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Bajo, Wangduephodrang
Department of Agriculture
Ministry of Agriculture and Forests

ROYAL GOVERNMENT OF BHUTAN

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Layout and design: Tanka Maya Pulami

For a copy of the report, contact:
Program Director
RNR-RDC, Bajothang
Post Box: 1263
Wangdue Phodrang
Bhutan
Tel: +975-2-481361 Fax: 481311
Email: ngawang@moaf.gov.bt

FOREWORD

It is a pleasure to publish the 31th Annual Technical Report of ARDC Bajo for the financial year 2015-16. 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, farming systems, research and communication and engineering sector. The report also provides highlights of activities implemented at Chimipang Royal Project/Frontline Agriculture Demonstration and Training Centre. Further, the report presents the human resources, financial progress 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.

Ngawang

Program Director

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RESEARCH AND SUPPORT STAFF

SN	Name	Qualification	Position Title
1	Ngawang	MSc. TropicalAgriculture	Program Director
Field Crops Sector			
2	Mahesh Ghimiray	MPhil.Plant Breeding	Rice Specialist
3	Ngawang Chhogyel	MSc. Rice	Dy. Chief Research Officer
4	Sangay Tshewang	MSc. Rural Science	Dy. Chief Research Officer
5	Tshering Wangchen*	BSc. Agriculture	Senior Research Officer
6	Thinley Gyem	MSc. Agri-Bussiness	Senior Research Officer
7	Cheku Dorji	BSc. Agriculture	Research Officer
8	Legjay	Diploma in Agriculture	Research Officer
9	Doley	Diploma in Agriculture	Sr.Research Assist-II
10	Lhab Gyem	Diploma in Agriculture	Sr.Research assist-III
12	Yeshey Dema	Diploma in Agriculture	Research Assist -I
Horticulture Sector			
13	Jigme	MSc. Horticulture	Dy. Chief Research Officer
14	Kinley Dorji	MSc. Horticulture	Dy. Chief Research Officer
15	Sonam Chophel	BSc. Agriculture	Research Officer
16	Gyeltshen Tshering	BSc. Agriculture	Research Officer
17	Arjun Ghallay	BSc. Agriculture	Research Officer
18	Dawa Delma	Diploma in Agriculture	Research Officer
19	Dawa Drukpa	Certificate in Agriculture	Sr.Research Assistt-III
20	Lungki	Diploma in Agriculture	Sr.Research assistt-III
21	Birkha Bdr. Tamang	Diploma in Agriculture	Research Assistt -I
22	Pasang Dorji	Diploma in Agriculture	Research Assistt -I
Farming Systems Sector			
23	Dr Yadunath Bajgai*	PhD in Agriculture	DyCRO
24	Tanka Maya Pulami	BSc. Agriculture	Research Officer
25	Karma Dema	Diploma in Agriculture	Sr.Research Assistt-II
26	Yeshi Zangpo	Diploma in Agriculture	Research Assistant -I
Engineering Sector			
27	Thinley Gyamtsho	MSc Natural Resource Mgt.	Principle Res Officer
28	Thinley Gyeltshen	Diploma in Civil Engg.	Dy.Executive Engineer
29	Puran Chhetri	Diploma in Civil Engg.	Assistant Engineer I
30	Indra Bdr.Raika	Electrical Engineering	Technician-I
RRCO			
31	Singye Phub	MSc. Agriculture	Principle Res Officer
32	Pema Lhamo	Certificate(XII)	Library Asst-III
Laboratory Sector			
33	Karma Yozer	Certificate in Basic Laboratory	Sr. Lab.Assistant-IV
34	Loday Jamtsho	Certificate	Lab Assitant-II
35	Tshering Yangdon	Certificate in Seed testing	Sr. Lab Assistant-III
ADTC / Royal Project			
36	Dophu Namgyel	Diploma in Agriculture	Sr.Research Assist. -III

37	Tshering Dorji	Diploma in Agriculture	Research Assistant -II
38	Dorji Khandu	Diploma in Agriculture	Research Assistant -II
30	Kinzang Dorji	Diploma In Forestry	Sr.Research Assistt -III
Administration Sector			
43	Dawa Zangpo	Diploma in VSc & AH	Sr. ADM.Officer
44	Sherub Dorji	Diploma in Finance Mgt.	Accounts Assistant-II
45	Sangay Gyeltshen**	Certificate in Store Mgt.	Sr.Store Keepeer
46	Tashi Tshering	Diploma in Information Mgt.	Sr.ICT-III
47	Lhamo	Certificate(XII)	Adm Assistant-III
48	Gyem Lham	Certificate(XII)	Sr.Despatcher
49	Ugyen Tashi	Certificate in Driving	Driver- I
50	Nidup	Certificate in Driving	Driver- I
51	Tenzin Loday	Certificate in Driving	Driver- I
52	Mon Bdr. Rai	Certificate in Driving	Driver- I
53	Deo Raj Pradhan	Certificate in Driving	Driver- II
54	Dorji Choden	Certificate (X)	PABX Operator
55	Bago	Certificate (VI)	Messanger
56	Bikash Rai	Certificate in Driving	Tractor Driver
57	Nedup	Certificate in Driving	Tractor Driver
58	Farm Attendants (Bajo)		34 numbers
59	Farm Attendants (ADTC)		30 numbers
	Night Guard		1 number

