Research Article

Evaluation of short duration rice (*Oryza sativa*) varieties as a strategy to cope with climate change

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Short duration rice varieties for drought stress (Photo Credit: Ngawang Chhogyel)

Abstract

Ten elite short duration rice varieties were introduced from Bangladesh Rice Research Institute (BRRI), Bangladesh and evaluated at the Renewable Natural Resources Research and Development Centre - Bhur, in Sarpang in 2014. The varieties were tested both as the spring and main season crops to assess their potential for rice double cropping and crop intensification program of the Department of Agriculture. Rice varieties with short maturity duration are needed to adapt to the changing climate and altered growing conditions. The result from the spring crop showed that almost all the introduced varieties were not better than the local check (IR20913) in terms of earliness. Their days to flowering (DTF) ranged from 110 days (d) to 131 days except for one variety which had 103 days. IR 20913 flowered in 110 day and most of the varieties took about 2 weeks or longer to flower. However, the same varieties tested in the main season flowered

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between 81 d to 99 d which is comparable to the local check (Bhur Kambja 1) with 90 d. As the Spring crop, these varieties were not better than the local checks in terms of their earliness. But the Bangladesh Rice Research Institute (BRRI) varieties like BRRI dhan26, 28, 56 and 58 were identified to be suitable for other agronomic traits such as crop stand, plant height and yield. These varieties produced grain yield of over 2 t/ha. Thus, four of the elite varieties have been selected and will be further evaluated prior to their release as climate resilient varieties.

Key word: Climate smart varieties, days to flowering, short maturity duration, crop intensification program, Bhutan

Introduction

Rice is Bhutan's number one food crop and is grown throughout the country. Bhutan's rice agro-ecology extends from an elevation of about 150 m in the South to about 2600 masl in the North. Ghimiray *et al*. (2008) mentioned that there are as many as 500rice varieties in Bhutan which are maintained at the National Gene Bank, Serbithang in Thimphu. However, there is a dearth of short duration varieties which will fit well into the reduced growing period brought about by the changing climatic and rainfall pattern. It has been reported that climate change is imminent and the world is already experiencing the extreme weather events threatening world food production (Wassmann *et al*. 2009; IPCC 2007).Global warming and climate change are predicted to have a major impact on rice production necessitating both adaption and mitigation strategies. Among the agricultural crops, rice is highly vulnerable to climatic extremes such as drought, unseasonal rains, flooding and high temperature stress. Of late, Bhutan has been witnessing some unpredictable weather events which has threatened the economy and livelihood of the people. In the event of climate change, affected are mainly the poor farmers who lose their farm assets such as crops and potential land to the forces of nature. Farming works are highly susceptible to climatic shocks and failure due to myriad interplay of factors. Among the most important factors are the climatic and environmental factors such as temperature and rainfall as they directly affect agricultural productivity. In Bhutan, potential farm lands are reported to be increasingly getting fallowed owing to both increased frequency and intensity of biotic and abiotic stresses, exacerbated by non-farming economic opportunities for farmers. This poses major risk of increased dependence on other countries for food supply that would lead to escalation in food import bills and widen trade deficit. Thus, the country's goal of food self sufficiency is at major stake and this warrants more research work on generation of climate smart technologies. Given the intrinsic nature of these risks, it is of paramount importance to develop various coping mechanisms to avoid or reduce the impact of climate-induced risks. One area to look at is to have climate resilient crop varieties and those which would fit into the altered growing conditions.

The pattern of rainfall events are getting more and more erratic, the spring water sources are reported to be drying out, new pests and diseases are said to be emerging, and villages are greying. These manifestations are clear indicators of the climate-change induced occurrences that would lead to large decreases in agricultural production hurting the national economy. According to the Food and Agriculture Organization (FAO, 2014), one of the major technological options for adapting to climate change is to grow short duration rice varieties that can escape drought or submergences. Therefore, introduction and evaluation of short duration rice varieties would be imperative both from the view point of climate change as well as from the perspective of rice double cropping in potential areas of the country.

