attendants (ARDSC Tsirang)		18 numbers
57	Night Guard		1 number

*Transferred **Resigned

Summary

During the 2016-17 financial year, the field crops program evaluated more than 100 accessions of cereal crop germplasm of rice, wheat, and quinoa. A total of 78 entries at various level of evaluation including five at advanced stage of evaluation were carried out under the rice commodity. The five advanced stage varieties included TME 80518, Zhonghan, Sarju-52 and Ceres 1&2, which are concurrently evaluated in the farmers' fields in different dzongkhags as part of multi-locational trials. The best performing ones will be selected and proposed for release in 2018. The other activities under the rice commodity included on-station demonstration of released varieties and seed production for rice promotional programme. Under the wheat commodity, the Centre produced more than 2 MT of wheat seeds of recently released varieties, Bumthangkadrupchu, Bajosokhakaa and Gumasokhakaa which will be used for wheat promotional programmes in the potential Dzongkhags. The other activities included on-station research on bio-fortified wheat varieties and on-farm demonstration of integrated nutrient management technologies in Wangdue-Punakha valley. Under the oil seed commodity, two mustard varieties; Barisharisha 14 and Lumley tori and a sunflower variety introduced from Nepal were tested at the station. The Centre also made some progress on quinoa in terms of on-station and on-farm evaluation in the region. A number of demonstrations were conducted in the region from which seeds were collected for further multiplication in the current financial year. From the on-station trial, the centre was able to confirm its potential as both spring and summer crops. The yields were quite appreciable and in order to promote this new crop, there will be more evaluation and demonstrations in the near future.

Horticulture crops research and development focus on improving rural livelihood and to achieve vegetable and fruit self-sufficiency in the west central region. Horticulture sector staff of ARDC Bajo also serves as the counterparts to JICA Experts in implementation of Integrated Horticulture Promotion Project IHPP activities. The research and IHPP activities of the horticulture sector include germplasm collection, evaluation, generation of crop management technology, post-harvest practices, improved seeds, plant propagation techniques and maintenance of mother plants and breeder seeds of released crops besides varietal evaluation. The project focuses on the key features the horticulture development with respect to building of nursery capacities, crop production technology, and then the extension approaches. The key activities include on broadening the genetic base of the prioritized horticultural crops through either introduction or selection from local diversity. The on-station research comprise of study on fruits and nuts, vegetables, and medicinal and aromatic plants performance at both Bajo and Sub-station Tsirang. ARDSC Mithun also manages National Citrus Repository for production of clean citrus propagation material through regular biological indexing and testing of identified mother trees. In addition, the sub-center is also strengthening the facilities for large cardamom repository to enhance research and development.

On stations, progress in 2016-17 includes development of on-station research field infrastructures and revitalization of soil health, performance evaluation of introduced fruits and technology generation. This on-station serves as a foundation to the system to sustainably support and promote horticulture development.

Engineering sector mostly deal with the implementation of developmental activities such as site supervision services of construction work, infrastructure development, and road maintenance and irrigation infrastructure.

The Research Communication unit of this centre is responsible in facilitating and dissemination of successful agriculture research findings to its client service providers and relevant institutions for technological adoption. The process of technologies dissemination is largely done through production and distribution of extension leaflet and brochure, co-ordinate study visits to the centre, conducting field days to demonstrate new technologies,

organizing the review workshop and creating online information sharing platforms. The sector was also responsible for co-ordinating the Annual agriculture sample survey data management for the west-central region.

During the fiscal year 2016-2017, the unit in consultation with concerned sector has documented six technical reports on new technologies generated by the centre. The sector also developed three posters on emerging agriculture technologies for display at the centre. Apart from documentation, the sector routinely updated the information about the centre in the centre's webpage www.rcbajo.gov.bt *with updated news, information and reports. The unit also contributed relevant news and articles in MoAF webpage for information sharing. In addition, the unit also provided protocol services to diverse groups of visitors interested in agriculture research and development.*

1. FIELD CROPS

1.1. Rice research on-station and on-farm evaluation of rice

In 2016-2017, the field crops program evaluated 90 germplasm at various stages of evaluation. The evaluations were done both on-station and on-farm. The test materials included the advance lines from last year's trial, local land races, introductions from the International Rice Research Institute (IRRI), and the Banaras Hindu University (BHU) in India. The details of rice research activities undertaken by ARDC Bajo are discussed under the following headings.

1.1.1. Introduction nursery

Forty lines received from IRRI as International Irrigated Rice Observation Nursery (IIRON) were evaluated for uniformity, resistance against diseases, plant height crop stand and maturity under Bajo condition. From these, twenty best lines were selected for 2017 observation nursery from which lines will undergo vigorous screening and best ones will be selected for replicated initial evaluation trial (IET) in 2018.

The information on the performance of selected lines are presented in Table 1 below. The selected lines fall within a maturity duration of 130-160 d with plant height ranging from about 90 cm to 120 cm.

Table 1: Agronomic performance of IIRON lines on-station.

Sl. No	Varieties	DTF	Plant height (cm)	No of tillers hill^{-1}	Grain yield t ha^{-1}
1	IRRI 154	119	96	14	7.61
2	IRRI 156	120	104	13	8.91
3	IR 11A 306	122	100	11	8.87
4	IR 12N 110	125	104	16	8.40
5	IR 14D 155	122	105	17	8.18
6	IRRI 174	119	99	17	8.32
7	IRRI 123	118	101	17	8.23
8	IR 12L 248	114	99	16	8.87
9	GSR IR1-3-S6-XI-YI	118	97	11	7.51
10	IR IIA 534	113	100	19	8.31
11	IRRI 146	117	92	10	8.87
12	GSR IR1-14-D12-L1-L1	119	99	13	8.54
13	IR IIA 501	113	110	16	8.79
14	IRRI 180	122	104	15	8.24
15	IR IIA 255	122	104	18	7.45
16	IR 1OM 210	109	100	16	25.88
17	IR 12L 130	114	92	23	9.00
18	IR IIN 313	123	109	15	8.20
19	IRRI 179	120	107	21	29.40
20	IR 10M 300	119	100	14	7.38
21	BK2 (standard check)	118	105	18	7.41

1.1.2. Initial evaluation trial (IET)

Under IET, 18 entries including standard check Bajo Kaap2 were evaluated. The evaluation was done in experimental plot size of 3x4 m in randomized complete block design with three replications. All standard cultural practices were applied including recommended doses of NPK and herbicide for the control of grasses and sedges. NPK and butachlor were applied at 70:30:30 kg and 1.5 kg ai/ha respectively. In addition to herbicide application, one manual weeding was carried out one month after transplanting. Irrigation water was applied as and when required and no chemical insecticides/fungicides were used to control the diseases and pests. The crops were harvested at 85% maturity in October from an area of 5.04 sqm.

All the entries performed well and in terms of grain yield, however, the entries did not show any statistically significant difference (P_{05}=0.25). The grain yield in absolute values ranged between 5-7 t/ha (Figure 1). The test materials were actually the advance lines of 2014 IRRI nursery and were the best selections from the previous two years of varietal evaluations at the research station. Among the germplasm tested in the current experiment, IR 11A-208, IR 06N-170 and IR 09N-522 were the top three performers with grain yield record of 7 t/ha, 6.8 t/ha and 6.6 t/ha respectively. Lowest grain yield was recorded in IR 09A-228 (5.5 t/ha) and CT16658-5-2-3SR-2-1(5.56 t/ha), and their values were also below that of the standard check (BK 2) which produced 6t/ha. IR 06M-150, IR 9L-120, IR 09A-220, IR 10N-269, IR 05A-235, and Sahabhaji yielded slightly over 6 t/h ha. Based on the yield performance and other parameters, 14 entries were selected for advanced evaluation trial in 2017 season.

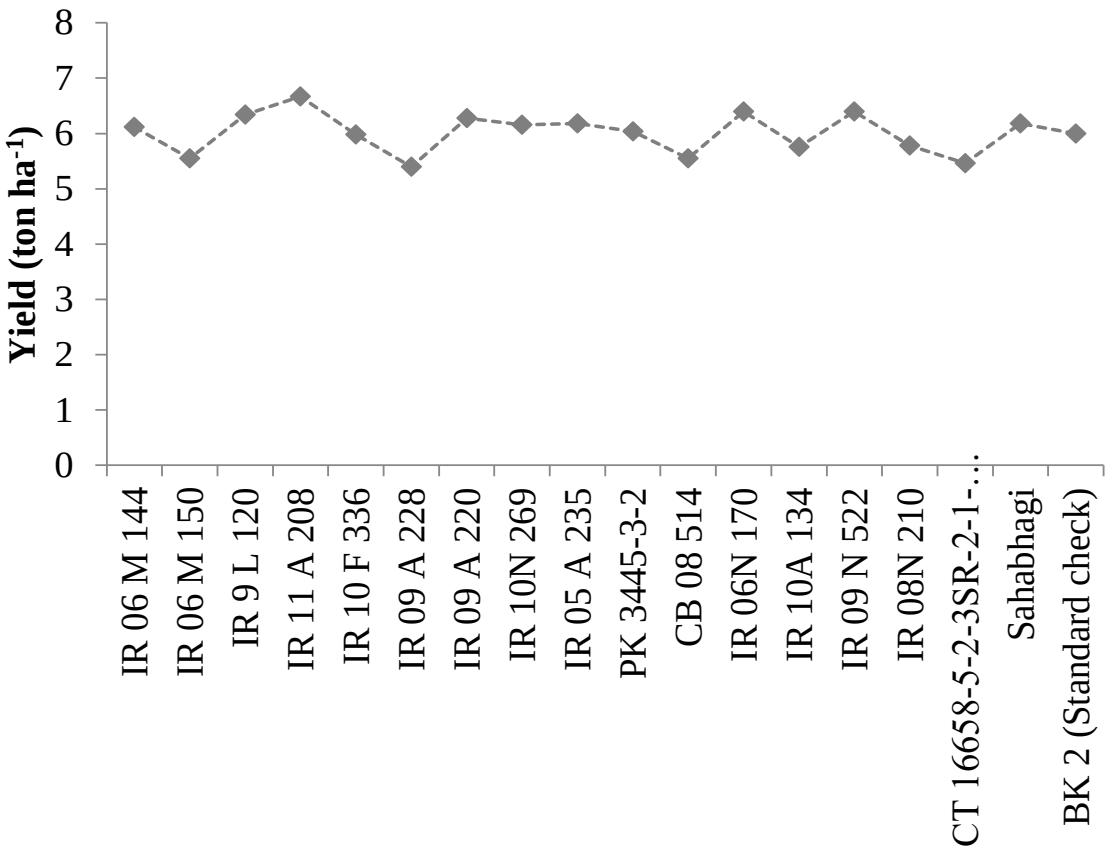


Figure 1: Grain yield of eighteen germplasm

1.1.3. Advance Evaluation Trial (AET)

Five advance lines from the previous years' trial were re-evaluated on a larger plot following standard protocol and same management practices. Bajo Kaap 2 was used as the standard check and the grain yield from these entries were compared to that of Bajo Kaap2.

At 85% maturity, cropcut was carried out and their yield was compared as shown in Table 2. The grain yield of the test varieties ranged between 6.6 t/ha to 8.14 t/ha. Highest yield was obtained from TME 80518 followed by Sarju 52 with 6.51 t/ha and the lowest yielding entry was Ceres 1 (6.1 7 t/ha), though not much different from the standard with 6.43 t/ha.

In terms of days to flowering (DFT), all the entries took less number of days (average of 124 d) as compared to the standard check (125). Overall, the entries had more or less the same maturity duration, thus, would fall in the medium maturity group. On the other hand, most of the entries were taller than the standard check (96 cm) except Sarju-52 and Zhunghun with plant height of 91 cm and 87 cm respectively. In terms of number of tillers per hill, all the test entries fall under the same category and ranged from 9 to 12.

Table 2: Yield difference among the advance lines evaluated on larger plot on-station

Treatment	DTF	Plant Height (cm)	No of Tillers hill^{-1}	Grain yield (t ha^{-1})
TME 80518	122	109	12	8.14
ZHUNGHAN	125	87	11	6.26
SURJU 52	127	91	11	6.51
CERES 1	124	107	10	6.17
CERES 2	126	104	9	6.26
Average	124	99.6	10.6	6.67
Bk-2 (std check)	125	96	12	6.43

1.1.4. Seed production

From the trial plots, seed production and demonstration blocks, 6 MT paddy seed was produced in 2016 season (Table 3). Paddy seeds of the released varieties such as Bajo Kaap1and 2; Bajo Maap1 and 2; IR-64; IR20913; No.11 and Khangma Maap were produced to support promotional programmes in the Dzongkhags. Bajo also produced some seeds of unreleased varieties like BRRI dhan 28 and IR28 for spring crop and adhoc request. The seeds of varieties such as Black rice, BHT-1, BHT-2 and BHT-3 were for demonstration purpose only since they are longer duration varieties and quite susceptible to diseases.

Table 3: Quantity of seed produced from released and potential varieties

Sl No	Variety	Quantity (kg)	Remark
1	Bajo kaap -1	166	Released variety
2	Bajo kaap -2	492	
3	Bajo maap -1	141	
4	Bajo maap-2	540	
5	IR 64	1056	
6	IR 20913	500	
7	Khangma map	136	
8	NO 11	37	
9	IR 28	1000	Not released
10	BRRI dhan28	258	
11	Black Rice	80	
12	Bhu-1	143	
13	Bhu-2	156	
14	Bhu-3	142	
15	Nabja	160	local variety
16	Tan Tshering	200	
17	Trial boarders (Mixture)	809	from trials
	Grand total	**6, 016**	

1.1.5. Characterization of germplasm

ARDC maintains breeder seeds of seven improved rice varieties such as IR-64, IR20913, Bajo Maap1, Bajo Maap2, Bajo Kaap1, Bajo Kaap2 and Khangma Maap. These varieties have been widely promoted in the mid-altitude regions of the country ever since their official release but basic information on the plant morphology and agronomic traits have not been documented. The rice researchers have initiated work on basic characterization of released varieties including some of the popular local land races. ARDC-Bajo, being the centre for field crops and rice commodity program is the repository of information for all the rice varieties, both released and traditional varieties. Table 4 provides some basic information about the released varieties. The local varieties studied included Ngabja, Tan Tshering and Bonday (Table 5).

Table 4: Varietal traits of released varieties grown in the region.

Characteristics	Unit	Varieties						
		IR-64	IR-20913	Khangma Maap	Bajo Kaap-I	Bajo Kaap-II	BM1	BM2
Agronomic traits								
Days to Flowering (DTF)	No of days to 50% flowering	115-120	90-95	100-105	120-125	120-125	115-120	100-110
Days to maturity (DTM)	No of days to 85% maturity	150-160	125-130	125-130	145-150	145-150	150-160	135-140
Leaf sheath colour	colour	green	green	green	green	green	green	green

Glag leaf angle	erect/intermediate/ drooping	erect	intermediate	horizontal	erect	Erect	erect	Erect
Leaf pubescence	glabrous /pubscent	glabrous	glabrous	pubscent	glabrous	globrous	glabrous	glabrous
Ligule colour	colour	whitish	whitish	whitish	whitish	whitish	whitish	Whitish
Ligule shape	Acuminate/ truncate/ cleft	2-cleft	2-cleft	2 cleft	2 cleft	2-cleft	2-cleft	2-cleft
Plant height at heading	cm	80-85	130-135	120-125	100-105	100-105	95-100	95-100
Panicle exertion	full/moderate	full	full	full	full	full	full	full
Panicle type	compact/ open	compact	open	open	compact	compact	compact	compact
No. of grains per panicle	No	150-160	115-120	90-100	140-150	140-150	125-135	130-140
Panicle length	cm	25-30	23-26	18-20	22-25	24-27	22-24	23-26
No. of tillers per hill	Nos	13-14	10	10	14-16	15-17	13-15	13-14
Presence of awn	Present/ absent	absent	present	absent	absent	absent	present (spiny)	present (spiny)
Presence of apiculus	Yes/No	not prominent	not prominent	prominent	not prominent	not prominent	prominent	prominent
Apiculus colour	colour	grain colour	same as gain colour	dark brown	same as grain colour	same as grain colour	purplish brown	purplish brown
Threshability	Easy/Medium/High	easy	easy	easy	easy	easy	easy	easy
Grain yield at 14% MC	t/ha	6-7 t/ha	4-5t/ha	3.5-4.5 t/ha	6-7 t/ha	6-7t/ha	5-6 t/ha	5-6 t/ha
Milling recovery	%	70-75%	70-75%	80-85%	75-80%	75-80%	75-80%	75-80%
1000 grain weight	gm	28.5	28.6	30	27.27	28	27	27.22
hull colour	colour	golden	golden	straw with brown furrow	straw	straw	dark golden/ straw	dark/ dirty straw
Kernel colour	colour	white	white	red	white	white	light red	Red
Grain length (with hull)	mm	9.56	9.29	7.02	9.06	9.05	8.90	8.38
Grain width (with hull)	mm	2.28	3.20	4.12	3.09	3.43	3.08	4.08
Grain size	based on length	extra long	extra-long grain	long grain	extra-long grain	extra long	extra long	extra long
Grain length (milled rice)	mm	7.41	7.05	5.87	6.85	6.66	6.85	6.15
Grain width (milled rice)	mm	2.33	2.63	3.13	2.46	2.27	2.52	2.75
L/B ratio	ratio	3.20	2.70	1.88	2.79	2.84	2.73	2.23
Scent	Yes/No	absent	absent	absent	absent	absent	absent	absent
Grain shape (dehulled)	based on l/b ratio	slender	medium slender	bold	medium slender	medium slender	medium slender	medium bold

Table 5: Varietal characteristics of premium local rice varieties of the region

General information	Bonday	Tan Tshering	Ngabja	Remarks
Recommended agro-eco zone	800-1500m	1000-1500	800-1500	mid-altitude regions of the country
Days to Flowering	95-100	130	140	No of days to flower
Days to maturity	125-135	165-170	170-175	No of days to mature 85%
Leaf sheath colour	light green	green	green	colour
Ligules colour	whitish	whitish	whitish	colour
leaf pubescence	glabrous	glabrous	glabrous	glabrous/pubescent
Glag leaf angle	erect	erect	semi-erect	flage leaf attitude
Plant height at heading (cm)	90-95	120-130	130-140	
Panicle exersion	fully exerted	fully exerted	fully exerted	exersion character
Panicle type	open	open	open	open/compact/loose
No. of grains per panicle	100-110	160-170	100-110	nos of grains
Panicle length	21-25	25-29	21-25	length in cm
No. of tillers per hill	10-12	7-10	6-8	Nos of tillers
Presence of awn	Present (long)	absent	absent	Presence/absence of awns
Presence of apiculus	not prominent	prominent	prominent	Upper 1/4th of the panicle has awns and hence apiculus considered as not prominent
Apiculus colour	grain colour	grain colour	grain colour	same as the grain
Shattering	high	high	high	
Grain yield at 14% MC	2.2-2.8 t	3.00-4.00	3-3.5.00	t/ha
1000 grain weight	24.6	25.6	29	
hull colour	golden/straw	golden/straw	golden/straw	
Kernel colour	white	white	white	
Grain size	long medium	long grain	short	Based on grain length (mm) extra-long, long medium and short
Grain length (dehulled)	6.46	6.69	6.02	Measurement of dehulled brown rice
Grain width (dehulled)	2.27	2.22	2.68	
L/B ratio	2.84	3.02	2.3	
Scent	Yes	no	no	
Grain shape	medium slender	slender	medium bold	based on l/b ratio

1.1.6. Improving local varieties through cross-breeding

Bhutan has an area of 38,394 km^2 and with a population of approximately 700,000. The cultivated area is only about 3%, including wetland, dry land for horticulture and fallow rotation. Around 23,000 hectare of land is under rice in Bhutan with production of 78,000 tones. This meets less than 50% of Bhutan's rice requirement. The deficit is met from rice imports from India. Rice is indispensable in the Bhutanese culture, tradition, religion and farmers' livelihoods. The per capita consumption of rice is computed at 140 kg milled rice per year.

Rice is grown from tropical lowlands (200 m) in the south up to elevations of 2700 m in the north. Rice environments are broadly grouped into three altitude zones. The high altitude zone, also called as warm temperate zone, covers rice areas from 1600 m and above. Around 20% of the rice areas fall under this zone. The mid altitude zone accounts for 45% of the rice area with elevation ranging from 700 m to 1500 m. the remaining 35% is the low altitude zone (200 m – 600 m) in the southern part of Bhutan and also referred to as the wet sub-tropical zone.