*Transferred **Retired

EXECUTIVE SUMMARY

This report presents an outcome of the research and development activities of RNRRDC Bajo for the financial year 2015-2016. The progress has been reported sector wise.

FIELD CROPS

The main objective of implementing the Field Crops research is to increase the productivity of different cereals, oilseeds and pulses. Research and Development works were equally emphasized both on station and on farm. The centre continued to evaluate elite lines and commercial varieties received through international research institutes. About 70 varieties of rice underwent various stages of evaluation. IR 28 was tested on farm to evaluate its potentiality for release. Advanced evaluation trail is the last stage of evaluation process at the research station prior to on farm trial. A total of 34 elite breeding lines from the IRRI were selected from previous year's introduction nursery and grown in single observation as Adaptation trial.

Seed production and distribution forms an important aspect of the centres research and development activities. Nine high yielding varieties of paddy were grown at the centre during the cropping season of 2015 and about 17.0 MT of paddy seed was obtained.

Evaluation of high yielding varieties of wheat started gaining momentum with good number of materials received from ICARDA, CIMMYT regional office based in Nepal and CIMMYT Mexico. On-farm Production Evaluation of facultative wheats was carried out in Bumthang with three elite genotypes were evaluated for yield potential and desirable agronomic traits. Fifty lines of wheat were evaluated to assess their adaptability and grain contents of these micronutrients. 20 lines in SAARC trap nursery, 50 Bangladeshi lines and 88 each lines from ICARDA for yellow rust, leaf rust and stem rust were studied on-station at RNR RDC, Bajo. Seed production of promising varieties of wheat was taken, as a parallel activity to the evaluation trial of various materials, which will further be up-scaled in the ensuing season.

Introduction and evaluation of Quinoa varieties on-station and on-farm trials were carried out. Quinoa evaluation trial involving two varieties *Amarilla Sacaca* and *Amarallia Maragani* was conducted at Phobjikha to assess their performance under high altitude upland condition. Ivory 123 was introduced and evaluated at RDC Bajo research station.

HORTICULTURE

The core objective of horticulture crops research is to improve rural livelihood and also to achieve vegetable and fruit self-sufficiency in the region and at the national level. The research activities of the horticulture sector include crop management technology, post-harvest practices, improved seeds, plant propagation techniques and maintenance of mother plants and breeder seeds of released crops besides varietal evaluation. The sector also focuses on broadening the genetic base of the prioritized horticultural crops through either introduction or selection from local diversity. The on-station research comprises of research on fruits and nuts and vegetables both Bajo and sub-station Tsirang.

The horticulture sector also gives equal importance to outreach programs wherein 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. Furthermore, the sector provides technical support to the farmers and also carries out capacity development of farmers and extension agents

FARMING SYSTEM

Farming systems activities on station mainly consisted the production of Diancha seeds and vermin-composting. The sector focused on the Gasa Organic Outreach Program through activities such as upland rice demonstration, mustard production, garlic cultivation, pear production and commercial production of vegetables.

Gubjithang Organic Commerical Vegetable Production Farm was inisitated for a women self-help group (*Guma Sanam Tshongdrel Detshen*) under Punakha Dzongkhag with the main goal of "to build a viable organic farm business"**.**

Soil unit under Farming System carried out thorough Review of Current Status of Soil Nutrients of Commodity Programs Potato and Wheat in the country. The review research is based on secondary data. Soil sampling study was carried out for West-Central Region covering five Dzongkhags Wandue Phodrang, Punakha, Gasa, Dagana and Tsirang.

RESEARCH COMUNICATION

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 2015-2016 the sector has updated the centre brochure and printed 200 copies 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.

RNR ENGINEERING

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.

AGRICULTURE TRAINING & DEMONSTRATION CENTRE (ATDC), CHIMIPANG

The utilization of crown property land at Chimipang was the outcomes of the Royal initiatives and defines priorities. Therefore the Royal command was issued on the utilization of the land by ARDC Bajo, mainly to establish research trials and to promote conservation of indigenous cereal crops and fruits. ATDC has total land coverage over 165 acres which was further fragmented into wetland of 110acres including marshy area and remaining 55acres of dry land. Currently for the cropping season, paddy cultivation was the dominant land use cereal crops which was followed by the vegetable production, Mushroom Production, strawberry cultivation, flower production, management of the fruit crops and campus beautification through landscaping. Moreover the Centre also has many collaborative activities with Royal Project Foundation Thailand.