One of the objectives of modern breeders is to obtain varieties that could mature quickly and are insensitive to day length, thereby permitting more crops each year in the same land (Bagchi *et al*. 2012; Hazell P.R 2010). Thus, crop intensification could enhance the total farm productivity and production. While the short duration varieties could very easily escape harsh dry spells and provide a window of opportunity to be harvested within a short period of time, it will give added advantages to enhance production through double cropping. Growing a short duration variety has other global significance as well. Hasan (2014) reported that growing short duration rice is one of the most important ways of mitigating methane emission, a greenhouse gas that contributes to climate change. The traditional rice varieties take about 160-200 days (De Datta, 1981) to mature and are highly susceptible to climatic events. Improved short duration varieties could be harvested in about 110 to 130 days. As Bhutan embarks on crop intensification, greater emphasis should be placed on the development and release of short duration varieties suitable for different agro-ecological zones and suitable for double cropping systems. Rice being a major food crop in the country, it should receive maximum priority for the research, investment and policy. It is going to be of immense importance to continue introduction and evaluation of rice varieties for yield potential, maturity duration, resistance to pests and diseases and grain quality. Therefore, the objective of this research is to evaluate and screen higher yielding short duration varieties brought from Bangladesh Rice Research Institute (BRRI), Bangladesh. Since the farming technologies are dependent on weather events and local conditions, the elite germplasm introductions would have to undergo several years of evaluation and screening processes prior to their promotion and release as climate resilient varieties.

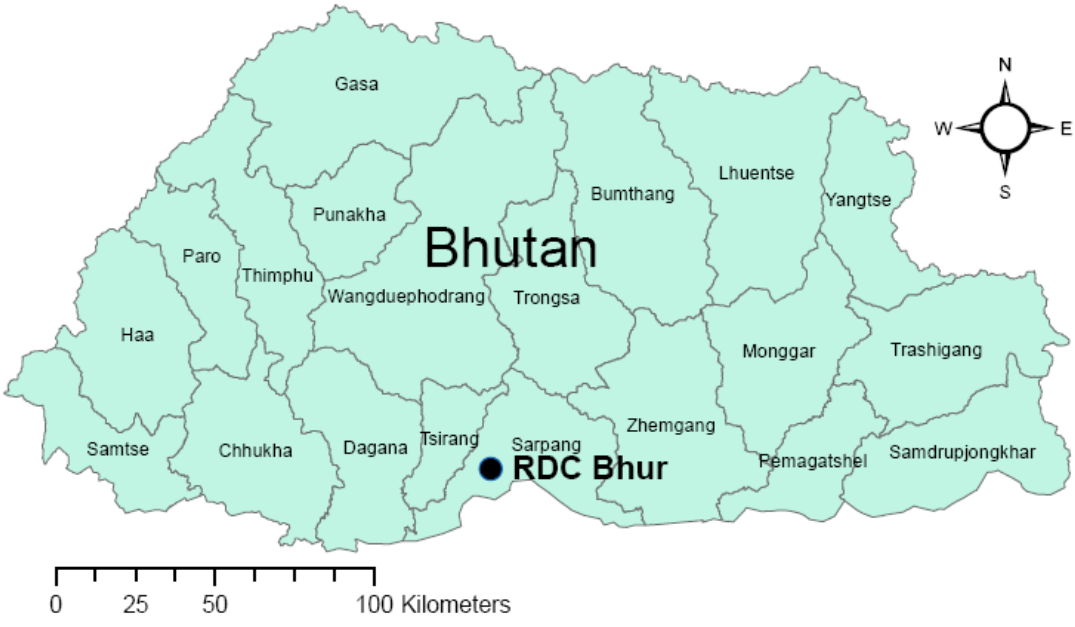

FIGURE 1 Map of Bhutan showing the place where the rice variety evaluation was conducted above mean sea level