History of rice breeding in Bhutan

The introduction of modern rice varieties was begun in 1982 following the establishment of then the Centre for Agricultural Research and Development (CARD), now renamed as Agricultural Research and Development Centre (ARDC). Many introduced rice varieties often fail due to the uniqueness and specificity of local growing conditions. To overcome such problems, a cross breeding program was started in 1995 in Bhutan to assimilate desired genes in Bhutanese local varieties. Improved varieties accounts about 42% of the national rice area.

IR 64 was the first modern rice variety released in 1988 in Bhutan. In 1999, four varieties were released of which only one (BR 153) was intended for the low altitude zone. BW 293 was released in 1990 for the low altitude zone. However this variety did not gain popularity due to its short plant stature. Barkat was released as a first crop variety in rice- rice sequence with the introduction of rice double cropping in the mid altitude zone in late 1980s. In 2002, *Yusiray kaap 1* and *Yusiray maap 1* which incorporated blast resistance genes in the native varieties were released. In 2010, two drought tolerant varieties (Bhur kambja 1 and 2) were released for low altitude. Released rice varieties have good yield potential and diverse genetic background.

Objectives in breeding rice

Yield: Rice is a crop with a high yield potential. Yet, the average yield of existing rice varieties in Bhutan is one of the lowest in the world. Yield is a complex character which may be influenced by many physiological processes within the plant. It is also affected by the response of the genotype to the environmental factors in which the plant is grown. In addition to assembling into a variety the most desirable combination of genes affecting the plant's capacity to manufacture food materials and to store them in the grain, it is necessary to include genes for resistance to those conditions in the environment which unfavorably affect the yield, such as lodging, disease resistance, and others. In Bhutanese breeding context, yield improvement of the local varieties is a priority.

Disease resistance: The principles of breeding for disease resistance in rice do not differ from those that apply to the breeding for resistance to disease in wheat. Resistant varieties must first be found and then genes for resistance may be transferred to adapted varieties. The principal rice disease that has received attention in Bhutan is blast. Therefore to incorporate disease resistant genes into local blast susceptible variety is one of our breeding goals.

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

to give consideration to genetic improvement in the grain characters, and to the milling and cooking characteristics of the rice.

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

Parents: Females parent- Shengamaap, Tan-tshering and Nabja; Male parent: IR 64, HUR 105, HUR 917, and HUR4-3

A total of 5 crosses were made between the varieties. The half-naked seeds were harvested except from the cross between Shengamaap and HUR105. The harvested half naked seeds will be sown in next season.

Table 6: List of crosses made

Female parent	Male parent	Remarks
Nabja	IR-64	1 panicle harvested
Tan-tshering	IR64	2 panicle harvested
Tan-tshering	HUR4-3	2 panicle harvested
Shengamap	HUR105	No harvest
Tan-tshering	HUR917	3 panicle harvested

Conclusion: The domestic rice production in Bhutan meets only about half of the national requirement despite the Royal Government of Bhutan wishing to raise the level of rice self-sufficiency in the country. One of the ways to increase production has been use of high yielding modern varieties. Rice research and development started in 1982 in Bhutan. The national rice research program is aimed towards developing new varieties coupled with better crop management practices.

A total of 23 varieties have been developed and released by DoA. Of the 23 varieties, 15 varieties are introductions and 8 have been developed locally. The ARDC-Bajo is making an attempt to bring back the rice breeding program into track after few years of neglect.

Three local varieties (Nabja, Tantshering and Shengamaap) are used as female parents and have been crossed with IR 64, and HUR varieties. The harvested half naked seeds are sown in pot for further evaluation and selection.

1.1.7. Evaluation of rice varieties introduced from Indian University,

During an official study visit to BHU (Banaras Hindu University), Varanasi, India by Rice Specialist and Field Crops Official, they brought back few kilos of paddy varieties on request from the university. Due to limited suitable varieties for rice double cropping in Bhutan, the officials made request for some early maturing and disease resistant paddy varieties from the university. HUR varieties were bred for hill conditions of Uttar Pradesh and Uttarakhand of India, and the varieties should be suitable in our conditions.

Six different HUR varieties (HUR-105, HUR-3022, HUR-917, HUR-4-4, HUR-B-2-1 and HUR-B-10-9) were brought and evaluated in introduction nursery during 2016-17 paddy

seasons. The nursery was established on 3rd June, 2016 and transplanted on 1st July, 2016, roughly a month after nursery establishment and harvested in the month of October.

Materials and Methods: The nursery was established following normal practice in the center and no chemical fertilizers were applied. Large single plot design was used during transplantation. Nutrient management, irrigation application and other agronomic practices were carried out based on requirement.
The morphological and agronomic data on plant height, number of tillers, maturity date and yield were collected following basic research protocol and procedures. For plant height data, the average of nine weeks data was used and the average of 10 hills was used for number of tillers data.

Results and discussion: Among the varieties, HUR-B2-1 had the maximum plant height and number of tillers at 100 cm and 28 respectively. For maturity duration, HUR4-3 variety matured in 139 days and it was the earliest maturing variety compared to others. The maximum day to mature (167 days) was taken by variety HUR-105 (Table 7).

Table 7: Data on plant height, No. of tillers, maturity date and yield

Sl No	Variety	Plant height (cm)	Tillers Nos	Maturity days	Yield (t/ha)
1.	HUR 105	84	15	167	1.76
2.	HUR 3022	75	19	149	1.63
3.	HUR 917	82	21	151	1.28
4.	HUR B2-1	101	28	149	1.63
5.	HUR10-9	99	16	144	1.64
6.	HUR4-3	85	15	139	0.86

The yields in general were low. The highest yield was produced by variety HUR-105 with 1.76 t/ha. Variety HUR4-3 yielded the least with 0.86 t/ha. Comparing to some of the best performing local varieties, the HUR varieties were found to be low yielding. Plant height and number of tillers seemed to be normal. Further evaluation of these varieties will be done in the next season.

1.1.8. Application of pheromone traps for identification of insect pests

As part of plant protection activities at the Centre, the field crop sector carried out a small research on the monitoring of different lepidopteron pests and other insect pests using different pheromone traps in the station research field.

For the study, a total of 16 pheromone traps from the NPPC inclusive of 4 stem borer traps and 12 armyworm traps were acquired. The pheromone traps type was limited due to unavailability at NPPC, where only the two mentioned types of traps were available. The traps were uniformly scattered and installed in the Centre's paddy field of about 5 acres. The readings were recorded at an interval of about 3 weeks. The traps were numbered from one to sixteen and data collected from the traps were recorded. The data parameters included number of insects captured in each trap, type of the pest (lepidopteron, hemipterans, etc) and the species of insects collected. The study began from mid of July when the traps were first installed in the fields. The first two readings (during the first month) did not record any insects in most of the traps except two traps were few beetles (ladybird) and a rice stem borer was observed.

In the third reading in September, few numbers of insects, particularly moths and beetles, were

observed in the traps. The insects were collected as per the trap number and were taken to NPPC for identifying the insect pests. From the total of 16 traps, 85 number of insect pests were captured and identified (Figure 2). The insects included stripped and yellow stem borer, beetles, bugs, army worm, hoppers, and case worms including some beneficial insects such as lady bird beetles.

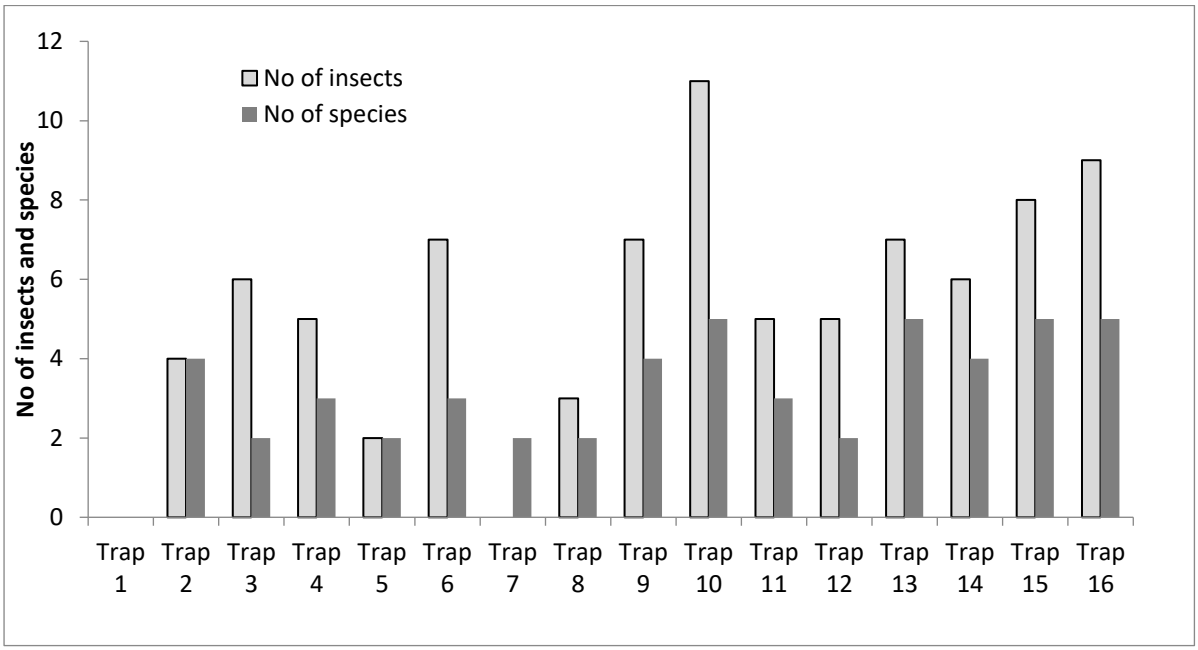


Figure 2: No of insects and species trapped in the pheromone traps laid out in the field

From the study, we can conclude that pheromone traps are an effective way of managing insect pests in the rice fields, and should be promoted in a large scale. The same study also showed that there exists many insects pests including the beneficial ones, thus, requiring for minized use of pesticides for ecosystem protection.

1.1.9. Economic analysis of spring rice production

Rice double cropping can play an important role in achieving food self-sufficiency by doubling production through offering an opportunity to utilize scarce wetlands twice a year (Andrews and Kassam, 1976). The spring rice concept was first introduced in the country in the early 1980s under the IFAD project to enhance paddy production for household self-sufficiency. The initiative continued for over a decade until it ceased in 2002 with the termination of the project (Chhogyel et al., 2014a). In 2012-2013 the Research and Development Centre (RDC) Bajo took the initiative to revive the spring rice cultivation at Rinchengang, Wangdue, which has been one of the prime cultivators of spring rice ever since the inception of the practice in the country (Chhogyel et al., Chhogyel et al., 2015). Currently the farmers of Rinchengang cultivate spring rice on about 30 ac land belonging to forty-four households (HHs). Despite various government interventions to promote spring rice, the practice has not picked up. According to records maintained at ARDC Bajo, the area under spring rice continues to lag below 100 acres although the initial projection was to bring entire rice fields of Rinchengang under double cropping system (RNR RDC-Bajo, 2013-2014).

With many practical issues raised by the growers, it is difficult to substantiate if the spring rice cultivation is economical for the farmers. The promotion of spring rice warranted a through

economic analysis of growing the crop to substantiate if spring rice practice is economically viable and advantageous for the farmers. This study is an attempt to understand the costs and returns involved in growing spring rice to help determine cost-effectiveness of the practice. The other objectives of the study are to quantify inputs, labour and materials required for spring rice cultivation and to determine the drivers and constraints of spring rice production. Such an understanding on cost and returns of the crop production would also help to assess the economic impacts of any possible new technologies in growing the crop.

Materials and Methods

Sampling: Rinchengang chiwog (sub-block) under Thedtsho Geowg (block) of Wangdue Dzongkhag was identified as the study site. The chiwog has 44 HHs involved in spring rice cultivation with 28.49 acres under cultivation. Employing a purposive sampling method, 100% sampling of all the 44 HHs was done. The respondents constituted 16 men and 28 women as depicted in Figure 3.

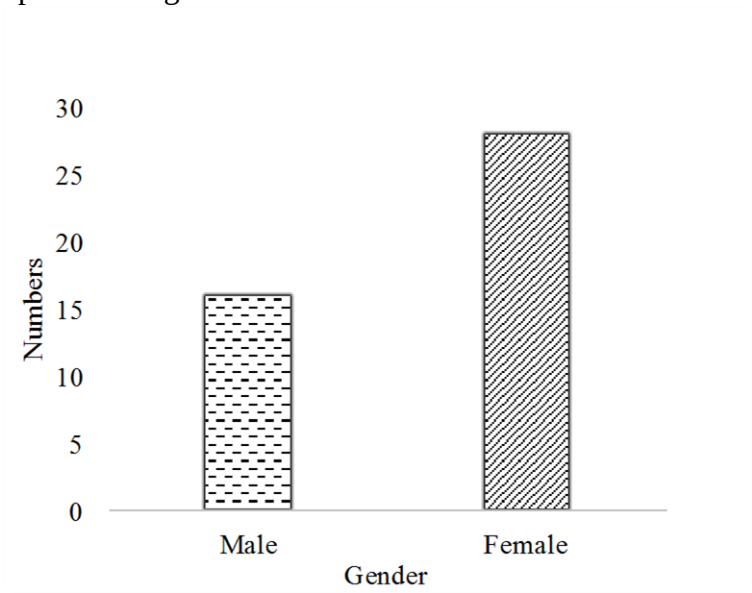


Figure 3: Number of male and female respondents

Data collection & Data analysis: An open-ended survey questionnaire was designed to collect data. Farmers were asked about their labour and material inputs and outputs from their fields. Individual interviews with each of the 44 HHs were conducted. Data was entered in a data entry form in MS EXCEL, which consisted of several worksheets linked together. Data analysis was done in MS excel.

Results and Discussion

Labour distribution: The study showed that there were variations in labour requirement for different farm activities from nursery to harvesting of the crop. Spring rice cultivation requires a total of 45mendays per acre of land (Table 8). Maximum labour was required for weeding and transplanting operations which constituted 9 (19.5%) and 7 (15.9%) mendays respectively. Harvesting activity with 6 man-days closely followed transplanting. The least labour requiring activities were terrace wall clearings, bund maintenance and grain cleaning with just one labour per acre.

Table 8: Labour days required for different farm activities

Farm activities	No. of Days	Percentage (%)	Std. deviation
Nursery	4	8.6	1.5
FYM	5	10.8	2.1
Terrace wall Maintenance	1	2.3	1.1
Ploughing	4	8.8	5.7
Irrigation	2	4.4	1.0
Bund Maintenance	1	3.2	0.6
Transplanting	7	15.9	2.3
Weeding	9	19.5	3.9
Harvesting	6	14.0	2.3
Threshing	4	7.9	1.5
Winnowing	1	2.0	0.5
Spraying of fertilizers/pesticides	1	2.4	0.2
TOTAL	**45**	**100**	**23**

Labour costs: Amongst the farm activities, weeding activity attributes the highest share of labour cost (20%) followed by transplanting (16%) and harvesting (14%) (Figure 4). The 45 labour days required for an acre of spring rice production is equated in terms of monetary value to a total cost of Nu.19, 967/acre. Similarly, weeding and transplanting activities are valued at a cost of Nu.3,983.90/acre and Nu.3204/acre respectively. Harvesting activity costed Nu. 2842.5/acre closely followed by manure application at Nu.2500/acre.

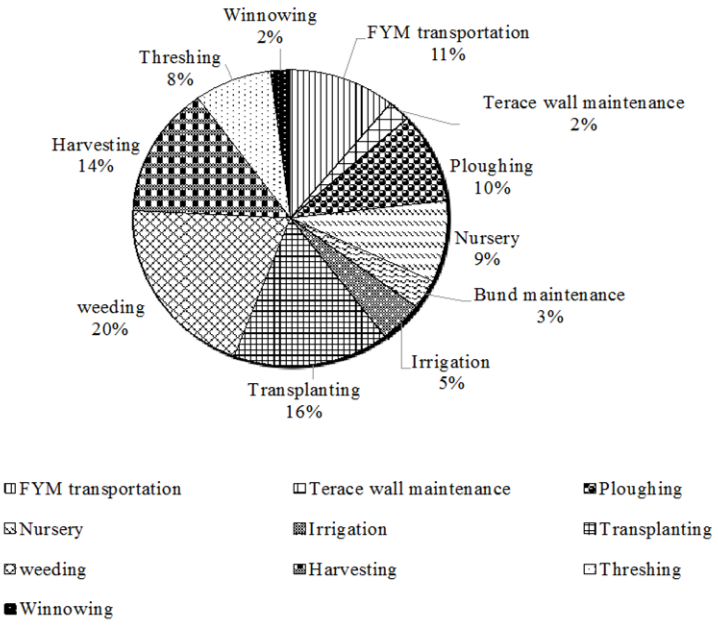


Figure 4: Percent share of costs for different farm activities

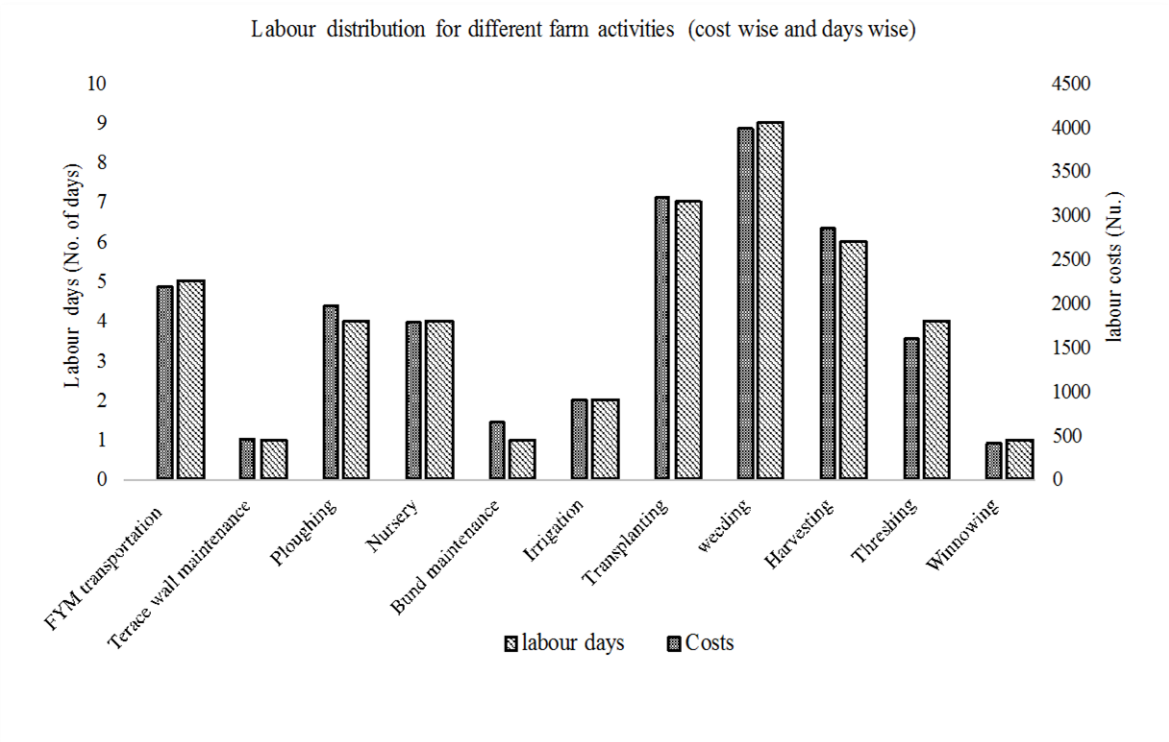


Figure 5: labour requirement for different activities and its corresponding costs

Material inputs: In the main field, 53% of the total cost is constituted by power tiller hiring cost, followed by fertilizers costs at 19% (Figure 5). In the nursery, seed and polythene sheet constitutes more than 90% of the total material costs.