1. FIELD CROPS

1.1. RICE

1.1.1. Pre-production evaluation trial for IR 28 rice variety in the mid-altitude valley of Wangdue-Punakha

Abstract

Following successful five years of vigorous evaluations at the Bajo research station, on-farm trial for IR28 was continued in four geogs of Wangdue –Punakha valley: Dzomi, Kabjisa, Guma and Thedtsho in 2015 season. The main objective of this on-farm trial was to gather more yield data on this variety in order for this variety to be proposed for release in 2016. This variety has already been tried in the farmers' field in 2014 and was found to be performing well. To further validate and confirm its yield potentiality, the experiment was repeated in four geogs. The grain yield of the test variety was compared with the local variety known as Ngabja. The average yield of IR28 in the four geogs was 5.35 t/ha while Ngabja's yield was just 3.53t/ha. There was a yield difference of 34% at the same level of management in the farmers' field. Thus, proving that IR 28 is a potential variety for promotion in Wangdue-Punakha valley including other mid-altitude dzongkhags of the country.

Introduction

Among the cereals crops, rice is the most important and is the most preferred food cereal for Bhutan. However, rising rice import has been a concern for the department of Agriculture over the last few years. In order to match rising demand for rice and increasing importation, enhanced research and development initiatives have been initiated (Chhogyel et al. 2015). Rice subject matter has often been a subject of discussions in both formal and informal forums. Thus, confirming that it is the most important and much sought after cereal grain for consumption in the country. Chhogyel et al. (2015) reported that the Department of Agriculture has initiated rice commercialization program with specific objective of increasing production to offset rice import and enhance domestic rice trade. This is important since the country doesn't have formal system of domestic rice sale and such intervention is going to help in mainstreaming rice marketing in the country. Though there were some breakthroughs in the research and development sector in the form of higher yielding varieties and technology packages, the farmers require more varietal options and vigorous promotion. Research and Development centres (RDCs) in the country screen and evaluate hundreds of varieties/lines every year and so far the Ministry has been able to release 23 varieties for various agro-ecological zones of the country. Each of these varieties has their own characteristics and it is only logical to continue to work on variety development so as to add some more to the existing list of varieties. The improved varieties that the centre work on and promote possess some basic characters like higher yielding, shorter and sturdier plant height, greater tillering ability, resistance to diseases and pests, more responsive external inputs of fertilizers. For the Bhutanese farmers, higher yielding varieties with medium height and medium maturity will be preferred (Ghimiray et. al., 2008). With increasing challenges from the onslaught of climatic vagaries and needing to feed more from dwindling production area, it is important that more vigorous research be continued and own sufficient varieties of different genetic background. Therefore, this on-farm trial is basically to contribute to the country's goal of increased rice self-sufficiency through development of higher yielding varieties and promotion in the farmers' field.

Materials and methods

The experiment was conducted in the geogs of Thedtsho, Guma, Dzomi and Kabjisa in Wangdue-PUnakha valley. The trial farmers were selected jointly by the Dzongkhag extension, geog administration and RDC Bajo. In each of the geogs, three farmers were selected and were provided 10 kg seeds with thorough advises about the importance and purposes of this experiment.

With the difficulty in design and layout challenges in the farmers' field, in all the cases, planting was done in single large plots. Seeds were sown in April coinciding with the farmer's nursery and sowing methods and all the cultural operations such as application of manures, irrigation, weedings, fertilizer application were done in accordance with the farmers local practices except that the crops were monitored and advises given from time to so as to have the experiment go well. A basal dose of NKP and N top dress was provided @ 70:40:40 kg per ha (NSSC, 2009). Weeding was done manually, and so were the harvesting operations. Grain at the harvest was adjusted to 14% and calculations were done based on the standard formula given below:

$$Grain\ yield\ (t/ha) = \text{MC}\frac{\text{plot yield (kg)}}{\text{1000x}}\ \text{X}\ \frac{\text{10,000}}{\text{Harvest area (sq.m)}}$$

Where MC=$MC = \frac{100-\text{GM}}{100-14}$, GM=grain moisture content at the time of harvest.

Data was compiled in MS excel and data were subjected to anova analysis using statistical software R version3.2.5. The same software was also used for plotting graphics.