Methods

Experiment site

The experiment was carried out at the Renewable Natural Resources Research and Development Centre (RNR RDC), Bhur, Gelephu in Sarpang Dzongkhag (Fig.1) in 2014. The RDC Bhur is located at an altitude of about 350 m1. It is about 7km drive from Gelephu town towards Sarpang and lies on the Gelephu-Tsirang high way. The place belongs to low altitude zone of Bhutan and experiences wet subtropical type of climate during the main rice growing season and dry and mild winter. Due to its location and weather conditions, it is possible to grow rice twice a year, as spring and main season crop. For spring crop, production season is from January to June, whereas, for the main season, it is from June to November. According to weather data maintained at the RDC Bhur, the place receives very heavy rainfall during the monsoon (June-September) and the monthly rainfall during this time of the year peaks at about 1300 mm rain. However, rain is scanty during the winter months (November to March) with about 40-50 mm rain. Since the agro-climatic conditions of RDC Bhur in Southern Bhutan are similar to many locations in Bangladesh, the BRRI rice varieties were sourced for evaluating their performance. Further, there is a large area of suitable rice land in the southern belt of the country where there is a need for both climate smart varieties as well as suitable varieties for double cropping to increase national food production.

Materials used

The test materials used for the experiment included 10 elite commercially grown rice varieties sourced from BRRI, Bangladesh. The varieties were BRRI Dhan26, BRRI Dhan28, BRRI Dhan45, BRRI Dhan36, BRRI Dhan45, BRRI Dhan49, BRRI Dhan56, BRRI Dhan58, BRRI Dhan60 and BRRI Dhan61. These varieties were tested against the standard local checks, IR 20913 (released variety for spring crop) and BhurKambja1 (for the main season crop). The reasons for using these two different local checks were that the former is the only short duration variety recommended for Spring crop (in rice-rice farming) and BhurKambja 1 is the best medium maturity main season variety for the low altitude regions of the country. These varieties were evaluated for their earliness, adaptability, pest and diseases resistance, yield and other agronomic traits.

Experiment design and cultural practices

The varieties were evaluated in a single plot of 5 m x 1.4 m maintaining planting distance of 20 cm x 20 cm. Inorganic fertilizers were applied with 70: 40: 20 NPK kg/ha. The weedicide, Butachlor was used to control weeds such as grasses and sedges, and it was applied with 1.5 kg a.i/ha three days after transplanting. In addition to chemical control of weeds, one hand weeding was done and irrigations were applied as and when required. Nurseries for the spring and main season crop were established in January and June respectively. Since seedlings are susceptible to the cold temperature during the spring months of January and February, nursery was raised under protected condition using poly tunnels.

Crop management operations such as transplanting, harvesting and threshing were done manually. The varieties were evaluated for earliness and their potential through measurement of basic agronomic traits. Thus, crop performance data gathered from the experiment included (1) days to flowering (days to 50% flowering) as a measure for maturity duration, (2) plant height, (3) number of productive tillers, (4) grain yield and 5) general observations on crop stand and resistance to diseases and insect pests. The data was compiled in Microsoft excel and analysed using R stats, version 2.15.1.

Results

Days to flowering (DTF)

The varieties showed significant difference in terms of days to flowering (DTF) in both, spring and main season of the experiment. For the spring crop, the test varieties took between 103 to 131 d to reach 50% flowering which is an important measure of maturity duration in rice. BRRI Dhan60 had the shortest DTF with 103 d while BRRI Dhan49 had the longest DTF value of 131 d. Most of the varieties were a little late maturing as compared to the standard local check (IR 20913) which had DTF of 110 d. In general, the test materials were not early maturing compared with the standard check when grown as a spring crop. On the other hand, the BRRI varieties, when grown as the main season crop had their DTF ranging between79 d to 99 d which were comparable to the standard local check, BhurKambja 1 with 90 d. The test varieties took about a week or shorter to reach flowering as compared with the BhurKambja 1 (Table 1). BRRI Dhan26 and BRRI Dhan28 reached flowering in about 81 d and were observed to have a good crop stand. In both the spring and main season crops, the mean days to flowering for BRRI Dhan26 and BRRI Dhan28 were comparable to the standard checks (IR 20913 and BhurKambja 1) and the differences were just about a week.