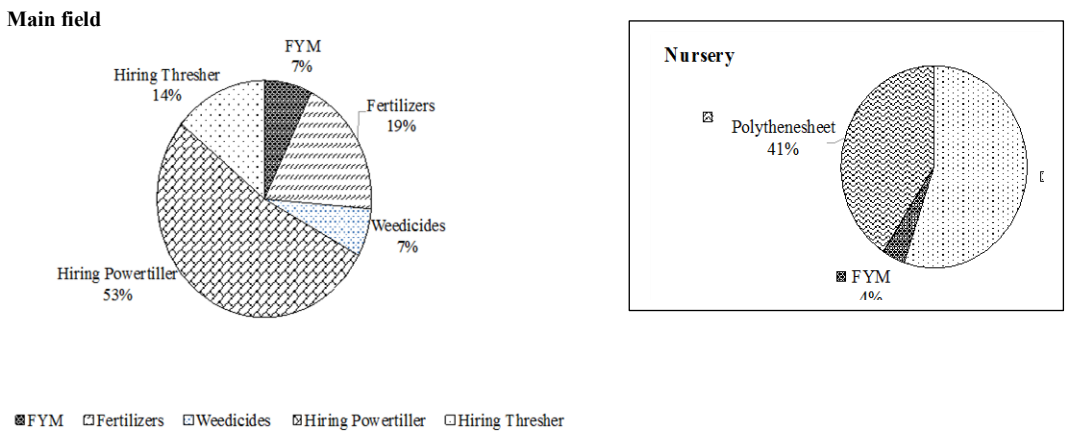


Figure 6 : Material costs in the main field and nursery

Total costs: The two components determining the costs are material costs and labour costs. The main inputs in spring rice include seeds, polythene sheets, herbicides and farmyard manure. Other inputs such as irrigation water and rental cost of land are overlooked since these have no direct implications in the production cost of the crop. The cost of labour constituted 64% of the total cost in the main field while it contributed 6% of the total costs in the nursery (Table 9). Cost of input materials in the nursery was 6% as against 24% in the main field. With a precent share of 70 (64% in main field and 6% in nursery), labour cost constitutes major share

of the total costs which translated to a total ofNu.19967.5/acre (*Nu.1774.4for nursery & Nu.18193.1 for main field*). Material costs comprise the remaining 30% of the total costs valued at a sum of Nu.8526.4/acre. The wide variation between labour and input cost shows that there is need for major intervention to reduce the drudgery of rice farming through farm mechanization.

Table 9: Proportion of total labour and material cost

Activities	Costs (Nu.)	Percent share (%)
Nursery inputs	1658.1	6
Inputs in the main field	6868.3	24
Labour costs (Nursery)	1774.4	6
Labour costs (Main field)	18193.1	64
TOTAL COSTS	**28493.9**	**100.0**

Crop guarding: As an off-season crop, bird attack is a major issue with regards to spring rice cultivation. Birds are seen attacking the crop from early morning till dark and from grain filling stage till harvesting. An ideal guarding requires farmers to spent about 10-11(from dawn to dusk) hours in the field for nearly1.5 months. This works out to a total of 30-40mendays per acre which is highly impractical for the farmers. In most cases, the elderly or children of the household are employed for crop guarding as the farmers themselves are busy tending to other field works. In the absence of such members, fields are left unguarded and only guarding when they are free. *The cost of production computed in this study does not include the crop guarding labour costs, as then the cost of production becomes exceedingly higher and most farmers* ***did not*** *guard the crop on regular basis.*

Yield, costs of production and net returns: The study showed that the average paddy yield without crop guarding was 0.65 t/ac. Based on this, the average cost of production per kg of paddy averaged at Nu. 48.5*(SD=13.1),* with 95% confidence interval ranging between Nu. 44.9< x <52.7. Total average cost of production per acre was Nu. 28784.2 *(SD=8065.1).*

Table 10: Production costs and net returns

Labour costs variation	Total costs (Nu.)	Standard Deviation
Labour costs for Nursery (Nu. /acre)	1774.4	669.6
Labour costs (main field Nu. /acre)	18193.1	6136.0
Total labour costs (Nu. /acre)	19967.5	3402.8
Total costs (Nu. /acre)	28784.2	8065.1
Total production (Kg/acre)	646.5	269.3
Costs of production (Nu. /Kg)	48.5	13.1
Net returns to land (Nu. /acre)	3039.8	20881.0
Net returns to all HH labour (Nu. /acre)	23007.3	21321.1
Net returns to labour (Nu. /person)	400.5	344.1

The crop data maintained at ARDC Bajo showed that the average yield was higher at 1.42 t/acre. Using this figure, the average cost of production per kg worked out to Nu. 20.56 per kg paddy. The difference in the cost of production is mainly attributed to difference in yield, which was noted to be quite low in the current study (extremely low in few cases due to bird attack problem). The net returns to land is Nu.3039.8 *(SD=20959.3)* per acre. If not for spring

rice, farmers leave the land fallow from Feb-June (spring rice duration), hence the net returns to land is justifiable. However, the net returns to labour (per Labour Day) is Nu. 400.5*(SD=343.5)*, which is below the prevailing wage rate of Nu.450 per Labour day. Net returns to all household labour for an acre production is Nu.23007.3 *(SD=21321.1*). The lower net returns to labour indicates that spring rice cultivation is economically in-efficient unless farmers have adequate household labour available.

Conclusion: The results from this study showed that on an average 45 labour days per acre is used for growing spring rice with over 45% of the labour use accounted for planting, weeding, harvesting and transportation of FYM. While farm mechanization has picked up over the last few years (particularly use of power tillers and threshers), there are still large opportunities to be explored in the areas of planting, harvesting and weeding.
The market price of paddy is Nu.32.3 per kg which is lower than the average production costs of Nu.48.5 per kg. The high production cost above the market price make spring paddy economically unviable for the growers. The high cost is mainly attributed to low yield due to bird attack problem and high labour costs. Thus, the enhancement of area under spring rice calls for the development of a bird control device/mechanism or a bird-free production strategy. Research in the areas of bird pest management and development of bird repellent rice varieties needs to be done. The other area of focus would be farm mechanization to help bring down the labour costs in the farming operations.

1.2. Rice commodity development activities under commercialization programme

Under Rice Commercialization the Centre has carried out the following activities during the fiscal year 2016-17

1.2.1. Promotion of HYV variety seeds

Like in the previous years, the national rice continued to promote improved rice varieties on larger scale. HYV seeds were supplied to different Dzongkhags based on the potential and needs of the Dzongkhags. Larger share of improved seeds have been allocated to major rice growing Dzongkhags like Sarpang, Dagana and Samtse which accounted for about 64% of the total seed supply. The programme also catered to both West-Central Region as well as outside based on the demands and need. Altogether, the national rice programme was able to promote 22.40 MT of improved seed comprising of six varieties across the Dzongkhag (Table 11).

Table 11: Quantity of improved rice seeds supplied to potential Dzongkhags, 2016

Dzongkhags	Bhur K1	Bhur k2	Khangma Maap	YRM2	Bajo Maap2	N0 11	Total
Sarpang	6000	0	0	0	0	0	6000
Samtse	3500	0	0	0	500	0	4000
Samdrup Jongkhar	0	0	0	0	0	0	0
Wangdue	0	0	640	500	0	1000	2140
Punakha	0	0	0	500	500	0	1000
Dagana	3065	0	1000	450	0	0	4515
Trongsa	0	0	3000	1000	0	300	4300
Gasa	0	0	440	0	0	0	440
	12565	**0**	**5080**	**2450**	**1000**	**1300**	**22395**

Additionally, from the on-station produced seeds, ARDC_Bajo was able to supply 1.8 MT HYV seeds to the dzongkhags and various agencies which comprised of 9 varieties. Thus, the seed supply was 24 MT in total.

1.2.2. Large scale cultivation of spring rice to enhance rice self sufficiency

The Department of Agriculture in collaboration with the newly established Farm Machinery Corporation Limited undertook a large scale cultivation of spring rice. Spring rice was cultivated on about 500 acre area in Sarpang, Samtse and Samdrup Jongkhar Dzongkhags. The crop varieties used were GB-1, GB-3 and Annanda which were sourced from West Bengal, India. While the actual works were executed by the FMCL, DoA provided the seeds and ARDC provided the technical advice. Since large scale spring rice has never been cultivated and FMCL, being inexperienced, the works did not go well, thus leading to marked reduction of paddy yield and production.

Yield and production: Prior to the actual harvest, a visit was made to the field and yields were assessed to see the potentiality of the varieties under spring condition. From the average field, the yields were found to be within the range of 800-1200 kg/ha. However, the overall yield and production was reported to be very low which is attributed to weediness of the field, low use of fertilizers and irrigation problem coupled with non-adherence to the technical advise provided by the rice specialist and the rice team. The total production was just 77.12 t with abysmally low yield of 193 kg/ac (Table 12). Much of the fields were completely under the cover of weeds and the crop stand was very poor, thus leading to reduction in yield and production. The issues with spring rice were as follows:

- Crop maturity and harvesting operations coincided with continuous and heavy early monsoon shower
- The crops were exposed to intermittent drought as irrigation water was not sufficient.
- There was also a problem of paddy grain drying, thus leading to a condition called viviparity (germination on standing crop) of rice grains.
- GB-3 variety was a bit late maturing as compared to the other two thus forcing to go for an early harvest which somehow might have contributed to reduced yield.

Table 12: Data on spring rice production and yield from three different sites

Sl.No	Production site	Area (ac)	Production (t)	Yield (t/ac)	Remarks
1	Chuzargang, Sarpang	136.00	18052.62	132.74	variety used was Annada
2	Gelephu, Sarpang	90.00	19874.58	220.83	Variety used was GB-1
3	Yoeseltse, Samtse	90.00	6180.95	68.68	Variety used was Annada and GB-3
4	P.thang, S/Jongkhar	94.00	33020.00	351.28	Variety used was Annada and GB-3
	Total/average	**410.00**	**77128.15**	**193.38**	

1.3. On-station and on-farm evaluation of Quinoa

ARDC Bajo continued with the evaluation and demonstration of promising lines of 2015 season both on-farm and on-station in West-Central Region. The evaluation and demonstrations were carried out in the five regional dzongkhags of Wangdue, Punakha, Tsirang, Dagana and Gasa. For these Dzongkhags, a total of 71 kg Quinoa seeds were supplied which was estimated to cover about 24 acres land Table 13). The quinoa varieties included

Ivory 123, Amarilla Marangani and Amarilla Sacaca and have been tried at different agro-ecological conditions.

Table 13: Quinoa seed distributed by ARDC Bajo details in West Central Region, 2016

No	Dzongkhags	Variety	Total (Kg)	Area (Acres)	Location
1	Gasa	Amarilla Marangani& Amarilla Sacaca, Ivory 123	6	2	
2	Punakha	Quinoa Ivory 123	12	4	
3	Punakha	Quinoa Ivory 123	4	1.33	CNR
4	Dagana	Quinoa Ivory 123	9	3	
5	Tsirang	Quinoa Ivory 123	13	4.3	
6	Tsirang	Quinoa Ivory 123, 1 set (9 varieties)	4	1.33	ARDC Bajo Sub-Center, Mithun
7	Wangdue	Quinoa Ivory 123	15	5	
			2	0.66	Phobjikha
		Amarilla Marangani & Amarilla Sacaca	2	0.66	Dangchu
			2	0.66	Sephu
			2	0.66	Khotokha
Total			**71**	**23.6**	

1.3.1. On-Station evaluation of Variety Ivory 123

The new Indian variety Ivory 123 was evaluated in large observation plot measuring 150 m^2. The field was thoroughly ploughed and levelled uniformly using power tiller. The crop was sown on the 25thof February 2016. The seeds were sown in line for easy weeding with a row to row spacing of 60 cm each. The seeds were sown uniformly and at later stage, the plants were thinned to maintain a plant to plant spacing of 25 cm. The crop was irrigated twice at 35 days and 90 days after sowing as the soil moisture was very minimal and the soil was very dry. Approximately 150-200 Kg of FYM was incorporated during land preparation along with commercial fertilizer as basal dose. At the later stage the crop was top dressed with Nitrogen @ 70 Kg/ha. A total of three weeding was carried out until the crop reached 110-120 days. No pest and diseases were observed during the growth stages. The crop was harvested manually on 16 June 2016. Three crop cut samples were taken with a sample size of 6m^2 each. The seed yield of Quinoa variety Ivory 123 at ARDC Bajo ranged between 1102 to 1220 Kg/acre (Table 14).

Table 14: Yield information of quinoa variety Ivory 123 at Bajo

Variety	Crop Cut Samples	Yield (Kg/acre)
Quinoa Ivory 123	1	1220
	2	1125
	3	1102
Mean 1149		

From the different location, a total of 151 kg Quinoa seeds was harvested as detailed in the Table 15.

Table 15: Total quinoa seeds harvested in 2016.

Sl No	Dzongkhag	Geog	Variety	Quantity (Kg)	Remarks
1	Dagana	Dorona	Ivory 123	5	
2	Punakha	Tewang	Ivory 123	6	
3	Wangdue	Sephu	AmarillaSacaca	5	
4	Gasa	Khatoe	AmarillaSacaca	5	
	ARDC Bajo			130	Those high altitude 2 varieties were sown in September 2016 (On station)
Total				**151**	

Major Issues of quinoa in the West Central Region

- Crop sowing was delayed due prolonged dry spell.
- Crop was completely damaged by hailstorm in Phobjikha Geog.
- Time of crop harvest coincided with the monsoon and the harvest was affected.

1.4. Wheat research activities

1.4.1. 17th Fusarium Head Blight Screening Nursery

Fusarium head blight is a serious disease causing huge economic losses to the wheat growers. This disease is particularly important in maize based system as fungus is reported to overwinter in maize debris. The same fungus then affects the wheat when grown as a following crop. As there is a great potential to increase the domestic wheat production through maize–wheat farming system, availability of disease resistant varieties is important. Therefore, 43 lines of wheat nursery were screened against Fusarium head blight at Tsirang station in collaboration with the International Maize and Wheat Improvement Centre.

The trials were laid out in a single observation line of 1.5 m length. The field was previously sown with maize, and crop residues were not removed to provide the congenial conditions for fungal development. The basal doses of organic and inorganic fertilizers were provided for optimum crop growth. Observations were made at reproductive stage, post flowering in particular. None of the lines exhibited any disease symptoms in the test location. It may be that the particular fungal species was not present in the current location, or there was no adequate inoculum to initiate the disease. However, lines demonstrating superior agronomic characters were selected for further evaluation.

1.4.2. Initial observation of world barley germplasm

Barley is a strategic crop in certain parts of Bhutan where crop provides main dietary requirement, and other social needs. The local productivity, however, is low as compared to both regional and international standards. One of the main attributing factors to this low productivity is the non-availability of improved varieties as there are no any improved varieties released and notified to date.

Through the generous assistance of the Plant Breeding Institute, University of Sydney, Australia, 320 lines were evaluated at Tsirang. These lines are the worldwide collections, which were reposited in the Institute. Trial was laid out in a single observation line of 1.5 m length as

determined by limited seed quantity. Field was previously sown with maize, and optimum soil fertility management practices were provided.

Of the 320 lines, 45 lines were initially found to be adaptable under local conditions in respect to maturity. These lines also possessed desirable grain size and plant height. These selected lines will be further screened to ascertain their performances. It may be noteworthy to mention that Gus, a variety susceptible to all rusts, was free from any disease in the test location in 2016–2017. This observation indicates that diseases including rusts are not of significant constraints to barley production in the locality.

1.4.3. Phenotypic characterization of traditional Barleys

In collaboration with the National Biodiversity Center, 29 accessions of local Barleys were phenotypically characterized at Tsirang station. Planting and recommended crop management practices were organized in timely and systematic manner. Given the technical expertise, the data collection was done by NBC personnel. As the report could have been already reflected in NBC report and to avoid duplication, a full report is not submitted here.

1.4.4. Rusts pathological studies

As organized yearly, SAARC rust trap nurseries were evaluated at Bajo station to monitor the rusts situation. Planting was done in November with recommended agronomic practices. While the rust disease incidence was monitored throughout the growing season, the disease appeared from March onwards. As in past years, leaf rust and yellow rust were the two major diseases observed (Table 16).

Table 16: Disease observation in SAARC rust trap nurseries in 2016–2017

Entry	2 March, 2017			17 March, 2017			1April, 2017			16 April, 2017		
	YR	LR	SR	YR	LR	SR	YR	LR	SR	YR	LR	SR
Annapurna	0	0	0	0	0	0	0	0	0	0	0	0
WL 1563	0	0	0	0	0	0	0	0	0	0	0	0
HD 2204	0	0	0	0	0	0	0	0	0	0	0	0
PBW 660	0	0	0	0	0	0	0	0	0	0	0	0
HD 2687	0	0	0	0	0	0	0	0	0	0	0	0
HD 2189	0	0	0	0	0	0	0	20S	0	0	30S	0
HP 163	0	0	0	10S	0	0	10S	20S	0	10S	30S	0
RAJ 3765	0	0	0	0	0	0	0	10S	0	0	10S	0
DWB 373	0	0	0	0	0	0	0	0	0	0	10S	0
PAK 81	0	0	0	0	0	0	0	0	0	0	10S	0
Punjab 85	0	0	0	10S	0	0	10S	10S	0	10S	30S	0
Chakwal 86	0	0	0	0	0	0	0	10S	0	0	20S	0
Faislabad 85	0	0	0	0	0	0	0	10S	0	0	20S	0
Inquilab 85	0	0	0	0	0	0	0	10S	0	0	30S	0
Faislabad 83	0	0	0	10S	0	0	10S	0	0	10S	10S	0
Rawal 87	0	0	0	10S	0	0	10S	0	0	10S	10S	0
Kohsar	0	0	0	0	0	0	0	0	0	0	10S	0
Bakhtwar	0	0	0	0	0	0	0	0	0	0	10S	0
Gaurab	0	0	0	0	0	0	0	0	0	0	10S	0
Morocco	0	0	0	10S	40S	0	20S	60S	0	20S	60S	0

1.4.5. Disease survey and surveillance

Rust surveillance is a paramount activity in disease management as it provides knowledge of the distribution and incidence of rust pathogens and pathotypes. Wheat rusts surveys were undertaken in major wheat growing regions in Bhutan using standard Borlaug Global Rust Initiative survey methodology. A total of 81 sites were covered with altitude ranging from 250 to 3500 masl, which are typical of the wheat growing environments in Bhutan.

Leaf rust (caused by *Pucciniatriticina* Eriks.) was the most scouted disease with its incidence occurring in majority of the growing environments from low (spring wheat ecosystem) to high altitudes (facultative winter areas). Of the 81 surveyed sites, 27 sites (33%) recorded leaf rust disease (Table 17). Irrespective of the growing environments, the disease was observed in areas where local cultivars are cultivated indicating the vulnerability of local cultivars to leaf rust. However, its late occurrence in the season when the crop had passed post flowering is likely to cause low yield impact. The lately released varieties such as Gumasokha kaa and Bumthangkaa Drukchu were resistant to leaf rust.

Yellow rust (caused by *Puccinia striformis* f. sp. *tritici*) was the second encountered disease, occurring in 21 sites (26%). Unlike in the past where yellow rust used to be scouted in mid altitude wheat growing areas, this season did not record any yellow rust. While the role of mass promotion of new disease resistant variety cannot be ruled out, even the local varieties in the mid altitude were unaffected most likely due to absence of spring shower. However, the disease was prevalent in facultative winter areas (>2500 masl) in traditional cultivars at low to medium incidence and severity. The new improved variety, Bumthangkaa Drukchu continued to demonstrate high resistance to yellow rust.

Stem rust (caused by *Puccinia graminis* f. sp. *tritici*) was not observed in any of the surveyed sites even at low warmer areas of < 1200 masl. The follow up surveys during the later crop growth stage even with high aerial temperatures of more than 20^0C confirmed the disease absence. The circumstances leading to absence of stem rust in Bhutan so far are not completely understood but is highly likely that there is no enough host population for inoculum initiation and development.

Wheat blast (caused by *Magnaporthe oryzae*), reported in Bangladesh and north-east India in recent years, was also monitored. Apart from sharing similar agro-ecological conditions between the southern foothills of Bhutan and those neighbors, the risks of informal seed exchange are also high owing to porous borders. Fortunately, none of the surveyed wheat sites in lower foothills showed typical symptoms resembling to that of blast.