Results and discussion

In all the multi-location trials, the main agronomic parameters measured included plant height, no of tillers per hill and grain yield (t/ha). The experiment results from all the sites showed that IR 28 produced a good yield which ranged from 4.2 t/ha to 6.1 t/ha. The average yield of Ngabja was just 3.53 t/ha which is 34% lower than the former. The highest yield was obtained at Dzomi (6.1 t/ha) followed by Guma(5.80 t/ha), Thedsho (5.26 t/ha) and least was at Kabjisa with just 4.20 t/ha (Table 1). In general, the yield performance of the test variety in comparison was good and the farmers have liked it. IR28's grain yield of 5.35 t/ha was way above the national average of 3.90 t/ha (DoA, 2014).

In terms of number of tillers per hill, IR 28 was by far the better performer with an average tillers ranging from 8 to 13 in different sites. On the other hand, Ngabja produced just about 7 tillers and averaged at 7 nos (Table 1). All together, the performance of IR 28 was superior with regard to grain yield and its tillering ability.

Table 1. Grain yield and number of productive tillers in all the four experiment sites

Geog	Plant height **(cm)	No of tilers per hill*	Yield (t/ha)*
Thetsho (wangdue)	94.5625a	13.00a	5.25ab
Dzomi (Punakha)	107.82a	11.00ab	6.10a
Guma (Punakha)	89.90a	8.00ab	5.80a
Kabjisa	91.00a	8.00ab	4.20bc
Ngabja (local check)	145.00b	7.00b	3.53c

*n**: highly significant difference, n*: significant difference*

With regard to plant height, it averaged at about 95.82 cm while its local counterpart was very tall measuring 145cm (Figure 1). Plant height is an important plant trait which has so much of bearings on the panicle bearing grains and overall performance of rice. The general trend was that the plant heights in different locations showed about a maximum of 10% difference in height and ranged between 89.00 to 1-7.80 cm. The maximum was observed at Dzomi geog of Punakha and shortest being at Guma with just 89.00 cm. The difference in plant height could be attributed to many factors such as weather, water level, management practices, and soil fertility. For the breeders, plant height is considered as one of the most important criteria since grain yield and plant heights are correlated (Yang et al., 2004). In order to carry heavy panicle bearing grains, short and sturdy plant are preferred by the breeders. Taller plants are low yielders and if fertilized, has tendency to lodge and therefore, tall local varieties are not the pick for the farmers, researchers and extensions. However, in the context of Bhutanese farmers, medium plant heights would be preferred to have a better trait off between grain yield and straw which is usually fed to animals during the lean seasons.

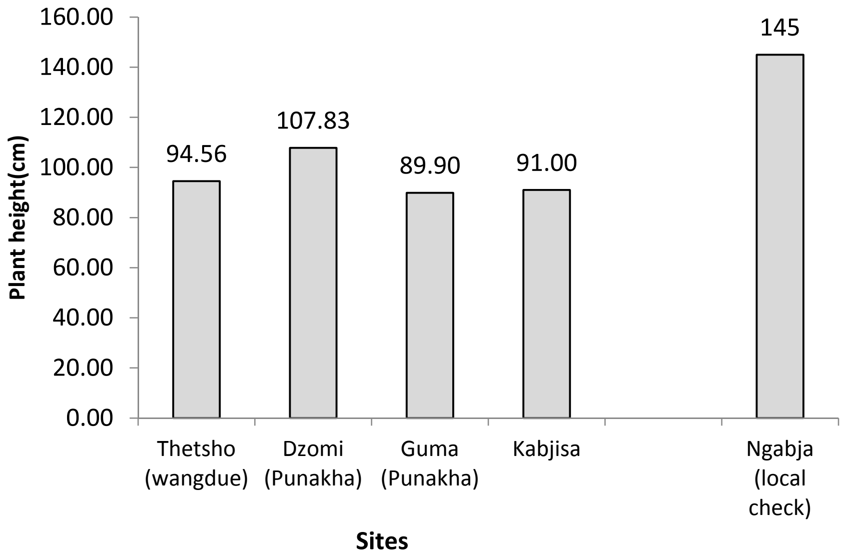

Fig.1.Plant height (cm) of IR28 compared among the various test sites of Wangdue-Punakha valley against the local check

Conclusion

From the pre-production evaluation trial result, it could be inferred that the IR28 is a better performer that the farmer's local counterpart (Ngabja). The yield difference of 34% between the two thus, indicated that the IR28 has the potential and could be promoted in larger scale. Even in terms of other yield attributes such as plant height and tillers, IR28 was the better option and therefore, it confirmed that it could do well under the mid-altitude geogs of Wangdue and Punakha Dzongkhags as one of the best improved varieties for enhancing the grain yield.

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1.1.2. Advanced Evaluation Trial of Breeding lines introduced from the international Rice Research Institute in the Philippines

Abstract

Advanced evaluation trail is the last stage of evaluation process at the research station prior to on farm trial. 8 advance lines were grown in an area of 10m ^{2} laid out in RCBD with BajoKaap 2 used as the standard check. Agronomic management practices such as Irrigation, fertilization and weeding operations were carried out as per recommendation and grain yield was assessed through sample crop cuts. The entries exhibited significantly higher values in the plant height and number of tillers per hill. The grain yield of the entries ranged between low of 4 t/ha to high of 6t/ha and almost all the test entries exhibited potential for further testing in the following season.