Table 1 Earliness of different Bangladesh Rice Research Institute (BRRI) varieties in terms of days to flowering (DTF) grown as spring and main season crop at Bhur farm, Gelephu.

Sl.No	Variety	Spring crop	Main Season
1	BRRI Dhan 26	118	81
2	BRRI Dhan 28	115	81
3	BRRI Dhan 36	118	86
4	BRRI Dhan 45	113	82
5	BRRI Dhan 49	131	99
6	BRRI Dhan 56	114	89
7	BRRI Dhan 57	124	91
8	BRRI Dhan 58	119	89
9	BRRI Dhan 60	103	79
10	BRRI Dhan 61	110	89
11	IR 20913	110	-
11	BhurKambja 1	-	90
	Mean days	116	87
	F-value	99.36***	33.14***

Plant height

Plant height (cm) of the 10 BRRI varieties ranged between 63 to 84 cm and 81 to 116 cm for spring and main season crops respectively (Fig.2). Under Spring condition, BRRI Dhan60 measured 66 cm, while BRRI Dhan61 measured 66 cm of heights. These two varieties were the shortest plants under the Spring condition and in both the seasons, BRRI Dhan26, BRRI Dhan28, BRRI Dhan56 and BRRI Dhan58 were observed to be taller with over 105 cm height. BRRI Dhan 56 was 116 cm in heightand was the tallest among the 10 test varieties. The two local checks, IR20913 (Spring) and BhurKambja 1 (main season) measured 104 cm and 100 cm respectively.