Table 17: Different rust diseases with the incidence in 2017 survey season

	No of sites		
Disease incidence	**Leaf rust**	**Yellow rust**	**Stem rust**
High (>40%)	5	3	0
Moderate (20 – 40%)	6	7	0
Low (<20%)	16	11	0
Total	**27**	**21**	

1.5. Wheat development activities

1.5.1. Promotion of improved wheat seeds

Wheat still remains a low-profile crop for farmers because of more competitive crops and labour shortage to name a few. However, there are enormous opportunities to elevate domestic production through optimum utilization of wetlands, which are otherwise left fallow after rice harvest. More importantly, with the availability of new wheat varieties, farmers are continuously encouraged to adopt new varieties. A strategy used to motivate and accelerate the adoption was the free seed support to farmers. To achieve this, seed has to be adequately produced, and mobilized through technical intervention and farmers' participatory approach. Though the National Seed Center took the lead role in wheat seed business, wheat program shouldered equal responsibility in sourcing the fund, liaising with different stakeholders and providing technical support. In 2016–2017, 37 MT of seeds was supported to major wheat growing Dzongkhags through wheat program. This seed support is expected to further inculcate our wheat farmers on the importance provided by Department to wheat production.

1.5.2. Seed production and maintenance of promising and released varieties

Considering the importance of varietal evaluation, elite germplasm from both regional and international centres are introduced and tested. The entries which are disease prone, low yielder and inferior in agronomic traits are discarded from station itself. The seeds of the potential lines which can possibly make to the commercial variety are multiplied in the station for wider on-farm testing in sizable area. As mandated, foundation seeds of the released varieties are also maintained in the station. In 2016, the seeds of following promising or released varieties were produced and maintained (Table 18).

Table 18: Quantities of wheat seed produced in 2015

Line/variety	Quantity (kg)	Remarks
NL-1073	300	Promising dryland line
Bumthangkaa Drukchu	100	Released *cv*. & intended for winter areas
Total	**400**	

1.6. Rice research activities at ARDSC, Menchuna, Tsirang

1.6.1. Production Evaluation of advanced rice lines

Through a series of on-station trials, rice program has identified six promising lines with better yield potential, and agronomic characters comparable to the existing commercial varieties. While on-station results are encouraging, the same are often not obtained when evaluated under farmers' management conditions. Therefore, it is important that the performance of the lines is ascertained through on-farm evaluation.

In 2016 rice season, rice trials were implemented in two sites, Sunkosh (600 masl) of Tsirang Dzongkhag and Thangna (1200 masl) of Dagana Dzongkhag. All the management practices were that of existing farmers' practices though farmers were imparted with best crop husbandry practices for higher yield. Based on the availability of advanced lines, six lines and four lines were tested at Sunkosh and Thangna, respectively.

Concurring with the on-station data, results from on-farm evaluation also showed potential in these advanced lines. Majority of the tested lines had an average grain yield comparable or

higher than the local cultivar (Table 19). Considering the farmers' interest towards these varieties, further promotional program through seed multiplication is in place.

Table 19: Agronomic traits of rice lines during on-farm evaluation in 2016

Varieties	Plant Height (Cm)	Grain Yield (t/ha)	Location
Sarju 52	61	4.7	Sunkosh
Zonghum	65	4.3	Sunkosh
Ceres 2	70	3.1	Sunkosh
Ceres 1	84	4.5	Sunkosh
TME80518	73	3.3	Sunkosh
IR-28	69	3.5	Sunkosh
Zangthey		1.9	Thangna
Attey		2.4	Thangna
IR-64	65	3.2	Thangna
Chotey Baith Guthey	96	3.1	Thangna

1.7. Maize Research Activities

1.7.1. Heat Resilient Maize trials

Global warming is a proven phenomenon, but its consequence to food production is a debatable issue. However, research activities have been initiated to mitigate the problem should the global warming be of major constraint in the near future. One such initiative is in maize where research tends to find the best tolerant varieties under heat stress conditions.

In collaboration with the National Maize Program of ARDC Wengkhar, 35 maize lines were tested at Sunkosh, Tsirang. As Sunkosh is situated at an elevation of 600 masl, higher temperatures are of common experience particularly during maize growing season. To avoid the heat escape and to expose the experimental lines to maximum heat, sowing was done in April. The results indicated some potential tolerant lines, which need further confirmation. As ARDC Wengkhar is compiling and producing the synthesized report, no separate report is provided here.

1.8. Seed production and maintenance

As entrusted with developmental mandate, ARDSC Tsirang also produced and maintained seeds of different released rice and 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 2016, a total of 2.69 MT of seeds were produced, which is expected to make a substantial contribution to overall cereals production (Table 20).

Table 20: Quantities of seeds produced and maintained at ARDSC Tsirang

Crop	Variety	Quantity (kgs)	Remarks
Rice	Khangma Maap	100	Upland variety
	Wangkhar Ray Kaap	1000	Irrigated and mid altitude variety
	Chaskarpa Ashom	1110	Improved and disease resistant *cv.*
	Ganesh–II	240	Improved variety
Maize	Yangtsipa	240	Old *cv*. but often in demand
	Total	**2690**	

2. HORTICULTURE

2.1. Fruits and nuts research activities

2.1.1. Farm infrastructure development

ARDC is one of the oldest Agricultural Research Centers in the country with the national mandate for coordinating field crops research. Therefore, major portion of research area is designed appropriate for paddy cultivation. Furthermore, continuous paddy cultivated in the past has impaired soil health. Orchard development is a long term investment that not only requires thorough planning of field infrastructures (access road, irrigation systems, composting structure, and field drainage) but also the good soil fertility. Thus, with the support from IHPP-JICA, an approximate area of 20 acres (13ac in Bajo and about 7ac in ARDSC Tsirang) has been successfully developed (Figure 7).

Figure 7: Farm Structure Development

About 13ac of land has been developed along with the farm infrastructure (farm shed, irrigation channels, drainages and internal farm road). A total of 1.5 km of internal farm road has been constructed which enhances overall efficiency of cultural operation and management. All the terrace area (14ac) is well connected with the irrigation water.

Figure 8: On-station Established orchards

More than 100 tons of compose (Bajo – 60 and Tsirang – 40) was prepared and incorporated into the soil to enhance and reclaim soil health. The area is currently planted with high value fruits and vegetables that were identified based on the current issues considering production costs and future market to achieve year round production. Simultaneously, the research focuses on generation of management technology for relatively new crop varieties such as grapes, kiwi, avocado, dragon fruit, persimmon and citrus. These fruits orchards will serve as a techno-park to showcase available technology and to serve as mother trees for further propagation.

2.1.2. Crop Rotation

Crop rotation of paddy field was done with the appropriate summer and winter vegetable crops at the beginning. It was then again rotated with paddy mainly to level the field and to reduce pest/disease incidence. The standing water maintained while cultivating paddy kills the pests (grubs, cutworms, leaf miners, etc) that spent part of their life-cycle in the soil. This has significantly helped to control the pests and disease in the following season.

2.1.3. Soil Health Improvement

Orchard establishment invariably require optimum soil depth for roots to proliferate without much resistance and thus aerial part grows proportionately. The future success of tree depends on the initial care rendered at nursery and early stages after transplanting.

The land was prepared to a sufficient depth (three to four feets) using a mini-excavator and thoroughly inversed prior to leveling. It was than cultivated with the legumes such as Soyabean (*Glycine max*) and Adzuki bean (*Vigna angularis*) and green manuring with *Sesbania* to improve soil fertility. The pods of Adzuki bean and soybean were harvested and its vegetative parts were incorporated into the soil. Similarly, sesbania (a height of about 2 feet) was directly incorporated into the soil using power-tiller rotator (Figure 9).

		
Adzuki beans intercropped	**Sesbania (Diancha)**	**Green manuring (Sesbania) incorporated**

Figure 9: Soil Health Improvement

Further, more than 100 tons of composts were prepared from the monsoon grown grass/weeds around the fields and bunds which were the incorporated into the soil after fully decomposed. Tons and tons of poultry manure were also procured and applied.

The soil condition improved both in structure and texture within a short span of one and half years. Earth worms have already started appearing in the fields indicating the availability of

organic matter in the reclaimed area. Also, the vigorous growth of the seedlings in the reclaimed field shows that soil fertility status has drastically improved (Figure 10)

Figure 10: Land Reclamation

2.1.4. Fruits and nuts germplasm

Research activities on fruits and nuts has been limited to citrus, peach, pear, persimmon, mango, pomegranate, avocado, walnut, chestnut, pecan. However, the production and yield of these fruits have been limited mainly due to lack of high quality planting material in sufficient quantity. Further, the released varieties (superior quality) have not penetrated much into the farmers' fields probably due to lack of awareness among the stakeholders. While there are many constraints to the horticulture development as identified through baseline survey report, one of the major constraints identified was the lack of quality seeds and seedlings. Therefore, IHPP project aimed at not only in strengthening of nursery but also to establish a system for sustainable production of quality seeds and seedlings through collection and maintenance of various horticulture crop germplasms. These germplasms are propagated to evaluate its performance and to serve as the mother tree for future multiplication.

Table 21: Some of the new crop varieties

Crops	From outside	From within country
Peach	Kurataki,	
Apricot	Khasha	
Pear	Yakumo, Niitake	Chojero Hosui, Kosui
Kiwi	Hayward	Wengkhar yellow, Yengkhar Green, Bajo red
Grape	Stubin, Portland	Campbell
Dragon fruit		

2.1.5. Performance evaluation (Fruits)

Earlier system of on-station trial served the purpose in evaluation of crop performance by getting down to the details of data collection, experimental procedures and then analysis. This process of trial not only proved lengthy but also expensive owing to the limited human resource capacity. While such evaluations are a necessary part of the horticulture research process, it has become increasingly important for the researchers to economize in order to enhance resource use efficiency and turn over from the investment.

It is imperative to prioritize the strategy so that the costs are kept minimal while the purpose of increasing production and improving quality is achieved. Therefore, IHPP focuses mostly on simple observation and performance evaluations.

Figure 11: Fruit Orchard

A total of 13 fruit orchards (subtropical apple, papaya, dragon fruit (kiwi, grapes, avocado, persimmon, peach and pear, citrus pomelo, lemon, grapefruit, trifoliate) were established. These orchards are observed for vegetative growth, pests and diseases, and their phonological stages for timing of the cultural operations. The orchards also serve as the management technology generation and demo-site for providing hands-on training of Researchers and extension agents by the Experts. Besides, the orchards also serve as a main source of mother trees for the improved cultivars in future for west central region. Currently, other research centers across the country depend on Wengkhar for the scion woods. Moreover, the private nurseries have very limited access to the improved cultivars hampering the multiplication and availability of seedlings. This lack of access to the quality cultivars by private nurseries resort them to unethical introduction of cultivars imposing huge biosecurity risk.

2.1.6. Fruits and vegetable nursery

Production of quality seeds and seedling is the key to sustain successful horticulture farming. Currently, there are a very few nurseries that produce seeds and seedlings. Much of the seeds (fruit and vegetables) used in Bhutan are imported. Sustainability in production self-sufficiency will depend ultimately on production of quality seeds in sufficient quantities. It is imperative to have a robust nursery systems in place achieve national goal of self-sufficiency and food security. Therefore, horticulture sector lead by JICA Expert (IHPP Project) initiated generating nursery technology for fruits and vegetables in enhancing production of quality seeds and seedling.

Figure 12: Fruits and Vegetable Nursery

2.1.7. Nursery infrastructure

A total of four large plastic houses (5x40 meters) and two (5x20 meters) dimension are established at ARDC Bajo. About 1400 fruits seedlings were produced and promoted by establishing demonstration orchards and focus villages. About 150 kg of vegetable seeds were produced of which 120 kg was promoted in West Central Region (WCR). Remaining 30 kg was saved for further multiplication.

2.1.8. Nursery production (fruits)

The demand for quality seed and seedlings still remains high and it is one of the issues that limit production in the region. Therefore, to supplement to the need for quality planting materials, ARDC Bajo focus on production of quality seedlings and maintenance of fruit crops mother plant. This nursery and mother trees also serves as a training field for private nursery operators and extension agents where hands-on training on different grafting techniques and technical guidance are provided.

Objectives:

- To produce quality seedlings required for research outreach program.
- To support private nursery operators in establishing the mother block of the released varieties, and conduct hands on training.

Method: The seed and seedlings of released varieties as well as potential varieties of fruits and nuts are produced and maintained. The nurseries are managed following the improved nursery production practices. For rootstock production seeds of local fruits are extracted in the absence of improved commercial rootstocks. Scion woods are collected from the mother block maintained at the station.

Table 22: Planting materials produced and maintained in horticulture nursery

Particulars	Variety	Total	Remarks
Pomelo	R3P4,R4P5, R3P9	1188	seedlings
	R3P4,R4P5, R3P9	50	grafted
Grapes	Campbel	314	cuttings
Avocado	Sikkim	20	seedlings
	Sikkim	1039	Seedlings
	Sikkim	947	Seedlings
	Brokdown	210	Seedlings
Lemon	Frost Ureka	26	grafted
Citrus rootstock	*Poncirus rubidoux*	147	Rootstock
	C. Volkameriana	126	Rootstock
	Citrus bigaradier	64	Rootstock

	Trifoliate USDA	1133	Rootstock
Kiwi	Wengkhar	90	seedlings
	Wengkhar	530	seedlings
Persimmon	Local	764	Rootstock
	Japan	1434	Rootstock
Loquat	Mogi Tanaka mixed	176	Seedlings
Pomegranate	Chaula	1010	Seedlings
	Chaula	800	Seedlings
Pecan nut	Mixed	242	Seedlings
Pear	local	774	Rootstock
Walnut	local	772	Rootstock
	Local Soft		Grafted
Pear	Shinko	41	Grafted
	Niitaka	28	Grafted
	Hosui	49	Grafted
	Yakumo	21	Grafted
	Chojero	35	Grafted
	Kosui	38	Grafted
Guava	Pink flesh	350	Seedlings
Peach	Local	13	
	Total	**11901**	

Observation: Fruit and nut nursery production technologies suitable within the region are available at ARDC-Bajo. The centre should continue to support the local nursery operators, through hands on training and technical backstopping.
To cater the seed and seedling needs of the region, promote trained private nursery growers.

2.2. Vegetable Research and Seed Production

2.2.1. Vegetable performance evaluation

Bhutan imports substantial amount of vegetables especially during the lean season. Given the diverse agro-climatic conditions, round the year production of vegetables in the country is possible provided suitable varieties are available. Therefore, to enable round the year and to substitute import, performance evaluation of various vegetable varieties was conducted on station as well as on farm in collaboration with Dzongkhag agriculture sector.
Simple evaluation was done for yield, cost, quality, pest and diseases, maturity in addition to sowing and harvesting period along with the timing of cultural operations considering the whole supply chain. Two times of summer vegetable experiment has been evaluated for identifying suitable summer vegetables crop and variety.
A total of nine summer vegetable crops listed has been identified

- Lady finger (3 varieties),
- Beans (2 varieties),
- Chili (1 variety),
- Capsicum (1 variety),
- Water melon (3 Varieties),
- Pumpkin (3 varieties),
- Zucchini (2 varieties),
- Cucumber (1 variety),
- Brinjal (2 varieties)

2.2.2. Evaluation of high β-carotene Tomato Lines from AVRDC

In order the meet the local demand of the country the Research Centre of the West Central Region started the evaluation of the six lines of high beta carotene tomato lines requested from AVRDC, Taiwan in October 2010. The lines were developed by the Scientists of the Centre containing 3-4 times more of vitamin A than the normal tomato. Although, we initially received six lines, only three lines (CLN 2366 A, CLN 2366 C, CLN 2070 A) were selected for advance evaluation based on their adaptability, production capacity and the geo-climatic suitability.

Objectives: The main objectives is to evaluate performance under mid (1200 masl) altitude conditions and to release nutritious tomato varieties for general cultivation

Methods: Sowing of seed was done in mid of May and transplanted by last week of June. The popular local variety Rattan was used as check. Each line (treatment) was replicated for three times with 36 plants. The recommended practices for tomato cultivation were followed. Random sampling of ten plants from each replication was evaluated to find out the production/performance of the individual lines.

Results and Findings: The production of CLN – 2366C was the highest with 51.96 kg from the total of 30 plants with average yield of 1.732 kg of fruits per plant followed by Ratan (local check). Other two lines; CLN-2070A and CLN-2366C performed below the local check in terms of yield per plant. The other indicators to be studied are the plant growth habit, resistant to pests and diseases as well as trying out in farmer's field in the coming season.

2.2.3. Evaluation of Late Blight Resistant Tomato Lines from AVRDC

Tomato is considered as one of the most important vegetables worldwide and it is the one of the key ingredient in Bhutanese cuisines. Annually, Bhutan imports huge chunk of tomatoes from India as domestic production is seasonal and limited by pests and diseases especially during the monsoon. Late blight (*Phytophthora infestans*) is one of the devastating diseases of tomato in Bhutan, ARDC - Bajo introduced seven lines of Late Blight Resistant cultivars from AVRDC Taiwan in October 2010. Initial field studies screened three out of seven varieties with better adaptability and production capacity. This experiment further evaluated the performance of these three Late Blight Resistance lines in the financial 2016-17.

Objectives: To evaluate the yield performance of the LBR lines for good horticultural traits and its resistance to late blight.

Method: The seeds are sown in mid of May and transplanted in the last week of June. The popular local variety (Rattan) was used as check. The RCB design with three replications was used for the individual lines with 36 plants each. The recommended practice for tomato cultivation was followed. Ten plants were randomly sampled from each replication and evaluated for their performance.

Results: The Graph below indicates the production data of three lines and the check (Rattan)

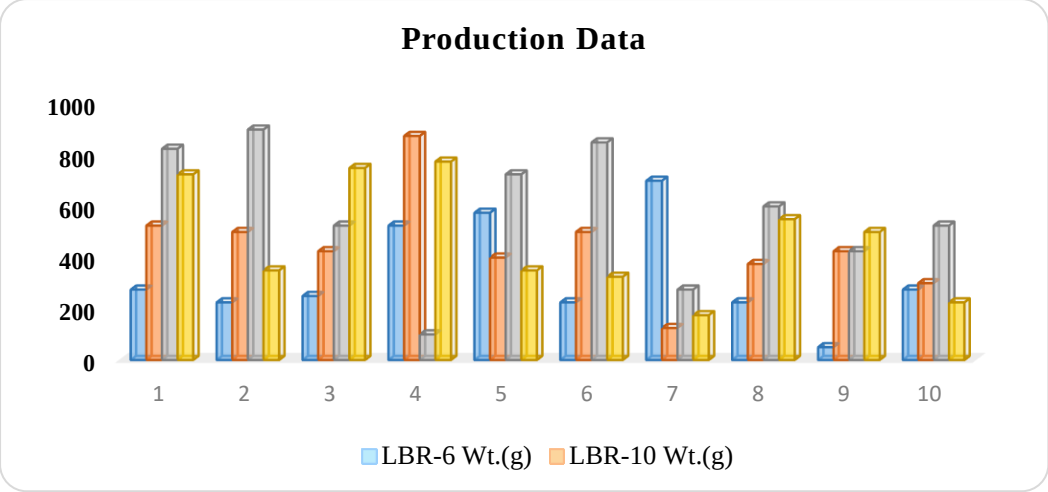


Figure 13: Production Data

Figure 14: Pictorial illustration of the LBR lines and Rattan

The production graph above indicates that the production of LBR-11 is highest (5750 grams from the average of 10 plants) followed by Rattan (4725 grams), LBR-10 (4450 grams) and LBR-6 (3325 grams). The other important components such as resistance to waterlogging conditions, pest and diseases and multi-location studies will be carried out in the coming season.

2.2.4. Vegetable Nursery

Quality seed is the basic and critical input for achieving the desired vegetable production. The availability of quality seeds in time at affordable price enables vegetable growers to grow their crop during the ideal time. The disease-free, healthy seed produce uniform, healthy and vigorous seedlings leading to higher yield and quality production. Hence, availability of quality seeds assumes paramount significance for achieving desirable results.