Keywords: Advanced evaluation trial, lines, standard check,

Introduction

Rice is an indispensable part of the Bhutanese diet with every family including rice on the menu, three meals a day. Consumption of milled rice in Bhutan is one of the highest in the region with per capita consumption of rice at approximately 137 kg per annum (PPD 2013). Rice in the country is often equated with food self-sufficiency affecting range of consumers including small-scale farmers. PPD (2013) states that the self-sufficiency of rice is 51.3 percent and the rest of the demand is met from imports. 54056 tons of rice was imported in the year 2011 incurring a total cost of Nu 854 million.

Since rice is imperative economically and socially, the public institutions mainly the Research and Development Centre (RDC) have been implementing activities in areas of rice research and development. The RDC's across the country has released 23 improved rice varieties suited across all the agro-climatic conditions of the country. These varieties have undergone performance adaptation on station before they are tested under farmer's field conditions. Accessibility to high yielding varieties is important since one of the ways of increasing grain productivity is through use of high yielding varieties coupled with improved management practices (Shrestha, 2004; Dobermann and White, 1999; Fan et al., 2005). Evaluation of rice germplasm is an annual activity as an effort to replace the traditional varieties with superior high yielding varieties. According to Ghimiray (2012) the improved variety adoption rate of rice stands at 42 percent. The rice activities carried out at the centre are aligned to improve the rice productivity in the country. These interventions will assist in attaining the national average productivity of 3.75 t ha^{-1}.The present study has an important objective to evaluatethe performance of germplam received from International Rice ResearchInstitute in the Philippines at the research station level.The Field crops research carried at RDC Bajo is a continuous cycle with most of the research activities revolving around germplasm introduction, evaluation, adaptation and management. The improved varieties and breeding lines of rice is received mainly from International Rice Research Institute (IRRI) in Philippines. Rice research follows a standard evaluation procedure established for field crops research. The objective of the evaluation of germplasm is thus, for screening and selecting best entries for further testing after which the best ones are proposed for release.

Materials and Methods

The materials to be tested are cultivated in smaller plots known as Introductory Nursery and are generally more in numbers. In the subsequent season, reduced selections from introductory nursery are subjected to further scrutiny in much larger plots called Observation Nursery. The observation nursery is replicated in much lesser number in the third year known as initial evaluation trial (IET). Breeding lines that are found superior undergo rigorous testing under replicated larger trials known as advanced evaluation trial. These cycles completes evaluation process on station.

The promising lines and varieties from the initial evaluation trail of the previous season were assessed at this stage. For the trial layout, a randomized complete block design with three replications was used. Seedlings were transplanted in an area of 10 m^2 plot with spacing of 20 cm x 20 cm. Chemical fertilizer was applied at the rate of 70:40:20 NPK kg ha^{-1}, with half the N top-dressed at panicle initiation. Butachlor 5G was applied at the rate of 1.5 kg a.i ha^{-1} to control monocot weeds. Hand weeding for *Shochum* management and irrigation were done as needed. A harvest area of 5.04 m^2 was used and grain moisture content was standardized at 14%.

Data analysis and graphics were done using statistical software R version 3.2.5

Results and Discussion

The plant height was measured at crop heading stage when the flag leaves were fully expanded. The different entries used for the trial showed significant variation in plant height. The shortest height was recorded in Zhonghun 1 (84.67 cm) and the longest plant was found out to be Ceres 1 (120.33 cm). *Plant height is an important criterion, for higher yielding performance of a cultivar and grain yield and plant heights were correlated in the development of new plant types or the ideotypes (Yang et. al (2014) (Peng et al., 1994).*In general, shorter plants are considered ideal since it avoids lodging but in Bhutanese context a medium plant height of (105-115cm) is preferred for its straw yield in addition to grain yield.

*Generally modern rice varieties tiller profusely but only few produce panicles. Reduced tillering enhances uniform maturity and flowering, uniform panicle size and more efficient use of horizontal space, and has been characterised as one of the new plant ideotypes for higher yield by IRRI(Janoria, 1989, Kim, 1992).*On average the number of tillers per hill varied between 9 to 11 in all the entries.