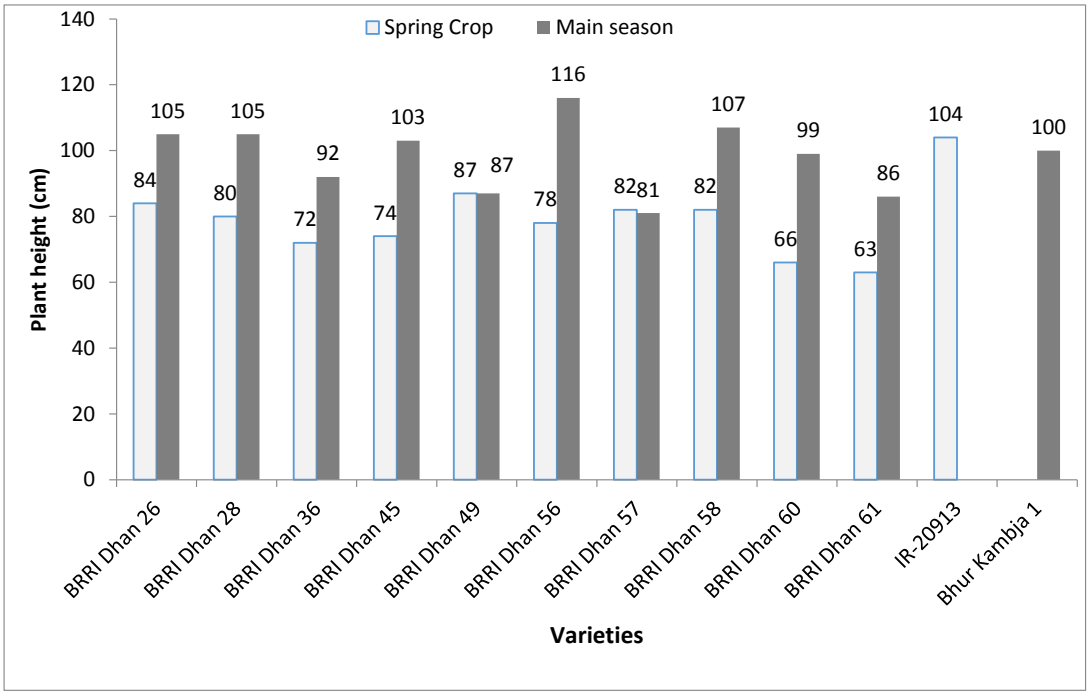

FIGURE 2 Mean plant heights (cm) of different Bangladesh Rice Research Institute (BRRI) varieties tested as the spring and main season crop against two different local checks (IR-20913 and Bhur Ray Kambja 1

Number of productive tillers perhill

All the 10 tested varieties were observed to have good tillering ability. The crop stand was good and the average number of productive tillers per hill in the experiment was 15 which is a standard number for higher yielding varieties. The productive tillers per hill ranged between 12 to 19 with the lowest being recorded in BRRI Dhan56 with just 12. BRRI Dhan61 produced the highest number of productive tillers with about 19 (Fig.3).

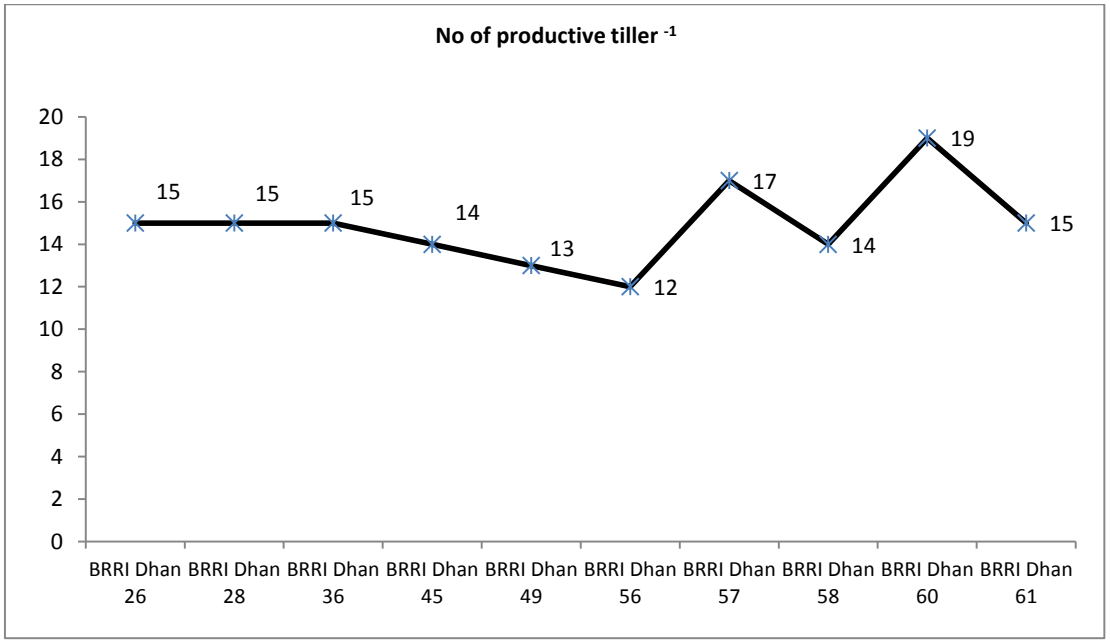

FIGURE 3 Comparison of no of productive tillers per hill among the ten Bangladesh Rice Research Institute (BRRI) rice varieties.