Some of the improved vegetable includes vegetables like, cauliflower, carrot, radish, mustard green, broccoli, Chinese cabbage, spinach, pea and green onion were produced following appropriate technologies. The seed produced in this season were;

- Radish 500 gm (Shogoin – 200 gm, Sakura Jima, Daikon - 300gm),
- Carrot 4.5 kg
- Chinese cabbage – 500 gm
- Broccoli 2 kg (SP Green, Edinburg, Dessico) –
- Pea 10 kg (Veg Pea and Snap Pea)
- Onion – 2 kg, Bulb (Bombay Red, Pune red, OL)

2.2.5. Evaluating Severity of Red Ant Infestation on Potato

Background

Bjasa village under Phangyul Gewog is located at an altitude of 1870-2100 masl. It is about 25 km from Wangdue town. The farmers in the area depend mainly on cereals and vegetables. Irrigation is the biggest issue and the yield and quality of the produces are usually low and inferior making it difficult for marketing. There is barely any income generating crop after they left potato cultivation sometimes back due to infestation of tuber by the red ant. Therefore, this study was conducted to assess the feasibility of reviving potato cultivation and to assess severity of red ant infestations.

Objectives

- To find out the degree of red ant infestation on potato tubers in Bjasa village.
- To make recommendation for future promotion of potato under Phangyul Gewog.

Method

The trial was set up on 10/2/2017 covering an area of 300 m2 of seed potato (Kufrijyoti) variety at an altitude of 1870 masl. The length and breadth of the trial was 30 m by 5 m keeping the row-row distance of 60 cm and plant to plant distance of 20 cm with the total seeds of 25 per ridge. Package of practices for potato was followed. The production was also assessed. Sowing of potato was carried out on 10/2/2017. As the trial was set up with a purpose to find out the degree of red ant infestation, the production per plant, production from 6 square meters and the degree of red ant infestation from 20 plants were taken randomly to find out the quality of the tubers and the production from the locality. In order to reduce the production error crop cuts from different location was also conducted. Finally the trial was harvested on 7/6/2017. Twenty plants were harvested randomly from the trial plot using the lucky dip system to prevent the biasness. The weight of the samples were measured for individual tubers. The crop cut area of 6 m2 (2m x3m) was applied.

Result and Discussion

The production data above is the result of the average crop cut carried out in five different fields of the farmers. An average production of five farmers was 6600 kg per acre which is more than the national average production of 3595 kilograms (RNR Statistics, 2015).

The numbers of scars for different categories was calculated based on the weight of the tubers: 0-30 gm., 31-60 gm, 61-90 gm and 91-120 gm. The pie charts below are the average production data from the crop cut of five individual farmers' field.

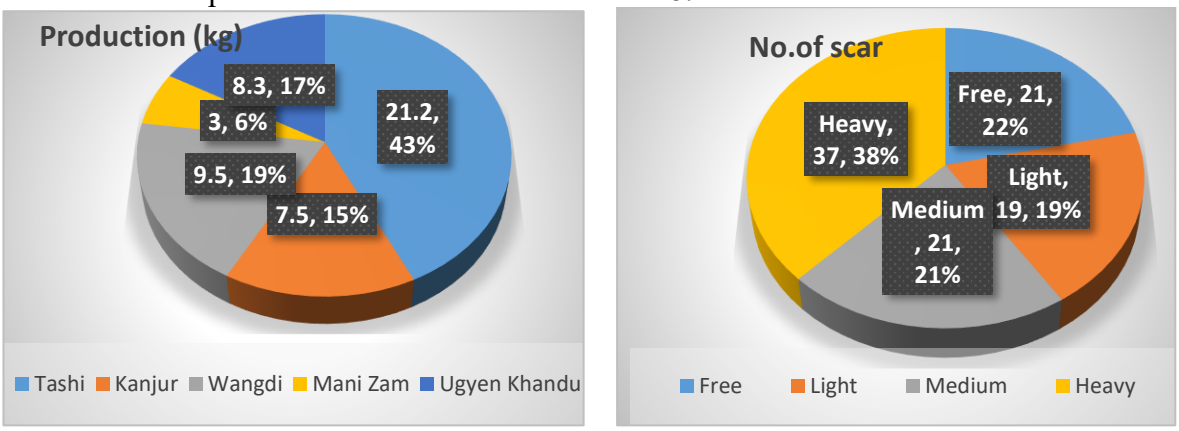


Figure 15: The average production data from the crop cut of five individual field.

The scar percentage indicates that 38% was under category “heavy” followed by “free” - 22%. Although, the yield per acre was higher than the national average production data, 38% of the produce was heavily scared by red ant.

The sector also offers equal importance to outreach programs wherein the demonstration of superior varieties over the existing ones and alternative cash crops options are implemented based on location specific farming systems in collaboration with extension officials. A total of nine assorted fruit demonstration orchards were established in four Dzongkhags. The survival of fruit plants in the field is above 90% as of now although it was planted in dry winter season (February-March, 2017). In order to increase the quantity of high quality seed production, four new nursery operators are trained and provided with the basic supports.

2.2.6. Bulb onion promotion

The bulb onion was one of the main ingredients in Bhutanese dish and almost all of the onions found in market were from India where we need to spend a lot of Indian currency which is quite expensive on our economy. So to reduce the import, the initiative was taken in promotion of onion in Punakha dzongkhag. In consultation with dzongkhag agriculture sector we have selected 12 farmers from Danchi, 1 from Toedwang,2 from Guma and 1 from Dzomi. In total 16 farmers were brought into onion cultivation with minimum of 30 decimal of land.

The selected farmers were provided hands on training on proper land preparation and sowing of seed. The farmers were taught to maintain the sowing depth of triple the size of the seed for easy germination which was a problem at present situation in the field. They were also informed on the importance of mulching after sowing the seed and periodic irrigation to enhance the germination

The performance of the onion was accepted by the farmers and even made some income from the sale of the onion. However, the only issue raised was on the bolting and notable to cure properly. The maximum bolting was observed on Bombay red and almost nil bolting on Pune red. For that the farmers were advised to use Pune red instead of Bombay red.

2.3. Outreach Approach (ORP)

The ORP is an efficient, popular and widely followed extension approach in disseminating new technologies to the farmer’s field. The ORP involves active participation of the research, extension and farmers’ right from the planning until it is fully adopted. This joint efforts or involvement favour faster adoption of the technologies.

ORP consists of three main extension activities implemented in the systematic manner for specific purposes within the resource (seedlings, expertise, and material support) limit. The beneficiaries are screened based on the selection guidelines prepared for specific purpose.

1. Demonstration of orchard management technology
2. Focus village approach for assorted fruit plants
3. Farmers capacity building
4. Top-working

2.3.1. Demonstration of orchard management technology

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. As such nine demonstration orchards were developed in last financial year in west central region.

2.3.2. Fruits and nuts demonstration (Punakha Dzongkhag)

The objectives of establishing of fruit demonstration orchards are as follows:

- To demonstrate the superior and promising fruit cultivars for income generation.
- To demonstrate the systematic orchard management system for better quality and better yield.
- To serve as mother block for easy access to the farmers of vicinity.

Materials and Methods

The orchard was established in collaboration with dzongkhag agriculture sector and geog agriculture sector. The selection of the farmers was done by the geog agriculture extension and layout and plantation was carried out jointly in order to share the accountability of the impact. The distance of 5 meters was maintained in between the plant to plant and row to row. The size of the planting pit was maintained at 3 feet depth and 3 feet wide. The farm yard manure and top soil was used in filling up of the pit about 10-20 cm above the ground level.

The monitoring of the orchard was done based on the request from the extension or even directly from farmer. As per our understanding the monitoring will be mostly done by concern extension agent and if the case is beyond their capacity than they will make request a request for the service.

Results

Table 23: The fruit demonstration orchards established as part of research outreach program in Punakha dzongkhag are as follows:

Geogs	Village	Name of farmer	Name of crops	Quantity (No)	Remarks
Talo	Lapthsakha	Am Hoylum	Pear	35	IHPP-JICA supported program
			Persimmon	17	
			Avocado	5	
Shangana	Jazekha	Kinley Gyeltshen	Persimmon	22	
			Avocado	12	
			Pear	23	
Barp	Tshokona	Karma	Avocado	20	RGoB supported program
Dzomi	Tsekha	Kinley Dorji	Pomegranate	40	
Guma	Lungsegang	Pemalhamo	Pear and peach	40	
Kabjisa	Demche	Dechen Peldon	Peach	40	
Talo	Dongkohka	Namgay	Pear	40	

Toepisa	Gyemkha	Pema Tshering	Walnut	40	
Toepisa	Chalikha	Dorji Gyeltshen	Avocado	40	

A total of 2 demonstration orchard under IHPP-JICA project and 7 orchards under RGoB support were established in March and April 2017 with 374 planting materials including both grafted non-grafted seedlings. The non-grafted seedlings were assumed to be grafted with superior cultivars in the 2 February and Mach 2018.

Observations and recommendations

- Through such activities, it creates a common platform for researchers and extension personals to collaborate closely in efficient and effective dissemination of technologies to farmers in the region.
- Farmers are made aware of the research systems and technologies available with the **research system.**

2.3.3. Improvement of Local fruit cultivars through top-Working

Objectives

- To improve the local fruit cultivars with improved and superior cultivars.
- Diversify fruit cultivation by the farmers
- Create awareness to the farmers on the system of top-working

Materials and Methods

The three geogs was identified by the dzongkhag agriculture sector for improvement of local cultivars for the fruit diversification in the region. The three identified geogs under Punakha dzongkhags were Lingmukha. Toepisa and Talo The top-working (rejuvenation) activities was carried out in the month of March 2017 in all the three geogs.

Result

Table 24: The numbers of local fruit trees top-worked in this fiscal 2016-2017 are as shown in the table below.

Sl.No	Geog	Total trees grafted	Remarks
1	Lingmukha	156	Mixed fruit trees
2	Toepisa	121	-do-
3	Talo	240	-do-
		517	

Research findings and recommendations

- The top-working on 3-4years old trees shows vigorous and healthy growth from the rejuvenated portion.

- Top-worked fruit trees shows more success rate than grafting
- Top-worked fruit plants come into production at least earlier than grafted fruit plants in general

The remaining balance is still maintained at the station for further multiplications.

2.3.4. Focus Village Approach

This component of outreach approach is basically a group approach aimed at promoting technology specific to a location at a community level (usually at a village level) involving interested farmers so that the growers achieve economies of scale.

In our context, usually eight to ten individual farmers are involved and a trained extension official takes a lead role in establishing a focus village. A lead farmer is thoroughly trained in the research station and improved planting materials and initial support is provided by IHPP-ARDC Bajo. This lead farmer becomes a facilitator although time to time technical support will be provided by the experts base on need.

2.3.5. Farmers' capacity building

Farmers capacity are building are usually carried out through different field visits to research centers, demonstration orchards, focus villages, participatory training and field days.

The selected farmers are initially provided with exposure visit to different research centers and farm fields. They are also taken to farmers' field to interact with the farmers who have already adopted the technology (farmers-farmers learning). Besides, there are also trained by the experts on critical management practices.

2.3.6. Establishment of demonstration orchards (Wangdue, Tsirang and Dagana)

The objectives of establishing of fruit demonstration orchards are as follows:

- To demonstrate the potential of promising fruit cultivars to diversify fruit cultivation;
- To demonstrate the available technology to farmer's field directly through on-farm demonstration; and
- To serve as mother block for future propagation for farmers in the area.

Materials and Methods

The RDC-Bajo horticulture implements this activity as part of the research outreach program. In the process, site selection, orchard layout and planting methods demonstration are carried out during the establishment of the orchard. Timely monitoring and technical advices wherever

necessary were provided to the collaborating farmers and the extension personals. The demonstration orchards were established in four dzongkhag.

Results

Table 25: The fruit demonstration orchard established as part of research outreach program in the Dzongkhag is as detailed in the table below

Dzongkhag	Geogs	Village	Name of farmer	Name of crops	Quantity (No)
Wangdue	Nahi	Tshokorthang	Tshering Wangchuk	Pear	24
				Persimmon	21
	Rubesa	Potojab	Migma Dorji	Persimmon	12
				Avocado	29
				Citrus	21
				Loquat	2
	Bjana	Pechogang	Dorji Pem	Pear	35
				Persimmon	15
				Loquat	1
	Bjana	Wakha	Sangey Dema	Pear	12
				Persimmon	18
	Daga	Umakhmey	Tshering Penjor	Avocado	10
		Umakhamey	Penden Wangchuk	Avocado	10
		Umakhamey	Phub Gyem	Pomegranate	20
		Drabsa	Kinley Wangmo	Pomegranate	20
		Zhingsabu	Chimi	Pomegranate	20
		Khenjina	Yeshi Dorji	Pomegranate	15
		Uma khamey	Tshering penjor	Pomegranate	10
		Dorji Wangmo	Drabesa	Pomegranate	10
		Pasang Wangmo	Nazikha	Pomegranate	10
		Choden	Nazhikha	Pomegranate	10
		Rinzin	Tokha	Pomegranate	10
		Kuchu	Umakhatoe	Pomegranate	20
Tsirang		Gopi Sherma		Persimmon	18
				Avocado	16
				Citrus	47
		Pasang Tamang		Persimmon	25
				Avocado	15
				Citrus	34
Dagana		Harka Gurung		Persimmon	20
				Citrus	65
		Tshering Tashi		Persimmon	15
				citrus	15

A total of 22 orchards were established in March and April 2017 with 732 planting materials including both grafted and seedling origin planting materials. In this way fruit orchard development is increasing yearly with many farmers becoming aware of the technology and the dividends it plays in the end of their livelihood.

Research findings and recommendations

- Through such activities, it creates a common platform for researchers and extension personals to collaborate closely in efficient and effective dissemination of technologies to farmers in the region.
- Farmers are made aware of the research systems and technologies available with the research system.

2.3.7. Improvement of Local fruit cultivars by top-Working

Top-working is one of the methods this is adopted to take improved cultivars to farmers' field by grafting on existing fruit trees. Annually, our center conducts top working in the client Dzongkhags.

Objectives

- To reach improve cultivars and superior cultivars to farmers field.
- Create awareness to the farmers on the system of top-working

Materials and method

For improvement of local cultivars and the fruit diversification in the region, three Dzongkhags (Tsirang, Dagana and Wangdue Dzongkhag) were covered during March and April 2017.

Result

Table 26: The number of local fruit trees top-worked in Wangdue in fiscal year 2016-17 is detailed below in the table.

Sl. No.	Geog	Village	Name of farmer	Contract No.	Fruit tree					Grand total
					Pear	Peach	Plum	Persimmon	Apple	
1	Bjana	Ngawang	Kumbu	17977433	2	1	1	4	0	8
2		Jagarlingchu	Tenzin Pelzang	17670883	1	2	4	1	0	8
4		Jagarlingchu	Rekay	17928418	2	3	0	0	0	5
5		Jagarlingchu	Choden	17995340	1	0	2	0	0	3
6		Jagarlingchu	Sonam Pem		2	2	1	0	0	5

7		Jagarlingchu	Lhawang Tshering	17663202	0	0	0	1	0	1
8		Jagarlingchu	Kumbu Dem		1	1	1	2	0	5
9		Jagarlingchu	Yangza	77264111	3	0	0	0	0	3
10		Jangkha	Tashi		1	2	2	4	0	9
11		Jangkha	Am Tshodey		1	0	0	1	0	2
12		Jangkha	Namgey		1	1	1	3	0	6
13		Jangkha	Gem Lham		0	0	4	2	0	6
14		Jangkha	Gup Dechen		1	1	1	1	0	4
15		Jangkha	Nidup		1	2	0	4	0	7
16		Jangkha	Namgey		0	1	1	2	0	4
17		Tseripangchu	Kumbu Dema		0	2	1	6	0	9
18		Namgeyling	Pema	17346053	1	6	4	3	0	14
19	Rubesa	Japhugonpa	Singey Wangmo		1	0	0	2	0	3
20		Japhugonpa	Ap Zoe		1	2	1	0	0	4
21		Japhugonpa	Gem Lham		2	0	1	1	0	4
22		Japhu	Ugyen Tshogpa		2	1	1	0	0	4
23		Japhu	Kuenga		3	1	1	0	0	5
24		Japhu	Ap Jue		2	2	0	2	0	6
25	Nahi	Tshokorthang	Tshering Wangchu	17828077	0	0	0	0	41	41
	Total Top-worked fruit trees				**29**	**30**	**27**	**39**	**41**	**166**

A total of 166 local fruit trees top-worked during the FY-2016-2017.

Observations

- The top-working proved to be the best method of improving and rejuvenating inferior local fruits cultivars
- Top-worked fruit trees grow more vigorously and come into bearing within 2-3 years, which helped farmers in generating income faster.

2.4. Kitchen gardening

With increasing literacy rate in the country, consumption of healthy food including vegetables and fruits has increased manifold. According to RNR statistic 2015, annually Bhutan imports vegetables and fruits worth 4B from the neighboring countries to meet the demand. In addition, sudden import ban imposed by BAFRA on certain vegetables like beans, cauliflower and chilli, aggravated the deficit situation. Therefore, kitchen garden has enormous scope not only grow the nutritious and fresh vegetable of family choice but also helps to ease the demand and self sufficiency. It is also found that kitchen garden bestow one with lots of health (keep one physically and emotionally active) and also financial benefits.

For this, one need not necessarily own a large area, where commercially gardening can be carried out, but a small patch of land at the backyard and in front of the house is enough to fulfill a family's demand of vegetables for certain period of time.

Cultivating vegetables literally for the purpose of family consumption is called "KITCHEN GARDENING". It utilizes minimal area, and there is intensive utilization of the area. This work assessed the production of different vegetables from an area of land.

Objectives

- To assess the consistency in the supply of the vegetables

Material and method

Nine different types of summer vegetables were planted in an area of 50*33m^2 at the center, ARDC,Bajo based on the cropping calendar. Solanaceous crop like chilli and tomato were staggeringly planted for three and two times, respectively. Similarly, other vegetable crops mentioned in the table were also cultivated. The quantity and number of harvest, quantity were recorded to see their consistency of supply as below

Table 27*:* Observations

Crop	Date of Planting	Number of Harvest	Quantity	Unit	Beneficiary number
1st staggered chilli	21.03.17	4	8	kg	8
2nd staggered chilli	03.04.17	3	9.5	kg	9
Brinjal	05.04.17	3	3	kg	5
Tomato	22.03.17	6	26	kg	26
Watermelon	22.03.17	2	2	kg	2
Beans	25.03.17	6	41	kg	40
Spinach	21.03.17	5	5	bundle	5
chives	21.03.17	10	48	Bundle	48
Beetroot	21.03.17	1	5	kg	6

From an area of 50*36m^2 one can harvest multiple number of produce, and we could see there is continuous supply of different vegetables at different period of time**.**

2.5. Floriculture

Small unit of Floriculture is also under taken sector at ARDC Bajo has been kept alive. Annually based on the demand and requirements, the flowering and ornamental plants are supplied to various institutions. In 2016-17, institutions that benefited from center's floriculture unit are;

1. Schools within the regions
2. Recreational parks
3. Armed forces (RBP)
4. Mega Hydro Power Project area (PHPAI and II) and
5. Beautification and landscaping of religious sites (Zomilingthang), under Punakha and Wangdue Dzongkhag.

Table 28: The quantity of flowers, shrubs, avenue trees maintained at the station, and distributed

Slno	Item	Produce No	Supply No	Balance
1	Golden hedge	200	130	70
2	Wangchuk meto (Red)	400	315	85
3	Wangchuk meto (yellow)	300	237	63
4	Wangchuk meto (Red double)	250	160	90
5	Sizigium	500	380	120
6	Boux hedge	620	615	5
7	Cassia	250	100	150
8	Gul mohar	50	50	0
9	Dog wood	170	170	0
10	Oak	50	50	0
11	Jagaranda	300	110	190
12	Bottle brush	250	125	125
`13	Ornamental plant (red leaf	150	115	35
14	Bamboo	60	60	0

2.6. Citrus Repository (RDSC Tsirang)

Citrus is one of the main export crops of Bhutan. The crop has well established marketing chain although its cultivation method remains traditional and export markets are limited to two neighboring countries (Bangladesh and India). On the contrary, Bhutan imports huge chunk of pulp (60-70%) for processing from outside country during the off-season. 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, 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.

2.6.1. Collection of germplasm and evaluation (varietal trials)

The main objective of the activity is to identify suitable varieties for various purposes (table, processing, tolerant and resistant to pest and diseases). The accessions are currently propagated at Citrus Repository, RDSC Tsirang. A varietal evaluation trial established on station at RDSC Tsirang and Bajo for evaluation and identification of suitable varieties for different purposes. The trial at Bajo is terminated while it is on-going at ARDSC Tsirang.