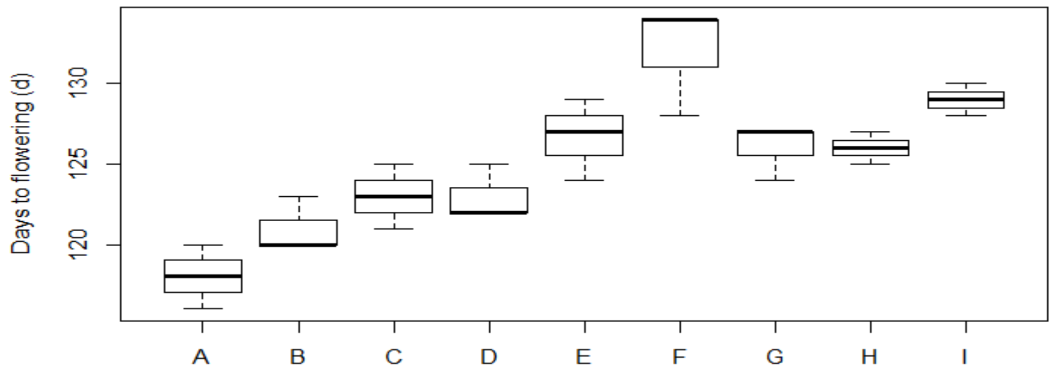
Table 1: Parameter of the advanced evaluation trial

Sl.No	Varieties	Plant height(cm)	No of tillers hill^{-1}
1	WAN XIAN 7777	98.67	9.00
2	TME 80518	95.67	10.00
3	Zhonghun 1	84.67	11.67
4	3147738	94.33	10.00
5	sarju 52	99.33	10.33
6	NP 96 11	100.00	10.33
7	ceres 1	120.33	9.00
8	ceres 2	98.67	9.33
9	BK 2	100.33	11.00
	Pr(>F)	0.000019	0.0259

Yield and plant height

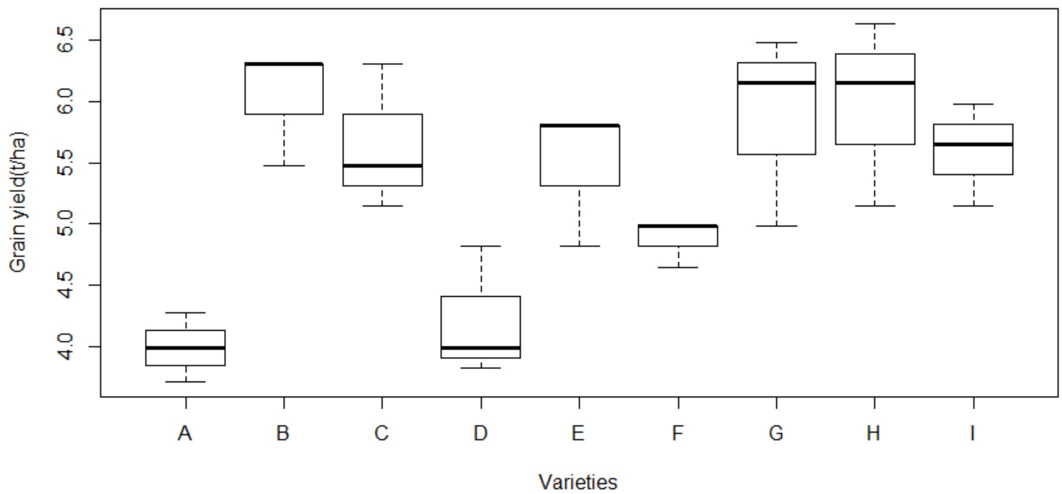
The lines tested showed significant variation in the yield. The highest yield was produced by TME 80518 at 6.4 t/ha followed by Ceres1 and Ceres 2 which produced above 6 t/ha. Wan Xian 777 and 3147738 produced the lowest yield with just 4t/ha. However, the general trend was that the test varieties equally performed compared to the BK2, the local check.

The lines showed significant differences in the flowering days. The varieties had their days to flowering ranging from 124d – 129d. Wan xian777 took the minimum days to flowers while NP 9611 took the longest (Figure 2). Although early maturing varieties are believed to have higher yield, their lack of sufficient time for vegetative growth may hamper the total yield(Chang et al., 1969). Medium growth duration of 110-120 days was found to be ideal for adequate vegetative growth and thus higher yield(Peng et al., 1994).In general, the test varieties were a little earlier than our local standard check (BK2) and the differences in DTF were more or less about a week. Based on the current yield and field observation, the varieties will be further tested bon-on station and on-farm.



A= WAN XIAN 7777, B= TME 80518, C= Zhonghun 1, D=3147738,E= sarju 52,F= NP 96 11, G= ceres 1,H= ceres

Figure 1: box plot of the days to flowering of AET



A= WAN XIAN 7777, B= TME 80518,C= Zhonghun 1, D=3147738,E= sarju 52,F= NP 96 11, G= ceres 1,H= ceres

Figure 2: box plot of the yield of AET

Conclusion

The main objective of this study is to assess the performance of elite lines in advanced stages. AET is the final stages of evaluation on-station and the promising varieties are tested on farm selecting few farmers. However, the researchers while framing the activities for the new financial year felt the need to re-evaluate 5 of the varieties in AET to reaffirm their potentiality.