Grain yield

The test rice varieties showed significant differences in terms of grain yield (t/ha) adjusted to 14% moisture content (Table 2). The rice variety, BRRI Dhan58 gave the highest grain yield of 2.67 t/ha under the Spring condition while BRRI Dhan58 produced the highest grain yield as the main season crop with 3.33 t/ha. The varieties like BRRI Dhan49 and BRRI Dhan57 were the late maturing and could not be harvested as the first crop in spring (Fig.4). On the other hand, all the 10 varieties grown as main season crop matured normally to producegrain yield of 1.6 t/ha to 4.22 t/ha. In both the seasons, the varieties such as BRRI Dhan26, BRRI Dhan28, BRRI Dhan56 and BRRI Dhan58 showed potential in terms of maturity, plant heights and produced better grain yield. Further, these varieties produced higher or comparable grain yield to the local checks, IR-20913 (Spring) and BhurKambja 1 (main season).

Table 2 Comparison of grain yield (t/ha) in the Spring and Main season crop

Sl. No	Spring crop		Main season	
	Variety	Grain yield (t/ha)	Variety	Grain yield (t/ha)
1	BRRI Dhan 26	2.01	BRRI Dhan 26	2.82
2	BRRI Dhan 28	2.14	BRRI Dhan 28	2.41
3	BRRI Dhan 36	2.22	BRRI Dhan 36	1.62
4	BRRI Dhan 45	1.71	BRRI Dhan 45	2.22
5	BRRI Dhan 56	1.57	BRRI Dhan 49	2.16
6	BRRI Dhan 58	2.67	BRRI Dhan 56	2.99
7	BRRI Dhan 60	1.12	BRRI Dhan 57	1.81
8	BRRI Dhan 61	1.73	BRRI Dhan 58	3.22
9	IR 20913 (Check)	1.72	BRRI Dhan 60	2.02
10	-	-	BRRI Dhan 61	2.6
11	-	-	BhurKambja 1 (Check)	3.99
	Mean yield	1.88		2.63
	F value	24.43***		37.98***

Figure 4 One of the two late maturing varieties Bangladesh Rice Research Institute (BRRI) (BRRI Dhan 49) not attaining maturity when other varieties were ready for harvest.

Discussions

Days to flowering (DTF)

Plant growth and development is a function of genotype and environmental condition (GxE) and therefore, environment has a marked influence on crop productivity and crop maturity. For optimum crop production, the agro-ecological conditions must be favourable and for this, the new varieties must be screened and evaluated over the years under a set of environment. In the current experiment, the varieties took as long as 110 d to 131 d to reach 50% flowering under the Spring condition. However, the same varieties when grown as the main season crop (June-November), they flowered in about 81 d to 99 d. This showed that most of the varieties were susceptible to the cold temperature of Spring delaying flowering time. Tropical rice varieties when grown under temperate condition take longer to flower and complete their lifecycle in longer time duration. Cold temperature of Spring season is a kind of stress for which varieties tolerant to such stress will be required. Plants subjected to stressful condition correspond to changes in the physiological order of growth performance and respond differently leading to a differing days to flower and maturity (Taig and Zeiger, 2002). Some of the effects of cold temperature on rice plant include leaf yellowing, stunted growth and delayed head formation (IRRI, 1974) and thus, varieties doing well under a colder Spring condition must be selected for further testing for promotion in rice-rice cropping system of Southern Bhutan. Those varieties taking longer to flower and mature were thus, not fit as a Spring crop. However, the varieties like BRRI Dhan26, 28, 56 and 58 had exhibited good crop stand and were comparable to the local check in terms of days to flowering. Moreover, these varieties performed well even as a main season crop and therefore were marked for further trait analysis over some more years. The DTF of these four varieties were even shorter as compared to the BhurKambja1(check) in the main season and based on other favourable characteristics, these varieties will undergo further evaluationsin the subsequent seasons. Currently, Bhur Kambja 1 is regarded as one of the best improved medium duration varieties recommended for the promotion in Southern Bhutan (DoA, 2011) and if any of the BRRI varieties perform better or comparable to it, there is high chance that those varieties might prove potential for release to farmers int he near future. Pandey *et al*. (2010) mentioned that the short maturity crops were one of the most important criteria for crop intensification programs. The target of earliness in varieties is for the avoidance of unfavourable conditions and provides window of opportunities (IRRI, 1994). Thus, in the wake of looming crisis of global warming and food security issues, development of short maturing crops should receive priority and focus.