2.6.2. Dissemination of key management practices

To showcase technology at shelf with respect to key orchard management practices, two demonstration orchards were set up at farmers' field (Thangna and Tsirangtoe). Also, whole Drujaygang geog under Dagana Dzongkhag has been mobilized for taking up area wide citrus management approach to mitigate Citrus Greening disease. All the citrus growers from Pangna, Thangna and Pangserpo Chiwogs (about 320 households) are involved in the group. The technical support and monitoring on implementation of calendar of activities will be continued. A technical report on assessment of orchard management technology adoption is under review in international peer review journal (Agriculture and Food Security).

2.6.3. Nursery technique for producing disease free planting materials

Graft transmissible diseases such as citrus greening, CTV, psorosis, etc has been the main issue across the globe. Establishment of citrus nursery is demanding both in term of resources and technicalities. A repository is established to cater the needs of disease free scion/bud woods. The harvesting of budwoods have begun and propagated. In addition, to assist researchers, nurserymen, extension officials etc, a technical guide on Nursery manage is published. We also evaluated physiochemical properties of locally available materials that is more rampantly used by nurseries in Bhutan. We also determined the citrus water requirement for different phonological stages of citrus for Dagana and Tsirang based on Tensiometer reading and reported. The outcome of the experiment will be published in peer reviewed journal.

2.6.4. Disease testing and implementation of repository protocol

As per the repository protocol, two additional blocks were constructed using polyhouse and screen net. These blocks still need structural improvement which we hope to conduct in the coming financial year. The blocks are as below

a. *Quarantine block*

This is the first block that any planting materials will have to pass through this block. The material will be treated with chemical as per protocol and propagated. Minimum of 41 days will be kept under this block and scrutinized for presence of quarantine pests or diseases. Once the proper graft union is formed, it will be transferred to diagnostic block. All, the activities conducted with the planting material introduced will be recorded. Currently, this block contained rootstock seedlings raised for propagation of introduced accessions

b. *Diagnostic block*

The purpose of this block is to maintain different mother trees for indicator plants, positive controls (HLB, CTV and other graft transmissible diseases), and conduct biological indexing as per the repository protocol. We have multiplied indicator plants required for regular indexing of mother and daughter trees. The block also houses rootstock for indexing and some samples of seedlings indexed for graft transmissible diseases especially greening. For this we have also developed a protocol.

c. *Daughter Block*

One of the main purposes of the repository is to produce high health status planting materials and daughter trees for nurseries. The construction concrete base for two daughter blocks have been completed and covered with standard psylid proof screen net. Currently, mother trees 13 lines have been maintained of which only three are local mandarin varieties. We also maintained lime and lemon varieties (bears lime, acid lime a local from Shemshong).

We have already started producing budsticks. Since we have limited number of mother trees (only 10 potted plant) for each promising lines, another (increased/daughter) block will be constructed to house more potted plants to increase the production of budwoods. With the financial support from ACIAR, we purchased both external (two polyhouse frames and polyethylene sheets, syntax) and internal components (irrigation, pots, etc). However, the irrigation systems for the block will be carried out in coming financial year.

2.7. Cardamom activities at ARDSC Tsirang

The Department of Agriculture through various funding source has supported 221291 cardamom seedlings for rehabilitation of diseased cardamom plantations in Chukha, Dagana, Samtse, Trongsa and Haa Dzongkhags and new orchard establishment in Pemagatshel Dzongkhag since FY 2012-2015

The department with the support from RRCDP has completed the construction of 7 cardamom seedling propagation houses costing Nu. 10.5 million in March 2014 at National Seed Center, Samtenling. The Propagation house is expected to produce 40,000 cardamom seedlings annually which will contribute in promotion and rehabilitation of approximately 26.4 acres annually.

2.8. Establishment of cardamom repository and research

The National Large Cardamom Repository at ADSC, Tsirang was conceived in 2012 to enable production of disease free planting material. This is because the ups and downs of cardamom industry in Bhutan largely depend on the quality of planting material. The issue delves both in terms of varietal characters and diseases that are often transmitted in large scale through use of uncertified and untested planting materials.

Therefore, this repository is aimed to institute a system of producing true-to-type and healthy planting material to sustain cardamom production in the country through varietal identification or characterization and passing it through several diseases screening process to ensure the quality and high health status. For this, a total of 2.8 acres land area is marked for establishment of Cardamom Repository where germplasm collection, evaluation and multiplication of known varieties is already initiated.

At present, the repository is in its initial stage of establishment, owing mainly to lack of budgetary support, with only a few poly houses to house the collections. Since, production of clean material requires standard infrastructure that meets technical requirement, there is an urgent need to procure screen houses that is must for production and maintenance of health tested mother plants. Currently, there are 26 large cardamom accession collected from Zhemgang, Chhukha and Sarpang districts in 2012- 2014. More accessions are being planned to be collected from within Bhutan and outside. Besides this, a few prominent varieties like Ramsey, Seremna, Golsey and Varlangey have also been planted in the field since 2015 and their performance will be evaluated from this harvesting season.

3. RNR Engineering Service- ARDC Bajo

3.1. ARDC Bajo internal farm road base course construction work

The Engineering Sector at ARDC Bajo along with the management and JICA team made a site visit for identification sites for the construction of ARDC Bajo internal farm road basecourse. In line with the outcome of the site visit, the sector prepared drawings, estimate and BoQ. The cost of the work was estimated at Nu727,112.00/-. The work was awarded to Ms Tandin Wang Construction, Punakha through open tendering at a contract price of Nu538,914.75. The duration of the implementation period was 2 months which was stipulated to start and complete on 08 April 2017 and 08 June 2017 respectively. The work was actually completed on 07 June 2017 and the final value of the work done was Nu556,321.31. The handing-taking of the work was done on 08 June 2017. Mr Thinley Gyeltshen (Principal Engineer) served as the site engineer for this work.

3.2. Construction of ESP Quarter (4Block-Double Unit) at ARDC Bajo

ARDC Bajo management visited the site for selection of construction sites for 3 Blocks of ESP Quarters at ARDC Bajo. Base on the directions of the management, the Engineering Sector prepared drawings, estimate and BoQ for the work. The cost was estimated Nu2,488,260/- for the three blocks (double units). The work was awarded to Ms CNC Construction, Wangdue through open tendering at contract price of Nu1,885,083.60 with an implementation duration of 120 days. As the quoted price was significantly lower compared to approve budget, the management decided to construct one additional block as there is dire need. Therefore, management decided to award additional work to the same contractor based on the progress of the initial package. As the contractor made good progress the management issued the work order for additional work based on the initial quoted rates valued at Nu928,361.20/ with additional duration of 40 days. The work was completed on 27 June 2017 within stipulated time and was taken over by the management on 29 June 2017. The handing-taking of the work was done on 29 June 2017. The final value of the work done was Nu2,421,079.97. Mr Puran Chettri (Assistant Engineer) served as the site engineer for civil works.

The electrical works was implemented departmentally. Base on 2015 BSR the cost of the work was estimated at Nu461,032/- while the cost of materials was estimated at Nu336,492.00 based on the local quotation rates. The work was started on 14 June 2017 and was completed on 28 June 2017 through the employment of ESP. The budget was re-appropriated from the saving of other construction works at ARDC Bajo. Mr Indra (Sr.Technician-III) served as the site engineer. The overall cost of construction of 4 blocks (double unit) including civil and electrical works was Nu2,757,571.97.

3.3. Re-electrification of Staff Quarters at ARDC Bajo

Based on the plan and allocated budget for the re-electrification of five staff quarters at ARDC Bajo, the Engineering Sector prepared estimate for the work. The overall estimated cost of the work was Nu825,495.00 as per BSR-2015. As the management directed to implement the work departmentally the sector prepared the list of materials to be procured, the cost of materials was estimate at Nu414,415/- based on the local quotation rates, and finally made the procurement. The sector implemented the work starting from 15 June 2017 and completed on 26 June 2017. Mr Indra (Sr. Technician-III) served as the site engineer for this work.

3.4. Construction of Farm-store cum Workshop for IHPP

The JICA team, management and the Engineering Sector visited the site to identify location and orientation for the construction of Store-cum-Workshop. This structure is RGOB component of the Integrated Horticulture Promotion Project supported by JICA. The sector prepared drawings, estimate and BoQ for the work. The cost of the work was estimated at Nu3,938,382.00. The implementation of the work was awarded to Ms Sangzang Construction (Punakha with CDB#7073) at a contract price of Nu2,897,734.37 through open tendering by ARDC Bajo with a project duration of five months. The work was started on 05 December 2016 and was stipulated to be completed by 30 April 2017. The final value of the work done is Nu2,674,468.29 and the completion was established on 28 April 2017. The handing-taking of the work was done on 28 April 2017. Mr Thinley Gyeltshen (Principal Engineer) served as the site engineer for the civil works and Mr Indra (Sr. Technician-III) served as the site engineer for electrical works.

3.5. Major Renovation of old office building– Farmers Training Hall for IHPP project

The JICA team and management decided to renovate RRCO Building against the initial proposal of construction of new building. Accordingly, JICA team, the management and the Engineering Sector visited the existing building and identified the areas of renovation of the building. The construction of training hall is part of IHPP project component to be financed by RGoB. The sector prepared drawings, estimate and BoQ for the major renovation of the building which will be used as farmers training hall for the project. The cost of the work was estimated at Nu2,815,801.85. The implementation of the work was awarded to Ms Tandin Wang Construction (Wangdue, CDB#7917) at a contract price of Nu2,181,919.00 through open tendering by ARDC Bajo with a project duration of 120 days (4 months). The work was started on 20 December 2016 and was stipulated to be completed by 20 May 2017. The final value of the work done is Nu2,039,204.47 and the completion was on 20 March 2017. The handing-taking of the work was done on 27 March 2017. Mr Thinley Gyeltshen (Principal Engineer) served as the site engineer for the civil works and Mr Indra (Sr. Technician-III) served as the site engineer for electrical works.

3.6. Improvement of On-station Irrigation Channels at ARDC Bajo

The farm channel improvement was planned to make realignment of channels within the farm area following the stoppage of first inlet channel from the army area owing to the unstable slope posing high risk of land degradation. Hence the existing command area of the channel has to be irrigated from other second inlet channel which requires the construction of new link channel (82m) and improvement of internal farmer channels below road (145m). Accordingly Engineering Sector prepared the estimate and BoQ. The estimated cost of the work was Nu555,745.00. The work was awarded to Ms Mendagang Construction (CDB#7500, Punakha) at contract price of Nu421,850.00 with implementation period of three months days. The work was started on 27 January 2017 and stipulated to be completed by 05 May 2017.

By the time the earth excavation work for the link channel (82m) between the highway and ARDC Bajo fencing was completed, Wangdue Municipal objected to the work as it was being built very near to the highway claiming that future infrastructure development along the high will be affected. Owing the objection from the municipal, ARDC Bajo management decided to build the link channel within the farm area which increased the length from 82m to 234m. As the channel section reduced for the new link channel the overall cost variation was not significant and accordingly there was no change in the duration of the project.

The work was actually completed on 27 April 2017 before the stipulated time and the final value of the work done was Nu447,844.00. The handing-taking of the work was done on 28 April 2017. Mr Thinley Gyeltshen (Principal Engineer) served as the site engineer for this works.

3.7. Construction of GI Chain-link Fencing at ARDSC Tsirang

The Engineering Sector along with the management of ARDC Bajo and ARDSC Tsirang made a visit to the proposed ARDSC Tsirang farm GI chain-link fencing construction site. Subsequently, the sector prepared drawings, estimate and BoQ for the construction of 810m of GI chain-link fencing. The cost of the work was estimated at Nu1,720,000.00. The implementation of the work was awarded to Ms Yungden Construction (CDB#7845, Gelephu) at a contract price of Nu1,684,715.00 (1,189,615.00+495,100.00) through open tendering by ARDC Bajo with a project duration of 170 days (initial package: 120 days + additional: 50 days). The work was started on 06 October 2016 and was stipulated to be completed by 25 March 2017. The final value of the work done was Nu1,551,445.52 and completed on 23 January 2017 . The handing-taking of the work was done on 16 February 2017. Mr Thinley Gyeltshen (Principal Engineer) served as the site engineer for this work.

3.8. Construction of Farm Shed at ARDSC Tsirang

As there were savings from the 2016-17 capitals works of ARDSC Tsirang, the management decided to utilized the budget for the of construction farm shed within the ARDSC Farm compound. This construction is in line with the IHPP project framework where RGoB is required to provide capitals for farm infrastructure development works. The immediate priority of JICA team was the need to construct farm shed at ARDSC Tsirang. Accordingly the team representing JICA team, the management of ARDC Bajo, ARDSC Tsirang and Engineering Sector visited the farm to identify the locations. Based on the recommendation of the site visit the sector prepared drawings, estimate and BoQ. The cost of the work was estimated at Nu245,886.00. The implementation of the work was awarded to Ms CNC Construction (CDB#7515, Wangdue) at a contract price of Nu270,651.56 through limited tendering by ARDC Bajo with a project duration of 60 days. The work was started on 29 May 2017 and was stipulated to be completed by 28 July 2017. The final value of the work done was Nu277,935.71 and completed on 28 June 2017 . The handing-taking of the work was done on 28 June 2017. Mr Nima Wangchuk (Junior Engineer) served as the site engineer for this work.

3.9. Installation of Compound Lighting at ARDSC Tsirang

As there were savings from the 2016-17 capitals works of ARDSC Tsirang, the management decided to utilized the budget for the of construction compound lighting system within the ARDSC Farm compound. Accordingly the team representing management of ARDC Bajo, ARDSC Tsirang and Engineering Sector visited the farm to identify the locations of light posts. Subsequently, the sector prepared estimated and BoQ. The estimated value of the work was Nu145,214.38 for erection of four post and associated electrical wiring and fittings. The implementation of the work was awarded to Ms Pelden Dorji Construction (CDB#7662, Wangdue) at a contract price of Nu145,000.00 through limited bidding by ARDC Bajo with a project duration of 45 days. The work was started on 19 May 2017 and was stipulated to be completed by 03 July 2017. The final value of the work done was Nu158,340.00 and completed on 26 June 2017 . The handing-taking of the work was done on 28 June 2017. Mr Indra (Sr. Technician-III) served as the site engineer for this work.

3.10. Regional Irrigation Infrastructures Development Services

3.10.1. Renovation of Baychu Irrigation Channel under Thedtsho Geog, Wangdue

The Engineering Sector started surveying of the Baychu Irrigation Scheme by second week of April 2014 and completed by first week of May 2015. After the survey the sector started to process survey data, prepare design drawings and estimate. As the cost of the initially proposed quantities of work (Nu21.46 million) exceeded the allocated budget (Nu18.0 million), the sector underwent several rounds of costing cutting cycles in terms of reprioritizing the item of work, re-preparing design, drawing and estimates requiring substantial amount of time. Final cost was estimate at Nu18.356 million against the budget amount of Nu18.0 million only. The tendering of the work was done by the Engineering Division while concerned Engineers from ARDC Bajo participated as members in Tender Opening and Evaluation Committees. The work was awarded to M/s Wanthang Construction at quoted amount of Nu17.669 million with the active project duration of 16 months (480days). The work site was handed over to the construction firm on 24 October 2015.

The main challenges of implementing irrigation channel renovation works includes:-

- Stop work during paddy season: For irrigation channel renovation works there is need to stop the work during paddy season to enable farmers to engage in paddy cultivation. If the project duration exceeds the single off-paddy season, there is need to determine Gross Project Duration (GPD) which provides basis for effective planning of the project with reference to cost associated with longer duration of project, the cost involve in cyclic mobilization-demobilization-remobilization of resources. As most of the contract firms have limited experiences in the irrigation renovation works making aware of the concerns and issues related to stopping of work during paddy season will be crucial for future irrigation channel renovation works.
- Work sites scattered along the channel length: Since the irrigation channel renovation work sites are scattered along the channel length provides challenges for monitoring, increased material transportation cost as it has to done manually, and manual carriage of materials require more time leading to delay of project. Most of the contract firms are not aware of such situations and fail to consider related cost resulting to low bid price. This leads to poor performance of the contractor during implementation.
- Drinking water pipe lines: Three drinking water pipelines are also aligned along the Baychu Irrigation Channel. One pipeline (90mm GI pipe) conveys water from the same source to Bajo villages under Thedtsho Geog, and other two pipelines (both 150mm DI pipes) traps same sources upstream of channel intake conveys water till municipal water treatment plant situated at Gangthang. As per the irrigation channel beneficiary farmers the pipes were laid without consultation with them. The main issues main issues of the pipelines includes (a) all threes pipelines laid on the surface without any trenching works, (b) in many cases the pipelines are laid within the channel- reducing the channel capacity, (c) pipeline crosses the channel within the effective channel conveyance section- leading to reduction of channel capacity and acting as a barrier for floating debris accumulation and ultimately leading to failure of channel due to overtopping of water (many channel collapse were attributed to this cause), (d) besides pipelines many pipeline props are constructed within the channel- thus reducing the channel capacity and acting as blockage for the floating debris, and (e) in addition these pipelines also stands as an obstruction to the implementation of renovation works in terms of increasing the cost and project duration

by having to construct drinking water pipeline by-pass works. The by-pass work at the channel intake site was estimate (BSR2015) at Nu2.578Million at additional duration of 27days.

- Highway widening works: Since the Baychu Irrigation Channel is aligned above the Wangdue-Trongsa High from Ganthang to Chuzomas, the highway widening works have undermined the stability of the slope between the channel and the road. In 2016 paddy season channel was completely collapsed at two locations damaging 366 m (212m+154m) length of channel. In 2017 paddy season about 80m of channel length stretch was damaged and the pipe conveyance length required would exceed 200m for this site owing to the necessary lack of static head.

The physical progress of the work stands at 50% completed by end of fiscal year 2016-17 with equivalent financial progress. The Active Project Duration (APD) completed stands at 293days (193days first season + 100days for second season) against total of 507 days (480days for initial package + 27days for additional work). This leaves balance project duration of 214 days (42%) requiring to complete balance 50% of the work. The work is expected to be completed by 30 May 2018 date assuming the third season work can be started latest by 28 October 2017. This gives GPD of 949 days. This gives GPD and APD ratio of 1.8718. Hence, APD can be scaled up by the factor to estimate GDP which will be useful for major irrigation channel renovation works in future. The site engineering service was provided by Mr Thinley Gyamtsho (Principal Research Officer).

3.10.2. Reconstruction of Baychu Irrigation Channel under Thedtsho Geog, Wangdue

In 2016 paddy season Baychu Irrigation Channel was damaged at two locations between Gangthang and Chuzomsa on 30 June 2016. The damaged of the channel was attributed to the land slip triggered by Wangdue-Trongsa Highway widening.

By 20 March 2017 ARDC Bajo submitted drawings and estimate for the re-construction of the damaged sections using HDPE pipe conveyance line across the actively sinking area. The cost of the pipe was based on the Indian pipe price as larger pipe sizes (315mm and 400mm diameter) were not being manufactured by DrukPipe. The overall cost of the re-construction was estimated at Nu2,227,138/-. Accordingly Department of Road (DoA) released Nu1,891,934.49/- for covering pipe conveyance works vide letter No. DoR/Lobeysa/Construction(17)/2016-2017/1846 dated 25 May 2017. Based on the stakeholder meeting conducted on 08 June 2017 discussed that Bhutan Polythene Company Ltd., (DrukPipe) would be starting to manufacture HDPE pipe sizes up 400mm diameter however the price are relatively higher [for instance Nu4,434.40/m for 400mm dia (PN4) for DrukPipe against Indian price of Nu1,626.24/m + BST] the forum decided to procure from DrukPipe in keeping with the government policy. ARDC Bajo was asked to prepare revised estimate based on the DrukPipe rate for requesting additional budget. The revised estimated amounting to Nu3,699,044/- was submitted to Dzongkhag which was then forwarded to DoA vide letter No. DAW/Agr-27/2017-18/20 dated 01 July 2017. On 30 June 2017 Department of Road responded vide Letter No DoR/Lobeysa/Construction(17)/2016-2017/2000 regretting for inability to provide the additional fund as budget proposal for upcoming financial year was already completed. As additional budget was not available ARDC Bajo was asked to prepare for the procurement with available budget. The site engineering service was provided by Mr Thinley Gyamtsho (Principal Engineer/Research Officer).