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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 2: Agronomic performance of IIRON lines on-station.

SN	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

1.1.3. 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.

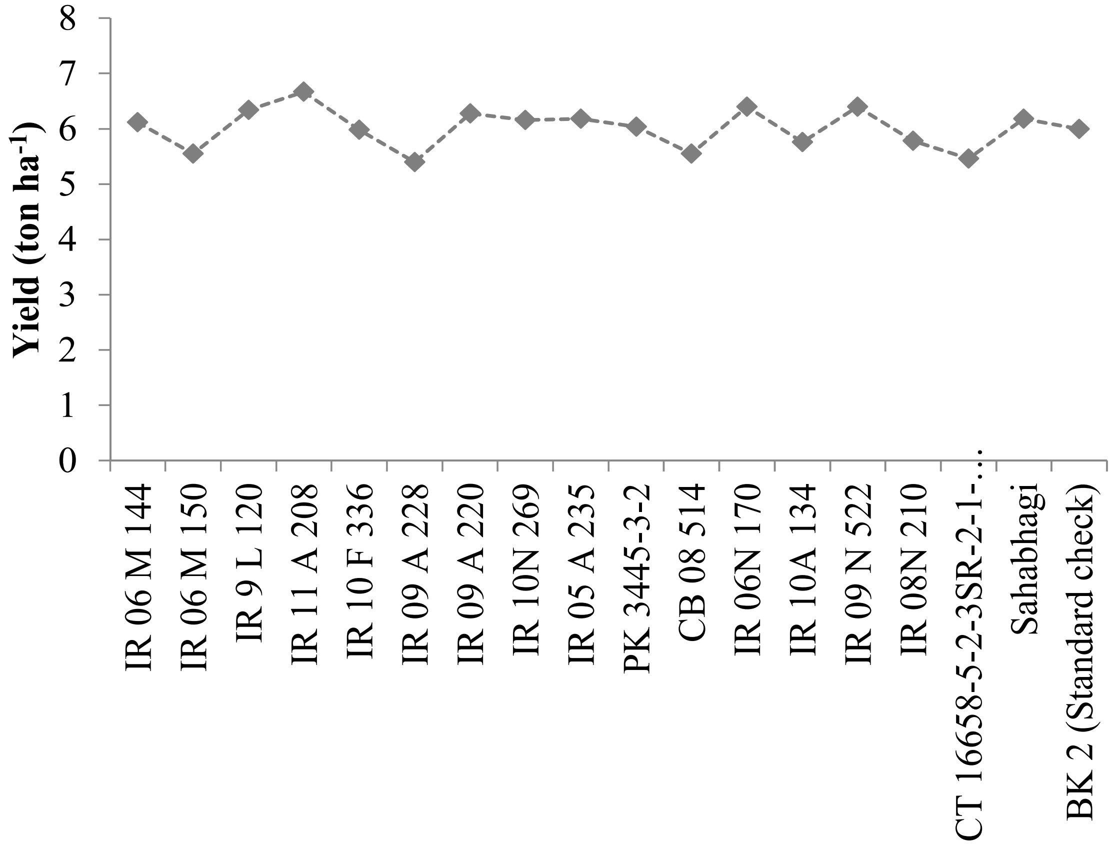

Figure 3: Grain yield of eighteen germplasm

1.1.4. 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 3: 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

1.1.5. 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 4: Quantity of seed produced from released and potential varieties

SN	Variety	Quantity (kg)	Remark
1	Bajo kaap -1	166	Released varieties
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 varieties

16	Tan Tshering	200	
17	Trial boarders (Mixture)	809	from trials
	Grand total	**6, 016**	

1.1.6. Characterization of rice 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 5: 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 6: 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

1.1.7. 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 7: 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.

1.1.8. Evaluation of rice varieties introduced from India

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 8: Plant height, No. of tillers, maturity date and yield

SN	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.

1.1.9. 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.