3.10.3. Construction of Irrigation Water Conveyance Siphon at Nhashingjakah, Ruepisa

Based on the request of Wangdue Dzongkhag Administration (DAW/Adm-22/2016/6898 dated 05 May 2016), ARDC Bajo conducted survey, prepared deign, drawing and estimate for the construction of irrigation water conveyance siphon pipeline. The study indicated that it is technically feasible to trap the over flow of the Hesothang Mini Hydropower Reservoir Tank situated above Wangdue-Tsirang Highway, and convey the water across the Punatshangchu to Nha-shing-jakha village under Ruepisa Geog through gravity siphon pipeline. The existing bridge constructed by Punatshangchu is proposed as river crossing structure for the pipeline. The cost of 964m long 200mm diameter siphon pipeline construction works is estimated at Nu1,755,313. As the over flow discharge is not known the pipeline designed based on the water requirement of command area of 28 acres with peak flow requirement of 36lps. The site engineering service was provided by Mr Thinley Gyamtsho (Principal Engineer/Research Officer).

3.10.4. Reconstruction of Whenkhang Irrigation Channel under Lanthelel Geog, Trongsa

Trongsa Dzongkhag Administration wrote to ARDC Bajo seeking technical support for redesign of Whenkhang Irrigation Channel intake structure on 23 November 2016. The channel is situated in Langthel Geog under Trongsa. The channel intake structure was buried by the fallowing debris from Rephey-Koshala Highway bypass construction works. Since the burial of the channel intake the complete reconstruction was done almost every year with the support of Dzongkhag and Department of Road only to find it being damaged by within on single rainfall event affecting the crop production.

3.10.5. Preliminary Field Visit and Survey

Based on the request of the Dazongkhag the Engineers from ARDC Bajo accompanied the DAO, Rephey-Koshala Highway bypass construction Site Engineer, Langthel Geog Officials and representative of beneficiary farmers visited the site on 01 February 2017. The team visited the site, discussed the problems and issues of past remedial works, and identified the alternative measures to address recurring problems at the irrigation channel intake created by the following debris. The identified options are stated below:-

a) Construct subsurface intake weir with perforated RRC pipe sump, and valve chamber to capture the low flow at the source which at the moment is not possible as the water flow below the surface of the deposited debris,

b) Construct gabion walls to protect the intake structure from being washing away by high flood and debris flows,

c) Construct PCC pipe casing for initial 60m of pipeline from the intake structures to prevent crashing of pipes by continuously debris, and

d) Construct the siphon pipeline to by-pass initial 200m of unstable channel section.

In accordance to the identified options the team conducted topographical survey of intake area and siphon pipe alignment on the same day. Based on the above identified options, survey data and other relevant information collected from the site, Geog and Dzongkhag, the ARDC Engineering Sector carried out design, prepared drawings, estimate, and BoQ. The re-designed intake construction cost was estimated at Nu2.476 million.

3.10.6. Implementation of the work

Department of Agriculture awarded the implementation of the work to Ms Nidup Construction through open tendering. The site was handed over to the construction firm on 15 May 2017 by Dzongkhag, Geog and ARDC Bajo. The work was stipulate to be complete by 15 July 2017. The site engineering services was to be provided by Dzongkhag Engineering Sector. A local level monitoring team for the constructions works was formulated.

3.10.7. Low yield of water at the intake

By 03 July 2017 Trongsa Dzongkhag Administration wrote a letter to ARDC Bajo seeking technical advice on the low yield of water based on the notification letter submitted by construction firm to the Dzongkhag even after reaching specified depth of excavation. The team comprised of the Geog Officials (The Gup, Tshogpa, and Agriculture Extension Officer), the representatives of beneficiary farmers, Dzongkhag (site engineer), the proprietor of the construction firm (Ms Nidup Construction), and the design engineer from ARDC Bajo made a site visit on the afternoon of 06 July 2017. A discussion meeting was conducted after the site visit in Dangdung village Lhakhang. Majority of the beneficiary farmers from Whenkhang and Dangdung villages participated in the meeting in addition to the site visit team members. Base on the site observations and the discussion with the concerned stakeholders the water availability at the source has declined significantly which are attributed to the following reasons:-

a) Debris deposits have created multiple flow paths of the water at the intake thus trapping of water at a single point is able to trap only faction of the flow (refer Figure 01 right picture). Therefore, to trap entire flow there is a need to construct longer and deeper weir covering the entire sub-surface flow cross-section area. This would demand high capital cost which may be even more expensive than constructing new irrigation scheme from a new source. Further this would require detail study on the local aquifer which is beyond the scope of technical capacity of ARDC Bajo and Department of Agriculture.

b) As per the farmers, in the past wetland under Whenkhang Irrigation Scheme used to be very productive. The framers from neighboring villages used to envy them because there used to be adequate water at the source, the water source being very near to their land required shorter length of channel requiring minimal maintenance. At present water availability at the source is reduced which is partly attributed to the improvement of irrigation channels of the upstream users reducing seepages and leakages. Besides debris deposit has completely disable us to trap event the small flow that is available at the source.

c) Based on the Google earth map the total catchment area of the present sources is about 6.72 sq.km, considering the upstream two irrigation channels with catchment area of 5.83 sq.km the net catchment area for Whenkhang Irrigation Channel is only 0.89 sq.km (= 6.72 - 5.83) which is relatively very small for the gross command area of 135 acres. Therefore, even if we are able to provide an intake structures that could capture all the available flow at the source, the potential water yield capacity of the catchment itself is very low and will not justify the heavy capital investment specially if there are alternative sources which can be developed using gravity conveyance line.

d) Some farmers mentioned that the nearest available source is Muyamchu which is about 5 to 5.5 km away from the village towards Koshala village. Besides Whenkhang, Dangdung and several other villages lies between two main tributaries of Mangduechu where much larger irrigation schemes can be developed which can trap water from much larger and reliable sources. This can be more robust strategy to overcome the negative climate change

impacts such as reducing or drying of local water sources which are rampant across the country.

Since the water availability has declined for the Whenkhang Irrigation Scheme of various reasons as stated earlier, the on-going channel improvement work was not going to improve the water availability situation even construction works are implement with revised design/drawings (increased intake structure size) and increased cost. This increased cost will be justifiable only if there are no alternative sources.

Further, that season has indicated that the reliability of the source is very poor and it has to depend completely on the on-set monsoon rainfall before the source becomes large enough and divert into their irrigation channel.

Therefore, from technical point of view that it was recommended that the work to be stopped and alternative source can be developed. The development of new source will not only improve the water availability during the rice season but also in the other seasons which will enable increase cropping intensity thereby enhancing the crop production in the long run.

3.10.8. Re-starting of the work

By 19 September 2017 the Dzongkhag Administration has issued the order to the construction firm to restart the work based on the direction of Hon'able Finance Minister Visit to the Geog. The beneficiary farmers have reported that there is enough water at the source at this time (September) and decided to continue the work. Mr Thinley Gyamtsho (Principal Engineer/Research Officer) provided the engineering services.

3.10.9. Renovation of Phenday Irrigation Channel under Talo Geog, Punakha

The survey, preparation of design, drawing and estimate for the renovation of Phenday Irrigation Channel was done by Engineering Sector at ARDC Bajo. The renovation cost of 22.4km long channel was estimated at Nu33,824,737.72. The work was tender and evaluated by Department of Agriculture. The bid amount of the lowest evaluated bid was Nu29,622,139.60, however the work was left un-awarderd due to the limited budget till 2016-17. The Ministry confirmed that the work will be awarded and implemented only in 2017-18 financial year. The 22.4 km long open channel traps irrigation from Toepirongchu and conveys to command area under Toep, Talo and Guma Geogs in Punakha. The main problem of the irrigation scheme includes (a) small source combined with high conveyance loss resulting in water shortage problem, and (b) the weak Water Users Group (WUG) and long channel length resulting in poor maintenance of the channel. Mr Puran Chettri (Assistant Engineer) served as the site engineer for civil works.

3.10.10. Construction of Dreychu Irrigation Channel Kana Geog, Dagana

The Engineering Sector under ARDC Bajo conducted survey, prepared design, drawings, estimate and tender documents for the construction of Dreychu Irrigation Scheme in 2014. The cost of constructing 7.2km long open channel with design flow capacity of 360lps was estimated at Nu29,498,993.37. The tendering, evaluation and awarding of the work was done by DoA Engineering Division. The work was awarded to Ms PST Construction at contract price of Nu28,999,998.10 with implementation duration of 18 months. This channel is designed to convey rrigation water from Dreychu water source to the command area in Namzhigang Village. This channel is not only expected supplement irrigation water for the

existing paddy fields in the village but also to provide irrigation water for dryland crops in the village. The physical progress of the work stands at (a) 70% of the formation cutting completed, (b) 100% of the intake structure completed, (c) 80% of aqueduct completed, (d) 32% of open channel lining works completed, and (e) 0% of outlet structures works completed by the end of 2016-17 fiscal years although the 100% of the project duration has lapsed. The challenges of the project includes (a) poor access to the project sites during the rainy season resulting in difficulty of reaching the materials on time, (b) difficulty of mobility of equipment within the project area as the project sites are spread along 7.2km channel length, and (c) frequent absconding of the Indian labours owing to the remoteness of the project sites. The above challenges not only delay the overall progress but also incur additional cost in terms of remobilization of the resources. Mr Puran Chettri (Assistant Engineer) served as the site engineer for civil works.

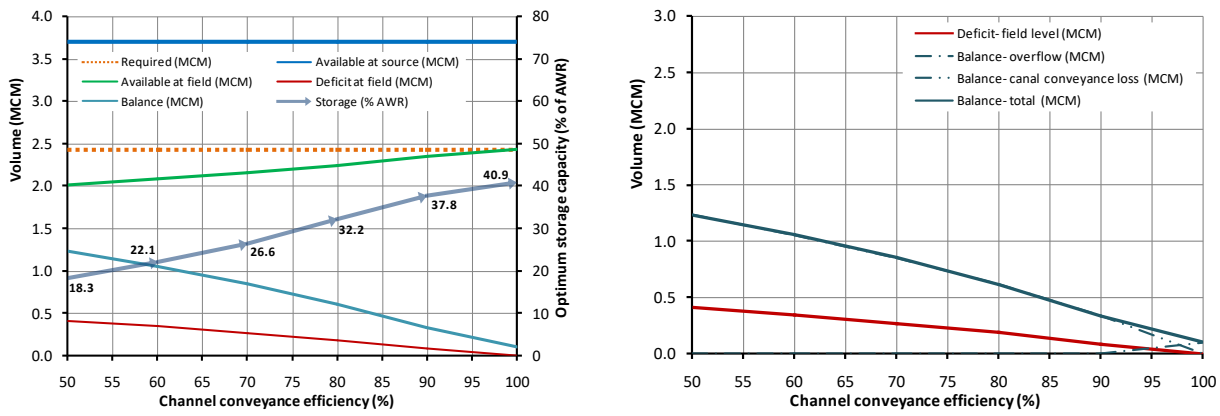
3.10.11. PFS: Construction of Water Reservoir under Dawakha Irrigation Scheme, Punakha

The Engineering Sector in collaboration with Punakha Dzongkhag and Toedwang Geog carried technical prefeasibility for the construction of irrigation water reservoir under Dawakha Irrigation Scheme.

The purposed of the feasibility study was to determine whether construction of irrigation water reservoir will help to increase the field level water availability thus improving the crop production. This required water balancing analysis which will indicate how much water is available in the system and how much is required.

The annual water availability pattern was determined using WECS method. The inputs required are rainfall data and catchment area. Accordingly catchment area determined from Google Earth and nearest rainfall data of Punakha was used to estimate mean monthly runoff at the Dawakha Channel Intake. The annual water requirement under Dawakha Irrigation Channel was determined using the National Irrigation Master Plan-2016 guidelines. Using the water availability and requirement pattern daily water balancing was done in Excel to determine diversion requirement, conveyances loss, daily balance/deficit, storage volume, storage losses for various scenarios.

A typical scenario is presented hereafter. The result indicates the analysis of the variation of annual field level water availability, field level deficit, water balance and optimum storage capacity requirement against channel conveyance efficiencies ranging 50% to 100% is shown for maximum channel carrying capacity of 375lps (32,400cu.m/day). **Error! Reference s ource not found.**(a) shows when channel conveyance efficiency is increase from 50% to 100% the field level water availability increase from 2.019MCM to about 2.434MCM with the corresponding decrease of field level deficit from 0.145MCM to zero at annual scale. The correspondingly the optimum field level reservoir capacity requirement ranges from 18.32 to 40.90 percent of annual water requirement. If the reservoir capacity is increased beyond these then the there is risk of over sizing which will never be filled with water as the limitations lies with the flow rate at the source, channel capacities, and conveyance efficiencies. For instance at 100% conveyance efficiency, the optimum reservoir capacity required is only 40.9% (0.996MCM) of the annual water requirement. The figure shows that despite there is field level water deficit there is also un-managed water balance ranging from 1.234MCM to water 0.101MCM.



(a) (b)

Figure 16 (a) and (b): Case- A annual balance variation against channel conveyance efficiencies at channel conveyance capacity of 375lps for Dawakha Irrigation Scheme: (a) Overall balance variation, and (b) Components of un-managed water balance.

Error! Reference source not found.(b) shows the variation of the components of un-managed a nnual water balances. It indicates that for maximum channel conveyance capacity of 375lps, the quantity of un-managed water balance reduces from 1.234MCM at 50% channel conveyance to 0.101MCM at 100% conveyance efficiency. The increase is mainly due to the improvement of channel conveyance efficiency thus increasing the availability at the field level for a given channel capacity. The main components of un-managed water balance are channel conveyance loss and channel conveyance capacity. Since the channel carrying capacity is based on the peak flow available at source zero, however losses due to conveyance efficiency decreases from 1.234MCM to zero for the 50% to 100% conveyance efficiency improvement.

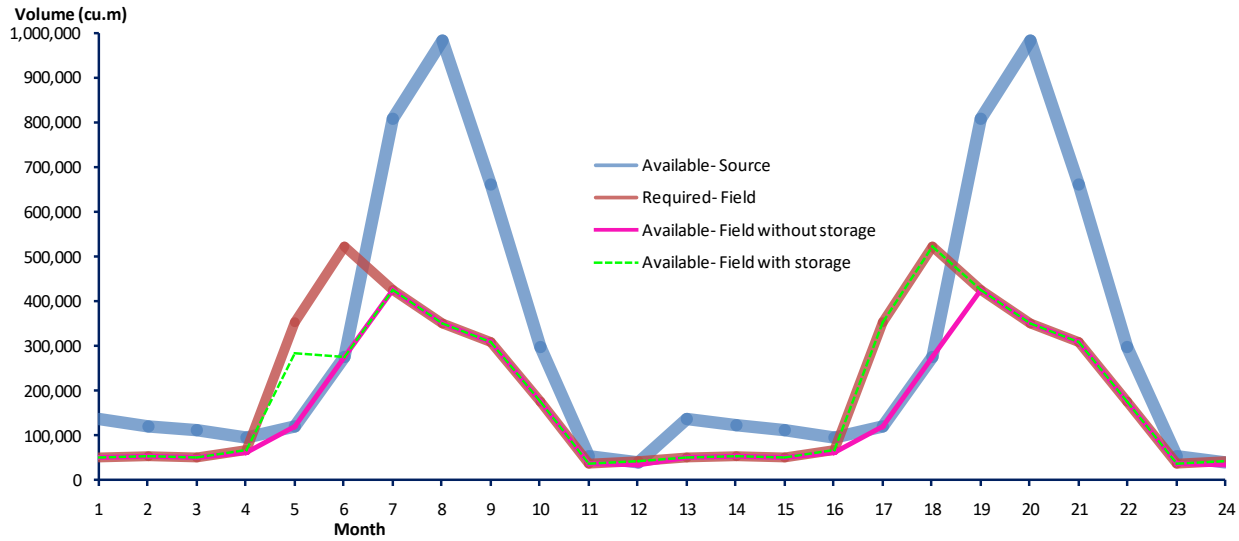


Figure 17: A typical temporal water balance pattern for Case-A water availability situation with 375lps channel capacity and 100% conveyance efficiency at an optimum storage capacity of 40.9% of AWR.

Error! Reference source not found. shows a typical two year cycle temporal water balance p attern for Case-A water availability situation at source with 375lps channel capacity at 100%

conveyance efficiency with optimum storage capacity of 40.9% of annual water requirement at monthly interval. The figure shows that starting from first to fourth month water requirement is less than the available water hence water available at field level coincides with the requirement curve. Field level water requirement curve goes above the water available curve at source from forth to sixth month for first year and 16 to 18 month for second year indicating system level water deficit situation. Although the water available curve lies below water requirement curve owing to limited time (four months) of fill up for the first year but for the second year the curves coincides indicating zero deficit. Therefore for the first year the field level deficit is estimate at 13.1% and subsequent year there will be no deficit at all with storage capacity of 40.9% AWR. For other scenarios refer main report.

The feasibility study indicates that water availability at the field level under Dawakha irrigation Scheme can be improved to support the cropping requirement with the existing catchment area. But this requires not only construction of irrigation water storage reservoirs but also need to increase channel conveyance capacity, minimize conveyance and storage losses. This water balancing approach provides effective tool in optimizing the reservoir capacity under a give scenario.

Mr Thinley Gyamtsho (Principal Engineer/Research Officer) provided the engineering services

3.10.12. PFS: Construction of Water Reservoir in Thara village under Guma Geog, Punakha.

The Engineering Sector in collaboration with Punakha Dzongkhag and Guma Geog is in the process of carrying out similar technical prefeasibility for the construction of irrigation water reservoir Thara village under Guma Geog. Mr Thinley Gyamtsho (Principal Engineer/Research Officer) provided the engineering services

3.10.13. PFS: Construction of Lift Irrigation for Phangyul Geog, Wangdue.

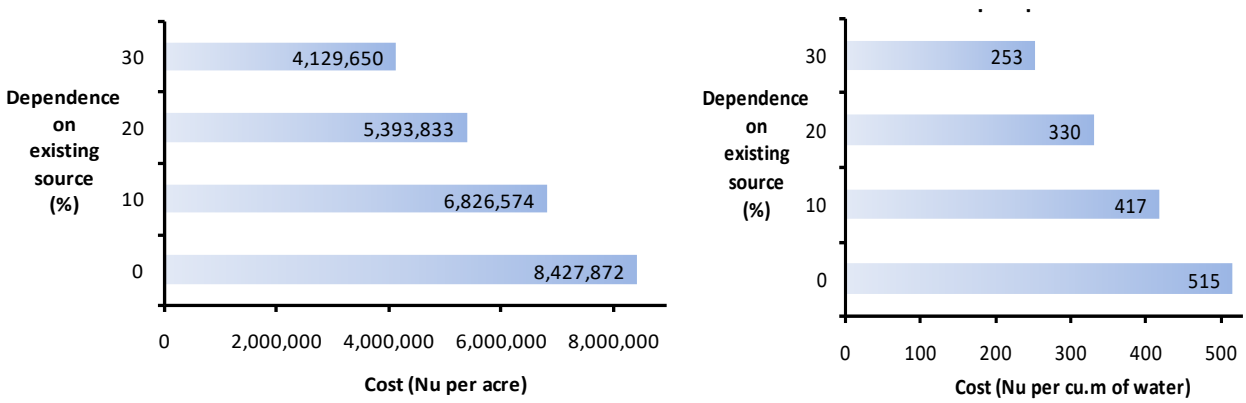
The Engineering Sector conducted preliminary feasibility study for construction of Lift Irrigation for Phanyul Geog as an alternative to construction of 34km long gravity open irrigation channel from a source located in Kazhi Geog and half of the channel alignment following within the geog. The command area considered for lift irrigation is only 300 acres against gross command area of 654 acres. In comparison the command area considered for 34km long open channel was 1000acres covering 100% of Phangyul Villages and only 50% of villages under Kazhi Geog.

The intake of the lift irrigation is proposed to be located near Rakizampa situated at 1455m above mean sea level while the delivery point is situated Chungdue Lhakhang on the Lhachu Irrigation Channel at an elevation of 2080m. The static head of this pumping system is 625m. Considering command area of 300 acres the peak design flow required is 385 lps. For a single pipe the corresponding pipe size required is 630mm diameter. Maintaining flow velocity between 0.5m and 2.50m, and assuming a head loss in the fitting 2% of the static head the total dynamic head works out to 665.42m

Considering the electricity as the energy input for operation of pump and with the prevailing energy rate the annual operation cost was estimate and the results are presented on Figure 3.3 and 3.4 for varying degree of dependence on existing water source. For this analysis the pump and motor are assumed to operate at 75% and 90% efficiency.

For 30% dependence on existing irrigation water the annual pumping cost is estimated at Nu4.129 million per acre. The cost increased to Nu8.427 million per acre with 0% dependence

on existing source or 100% pumping. Alternatively cost of pumping for 1 cubic meter of water (1000 liters) with 30% dependence on existing source is Nu253 (Nu0.53 per liter). Similarly, with 0% dependence on existing water source or 100% pumping the unit cost is Nu515 per cubic meter of water pumped.



(a) (b)

Figure 18 (a) and (b): Cost of pumping for various degree of dependence on existing irrigation channel water: (a) Cost per acre of land (Nu/acre), and (b) Cost per cubic meter of water pumped.

4. RESEARCH COMMUNICATION

4.1. Publication of extension materials

The Research Communication sector is mainly responsible for disseminating successful research results of all research disciplines of the Centre to the extension system of various departments for their adoption and adaption. It is largely done through extension leaflet distribution, organizing study visits in the Centre, field days, review workshop and online information sharing. The sector is also responsible in coordinating the Annual Agriculture Sample Survey for the West-Central Region.

During the Fiscal Year 2016-2017 the Research and Communication sector has updated the Centre brochure for distribution to guest visiting the Centre. The sector has developed six technical leaflets of new technologies generated by the Centre in consultation with concerned sectors.

4.2. Coordinate Centre visit by farmers, students and official guests

During this fiscal year 2015-2016, this Centre have been visited by various groups of visitors comprising of farmers, students, youths, trainees from various schools & institutes, Dzongkhag RNR Extension staff and Research officials. Learning objectives of visitors varies from one group to another. It has been found that farmers are more interested in seeing new crop varieties, which are high yielding. Extension personnel are also keen on new technologies and information related to those technologies whereas trainees, outsider guests and other institution visitors have specific objectives visiting the Centre. In general they are interested on the relevant technologies available in this research Centre. Altogether the sector has catered the protocol services to various groups who visited the Centre within the fiscal year 2016-7 as reflected in the annexures.

4.3. Information Management

Under this program, detailed lists of RNR publications produced by RDC Bajo as well as publications shared by other sister RDCs have been collected. In line with information management articles and pictures are uploaded at the Centre webpage www.rdcbajo.gov.bt. and also shared at MoAF www.moaf.gov.bt webpage. Library cataloguing has been maintained by the sector.

4.4. Coordinate Bi-annual Agriculture Sample Survey for West-Central Region

The sector is responsible for the annual agriculture survey for West-Central Region. As a focal person the sector co-ordinates the implementation of the survey and crosschecking of the data abnormalities before being submitted to the Department. Before the data collection the sector has covered all the five dzongkhags for distribution of sample questionnaires to extensions for data collection, briefing of questionaries and data collection and data entry. Installation of the CSPro software were carried out for all Extension to entry the data and they were trained in entering the data. Once the data collection and entry is completed the data is submitted to the Centre and the sector resubmit it to AEIMS after cross checking. The sector also collect crop-cut data of important crops, analyse it and submit to AEIMS along with the survey data for analysis and Agriculture Statistics Publication.

5. CHIMIPANG ROYAL PROJECT

The Chimipang Royal Project is an initiative from the royal office. It was officially instituted in 2012 as an Agriculture Demonstration and Training Centre under the supervision of ARDC Bajo and RPCO Thimphu. The Centre was established with the mandate to demonstrate new technologies in crop production. However, besides demonstration, the Centre also engages in the production of cereals and few horticulture crops for the purpose of marketing and generating income that goes into the Kidu fund of His Majesty. The project initially focused on cereals and fruit crops, however with the initiation of the Royal Flower Exhibition in 2015, emphasis on floriculture was necessitated. The other and major part of the project activity includes addressing the ad-hoc needs and requirements of the royal office. While the Centre functions as per its set of planned activities (annual work plan), the Centre is also directly liable to commands of the royal office.

5.1. Stock clearing of old paddy

The activities carried out under the rice commodity during the 2016-17 fiscal year includes the remains of paddy stock from 2013 and 2015 production was milled and sold to Army Welfare Project Gelephu. A sum of Nu.110250/- (One lakh and ten thousand two hundred fifty) was generated from the sale of 7305 kgs of rice, which was deposited to the Kidu fund. The details of the sale are represented in table 1.

Table 29: Detail of rice sold to AWP Gelephu

SN	Rice	Qty in kg	Remarks
1	White Rice (2013 Product)	5201	Sold to AWP @ Nu.15/Kg.
2	White Rice (2015 Product)	2104	
3	**Total**	**7305 kg**	

5.2. Land Reclamation and Management

Land reclamation is one of the main activities under the field crop sector. Majority lands at the project site are sloppy and unfit particularly for paddy production. Land terracing was done to reclaim the sloppy and uncultivable lands. Land leveling, soil compaction stone picking and bund preparation was carried out as part of the reclamation activity. The presence of higher quantities of calcium and stones at Chimepang site rendered poor soil quality. To enhance the soil quality and fertility, the developed terraces were filled with soil and legumes were grown. A total of 20 acres land was developed and paddy and mung bean cultivations were initiated.

5.3. Soil Nutrient Compensation

In-order to compensate the lost nutritive topsoil during excavation works, mung bean as cover crop and *Sesbania aculata* as green manure was grown. A total of 5 acres of land was planted with Sesbania that was later incorporated with soil during land pulverizing for paddy cultivation.

5.4. Nursery establishment

Paddy is one of the key focus products of the project. A total of six different varieties of paddy (detailed in Table 2) including local ones such as Ngabja and TanTshering were cultivated. Nursery for the same varieties was raised in a total area of 19 acres. Details of nursery raised are represented in table below.

Table 30: Details of paddy nursery raised

SN	Varieties	Acres	Remarks
1	IR-64	10acres	0.25 acres of shangana Maap for seed production
2	Bajo Maap 1	1.5	
3	Tan Tshering	1.5	
4	Ngapja	2	
5	Bonday	2	
6	Chumja Maap	2	
7	**Total**	**19 acres**	

Table 31: Revenue generated from the sale of Paddy and Milled Rice 2016-17

5.5. Construction of low cost greenhouse

Considering the economic advantages of cultivating vegetables in green house as compared to open field production, the Centre carried out the establishment of low-cost greenhouse designed by RPF Thailand.

5.6. Trial on Thai cherry Tomatoes

To test the suitability of Thai cherry tomatoes under the Bhutanese condition, the center carried out a trial on three different varieties of Thai cherry tomato (table 4). Nursery was raised and plants were grown under greenhouse condition. While two varieties vis Re Cherry tomato and Orange cherry tomato were found favorable, the Chocolate cherry tomato didn't seem to respond well under the Bhutanese condition.

Commodities	Area	Total Production	Rate	Total Amount	Supplied to	Remarks	
IR64 (Paddy)	20 Ac	8205kgs	26		500kgs Seed	Including new terrace (5.5acres)	
Milled rice (IR 64) Total	-	1600 dry 428 kg 2570 kg 4598kgs	70 40	112000/- 102,800/-	Punakha Nyzerkha Sold	RPCO RPCO Sold from Project	
BM I (Paddy)	1.5Ac	1287kgs	26	2158/-	50kgs seed	83kgs sold	
Milled rice (BM I)	-	140kgs	45	6300/-	Sold	200kg in stock	
Ngapja (Paddy)	2 Ac	1096kgs	36		75kgs seed		
Milled rice (Ngapja)	-	197kgs	65	12,805/-	Sold	90kgs - during mass chili plantation, 100dre - palace during prince birth	
Bonday (Paddy)	2Ac	1670kgs	36	-	75kgs seed		
Bajo Maap II	1Ac	487kgs	26	-	-		
TOTAL	**26.5**			**236,063/**			

Table 32: Production details of Thai cherry tomatoes

SN	Particulars	Production (Kgs)	Remarks
1	Red Cherry Tomato	38	Favorable
2	Orange Cherry Tomato	26	Favorable
3	Chocolate Cherry Tomato	8	Weak

5.7. Vegetable Production

In collaboration with the Royal Project Foundation Thailand, the Centre cultivated the following vegetables (Table 5) with the objective to test its suitability under the Bhutanese condition.

Table 33: Different vegetables cultivated

SN	Particulars	Production (kgs)	Remarks

1	Water melon	487	Favorable
2	Bhutanese Chili	319	Some what good
3	Indian Chili	69	-do-
4	Pumpkin	13 pcs	Good
5	Broccoli	383 bundles	Favorable
6	Cabbage	16 bags	Good
7	Cauliflower	14.5	Good (Under GH)
8	Radish	10 bags	Good
9	Lettuce	130 bundles	Good
10	Tomato	120	Good (Under GH)

5.8. Fruit and nut

Three types of orchard; mixed orchard, kiwi block and citrus block are maintained with a total of 975 tress (table 6). For effective utilization of space within the orchard, intercropping of hybrid and wild asparagus was carried.

Table 34: Types of fruit orchard

SN	Type	Area/acres	No of Plants	Remarks
1	Mixed Orchard	5.93	597	Intercropped with Asparagus
2	Kiwi Block	1.2	128	
3	Citrus Block	2.017	250	Intercropped with Guava (50)
4	**Total**	**9.15**	**975**	

5.9. Floriculture

The floriculture sector engages with the production and maintenance of different flowers, ornamental trees and other tree species for supplying to the ad-hoc needs from the royal office. During the 2016-17 fiscal year, the floriculture sector maintained and supplied the following quantities (table 7) of flowers and ornamental trees.

Table 35: Details of ornamental crops supplied

SN	Particulars	Qty	Remarks
1	Flowers	11611	Supplied to various organization and celebration
2	Tree Species	2281	Supplied to various organization and celebration

5.10. Mushroom

As a demonstration farm, the center is involved with year round production of mushroom so to be able to demonstrate cultivation practices to the visitors whenever they come. The other objective of year round production is to meet the high demands for the crop from the nearby markets. The other main activity of the sector is the production of billets for supplying to project beneficiaries in Punakha district.

5.10.1. Shiitake Mushroom Production

During the 2016-17 fiscal year the Centre cultivated 1500 billets of Shitake mushroom, which yielded a total of 63kgs. The low yield is attributed to many reasons such as poor adaptability and management. The production details and revenue generated from the sale of the production is detailed in table 8.

Table 36: Sale Records of Shiitake Mushroom

SN	Commodity	Area/ Qty	Total Prod	Rate	Total Amount	Remarks
1	Shiitake Mushroom	1500 billets	63kgs	400	15,600/-	9 kgs offered to Gokha, 15kgs taken to Trongsa for National Day Celebration

5.10.2. Oyster Mushroom Production

A total of 191 bags of oyster mushroom were cultivated which yielded a total of 49kgs. The production and sale details are given in table 9.

Table 37: Production and Sale Records of Oyster Mushroom

SN	Commodity	Area/ Qty	Total Prod.	Rate	Total Amt	Remarks
2	Oyster Mushroom	191 bags	49kgs	200	9,500/-	2 kgs offered to Gokha, ongoing activities

5.10.3. Construction of shelves for mushroom fruiting

Considering the compactness of the mushroom shed, four layered wooden shelves were constructed inside the mushroom sheds to accommodate more billets/bags during the fruiting stage.

5.11. Strawberry

During the 2016-17 fiscal year, Dr. Narongchai and his team from Royal Project Foundation of Thailand first introduced strawberry to the farm. After the introduction of the crop, following activities were carried out:

5.11.1. Runner production

A total of 3600 nos of mother plants were planted both in poly house and open field for runner production. A total of 50,000 nos of runners were produced which were planted for fruit production.

5.11.2. Fruit Production

Planting of runners were carried out from September to October 2016.The runners were planted in approximately 2 acres in long ridge beds in alternate lines keeping plant-to-plant spacing of 20 cm and ridge-ridge spacing of 45cm. Timely intercultural operational such as weeding, mulching, watering and application of farmyard manure (FYM) were carried out. Covering of the plants with straw was done to protect the plants from frost damage. Despite 100%

flowering many plants remained in dormant stage due to the cold winter temperature at Chimipang. Rodent and bird attacks were observed during the fruiting stage of the crop.
A total of 181 boxes of fresh strawberry fruits were collated which generated a sum of Nu.18, 850/-(Eighteen thousand eight hundred fifty). More than 50 boxes of strawberries were offered to Royal Family and various other VVIPs.

5.12. Landscaping and beautification

5.12.1. Landscaping and beautification of recreational park

Ground layout in the Recreation Park was completed during 2015-16 fiscal year. A total of 150 native trees were root balled with assistance from Thai expertise. Currently the center has 301 no's of plants of 29 species. Other activities such as development of flower garden, irrigation system and plantation of ornamental crops to beautify the walkway and plantation site were done.

5.12.2. Plantation of Crotalaria (Sun hem) species

The planting of Crotalaria was done for improving the soil for planting other fruit crops. The plants were planted in the entire landscape area and parking area of the Centre.

5.12.3. Propagation of orchids

Propagation of both native and exotic orchids (contributed by the Thai experts) was carried out for protection and conservation purpose. A total of 43 native orchids and 80 exotic orchids of mixed variety were propagated and is currently being maintained at the Centre.

5.12.4. Fern garden and pond development

A small fern garden was developed and maintained at the Centre for the sole purpose of conserving the different ferns available in the country. A pond development is being carried out for the purpose of harvesting water for irrigation.

5.13. Developmental Activities

The developmental activities include:

5.13.1. Land consolidation and management

Land consolidation and management activity includes standard land terracing in paddy field, vegetable area and fruit orchards. The details of land development carried out are mentioned in table 10.

Table 38: Area of land consolidated to standard terracing

SN	Plot	Area	Activities
1	Horti-Vegetable Block	3.9 acres	Land terracing, reclaim and chili plantation
2	Paddy field	7 acres	Ground layout for standard terracing
3	Paddy field	8 acres	Leveling, stone collection and bunds preparation

4	**Total**	**18.9 acres**

5.13.2. Reservoir Pond and Tank construction

As the shortage of water for irrigation during the dry seasons is one of the major problems faced at the projects site, few reservoir ponds were constructed for the purpose of collecting water during the rainy seasons for irrigating the fields during the dry seasons. The details of ponds constructed are given in table 20.

Table 39: Details of reservoir ponds constructed

SN	Location of reservoir Pond/Tank	Purpose	Status
1	Near floriculture Block	To supplement irrigation in floriculture Block	Not in use (Depend on Punatsangchu)
2	Horti-Vegetable Block	Horticulture Block	Under maintenance
3	Middle of paddy field	Mushroom, floriculture, Orchid and ESP shed	In use
4	Near old ESP shed	Aesthetic value	Not in use

5.13.3. ESP Shed construction

Details of ESP shed constructed at the Centre are given in table 21.

Table 40: Details of reservoir ponds constructed

SN	Numbers of shed constructed	Remarks
1	2 sheds with 8 units	With simple Bhutanese painting

5.13.4. Others Developmental activities

1. Surveyed and Irrigation Pipe Lining from two different sources to supplement the water shortage at the Project site.
2. Development of Floriculture Block

Annexure 1: Training and Workshop abroad for the financial year 2016-17

Sl No	Date	Name	Place	Purpose
1	18-24/09/2016	Dawa Dukpa	Nepal	IHPP Study Tour
2	12-15/10/2016	Cheku Dorji	Banaras, Hindu University, India	Training on Quality Rice Seed Production.
3	30/10/2016-09/11/2016	Mahesh Ghimiray, Ngawang Chhogyel, Lhab Gem	India	Institutional visit to ICAR institutes
4	Nov, 2016	Ngawang, Program Director	China	Study Tour with Agriculture Minister
5	1/10/2016-15/12/2016	Tshering Dorji	International Centre for Agriculture, Egypt	Training on Soil and water management
6	20-29//12/2016	Thinley Gyem	New Delhi, India	Establish linkages with Institutes working for oil-seeds research.
7	18-21/01/2017	Sangay Tshewang	Hyderabad, India	Seed Industry Program
8	11/01/2017 - 8/03/2017	Jigme & Tashi Phuntsho	Japan	Fruits cultivation management on Deciduous & citrus fruits.
9	6-13/02/2017	Doley, Legjay & Ngawang (PD)	IARI, Delhi, India	Study visit to PAU.(attend, discussion, creating linkages)
10	13-25/02/2017	Karma Yoezer	Ryukus, Okinawa, Japan	Mushroom cultivation and quality Spawn Production Training.
11	20/02/2017-26/05/2017	Kinley Dorji	Japan	Training on “ICT-information & communication Technology.”
12	22/02/2017-03/03/2017	Pasang Tshering	NARC-Nepal	Training on Wheat Rust Surveillance and Monitoring
13	27/02/2017-03/03/2017	Karma Dema	Hyderabad, CIM,MYT India	Training on development and deployment of climate resilient maize verities.
14	17-29/04/2017	Arjun Kumar Ghallay	Gharaunda, India	Training on “Protected cultivation of high value vegetable”

Annexure2: Farmers study tour visit at the Centre, 2016- 17

Sl no	Farmers Group	Organizer Institute	No. of Farmers
1	Bji geog Agriculture farmers group	Agriculture Haa Dzongkhag	25
2	Farmers study tour (Agriculture)	Chokar Geog, Bumthang	19
3	Farmers study tour (Agriculture)	Chudzom geog, Sarpang	22
4	RNR Farmers study tour	Doteng geog Paro	36
5	Dairy Farming group	Bji geog, Haa	18
6	RNR Farmers study tour	Mewang geog, Thimphu	35
7	Livestock Farmers study tour	Samtse dzongkhag	18
8	Community Forestry Farmers group	Dogar geog, Paro	26
9	Farmers study tour (Agriculture)	Phuentenchu geog, Tsirang	15
10	Remote area farmers group	Kengkhar& Tsamang geogs, Mongar	32
11	CFMG farmers group	Zhemgang Dzongkhag	25
12	RNR Farmers study tour	Khamoed geog, Gasa	22
13	Farmers study tour (Agriculture)	Ura geog, Bumthang	18
14	Agriculture field staff and farmers	Mongar Dzongkhag	36
15	Farmers Experience Exchange Program	RDTC, Shemgang	38
16	Organic Vegetable Production	RDTC, Shemgang	22
17	Dairy Cooperative Group	Sangbaykha geog, Haa	20
18	BDBL Central region farmers	Central region	36
19	BDBL Farmers exposures tour	Assorted	32
20	Farmers study tour by Forestry	Nga geog, Paro	32
21	Park residents	Wangchuk Centennial National Park, Bumthang	18
22	Agriculture Farmers study tour	Samteyling geog, Sarpang	26
	Agriculture Farmers Study tour	Shemgang	38
22	Haa Tshogdue members and observers	Haa dzongkhag	29

Annexure 3: Visitors' details 2016-17

Sl no	Date	Name	Organization Adress	Purpose of the Visit
1	15.9.2016	FAO international consultant	FAO	Pilot Crop cutting Survey design for paddy and maize pleminary visit
2	13.12.2016	Hon'ble Minister Lyonpo Yeshey Dorji	MoAF, Thimphu	Filed visit to ARDC, Bajo
3	15.9.2016	BSc. ECS students	CNR, Lobesa	Block day study program for BSc. ECS students, CNR, Lobesa on watershed management
4	15.9.2016	BSc. Agriculture Students	CNR, Lobesa	Block day program for horticulture research visit
5	27.4.2016	XII science students	Punakha Central School	Understand about Agricultural Farming
6	22.6.2017	Director and team	DoA, MoAF, Thimphu	To strengthen the linkage between the department and RDCs, to discuss about the new intervention of DoA, and to discuss about field issues and problems.
7	22.4.2017	Hon'ble Minister Lyonpo Yeshey Dorji	MoAF, Thimphu	Monitor ongoing research activities
8	12.07.2016	Dr. Jacqueline Hughes, Deputy DG, IRRI & Dr. Uma Shanker Singh, IRRI Country Officer	IRRI, Philippines and India	Rice research discussion with Field Crops Researchers
9	15.01.2017	Hon'ble Minister Lyonpo Yeshey Dorji and team	MoAF, Thimphu	Back journey from Dagana visit
10	21.3.2017	Arsenio R. Samanu, Farming System-Agronomist Rice Production Specialist	FAO/TCP	Meeting/Training with Field crop sector & extension staff of Wangdue & Punakha Dzongkhag.