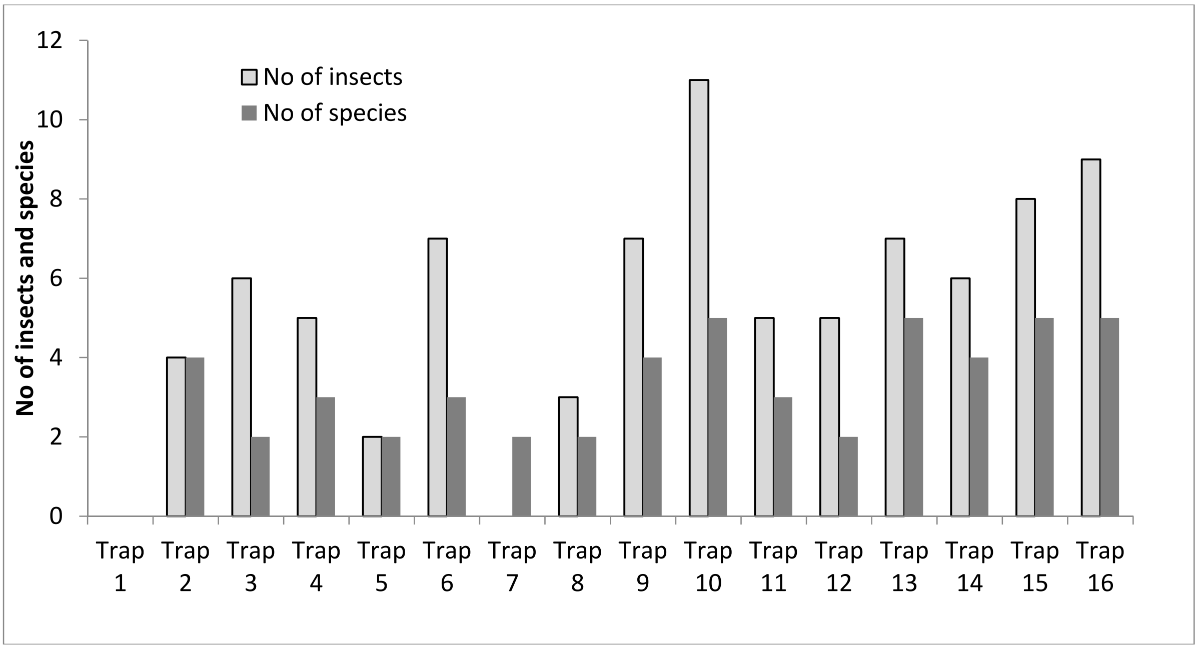

Figure 4: No of insects and species trapped in the pheromone traps laid out in the field

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 minimized use of pesticides for ecosystem protection.

1.1.10. 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.

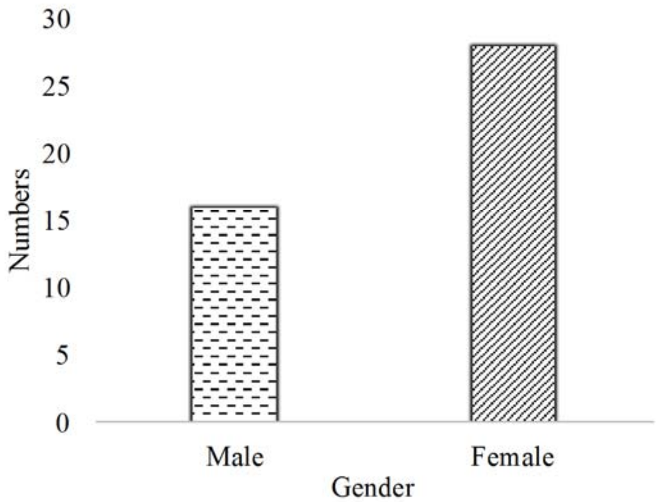

Figure 5: Number of male and female respondents

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 9: 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.

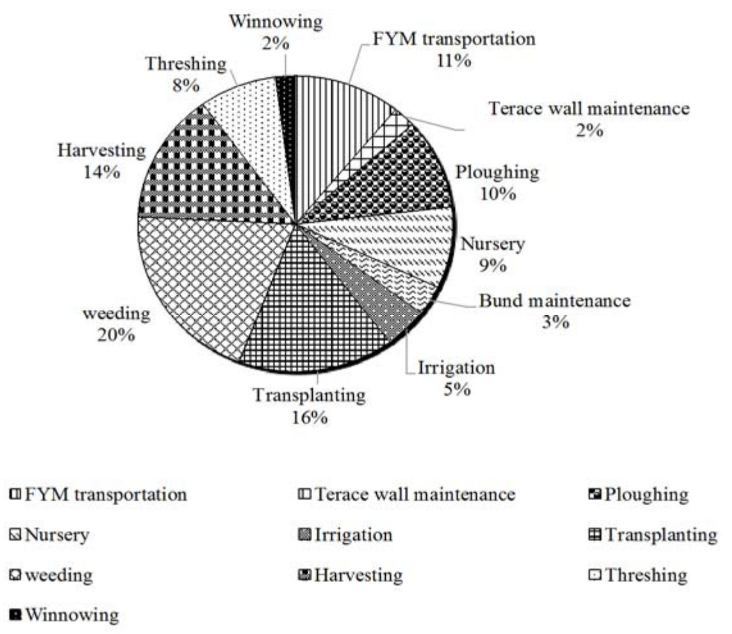

Figure 6: Percent share of costs for different farm activities