Plant height

Plant height (cm) is an important agronomic plant characteristic considered in rice evaluation trials. Rice grown under the Spring condition seemed to have been affected by cold condition with the plants exhibiting shorter heights. The same varieties grown under main season showed an increase in mean height. This confirms that the mild Spring cold condition of Southern Bhutan had affected plant growth and development indicating the need for varieties that tolerate some level of cold temperature for the first crop. The plants are normally stunted when exposed to cold leading to reduction in yield. Rice breeders and physiologists, consider plant height as one of the most important criteria as the grain yield and plant heights are always correlated in the development of new plant types, or the ideotypes (Yang *et al*., 2004). In the context of Bhutan, plant height is more important from the view point of farmers' preference for variety adoption. Since Bhutanese farmers use rice straw as cattle feed, the farmers prefer those varieties which

gives higher yield as well as more straw. The ideal plant height for the Bhutanese farmers should be above100 cm (Ghimiray *et al*.2008). Further, Chhogyel *et al*. (2013) mentioned that an ideal plant height for Bhutan would be a medium plant height of about 105-115 cm. In the current experiment, almost all the test varieties (for the main season crop)had their heights of about 100 cm or a little over 100 cm, making them ideal for Bhutanese farmers. BRRI Dhan26, BRRI Dhan28, BRRI Dhan56 and BRRI Dhan58 had plant heights of 105 cm, 105 cm, 116 cm and 107 cm respectively, and qualify for further testing, scrutiny and assessment.

Number of productive tillers perhill

Number of productive tillers per hill is an important yield component of rice crop which has direct relation with the grain yield. The number of productive tillers per hill, in the range of 12 to 19 in the current experiment showed that the BRRI varieties had good yield potential. However, the tiller numbers per hill were only recorded from the Spring crop. For the Spring crop, the nursery seedlings were exposed to mild cold stress which might have affected the plants' tillering ability. Nevertheless, the crop showed normal tillering even under spring condition and therefore, records were omitted in the main season. Based on agronomic parameters such as plant height, days to flowering, number of productive tillers, and general observation (crop stand, BRRI Dhan26, BRRI Dhan28, BRRI Dhan56 and BRRI Dhan58 were rated as superior. Yoshida (1981) mentioned that number of panicle bearing heads in rice is determined by the tillering ability of a variety. Thus, the tillering ability of these varieties was an additional pre-requisite for narrowing down the selection for further testing. Number of panicle bearing tillers is regarded as one of the most important yield components in rice which determine the ultimate yield (Baloch *et al*. 2006).

Grain yield

Under the Spring condition, BRRI Dhan26, BRRI Dhan28 and BRRI Dhan58 had grain yields of 2.01, 2.14 and 2.67 t/ha which was higher than that of the local check (IR 20913) at 1.72 t/ha. This showed yield difference of 17 % – 55% as compared to the local check. Based on the evaluation results, the varieties viz. BRRI Dhan26, BRRI Dhan28, and BRRI Dhan58 were found to be promising as a spring crop. The result from the main season evaluation also showed that the best performing varieties of the Spring condition gave good levels of grain yield. BRRI Dhan56 and BRRI Dhan58 were the two best performers with grain yield of 2.99 and 3.22 t/ha respectively, and were comparable to the yield of Bhurkambja 1 (local check) with 3.99 t/ha. Other varieties such as BRRI Dhan26 and BRRI Dhan28 also produced good yield of 2.82 and 2.41 t ha, respectively, when grown as the main season crop. In crop variety development, higher or optimum grain yield is the ultimate objective of crop physiologists, breeders, researchers and agronomists. For a country like Bhutan which imports about 50% of its rice requirement, rice yield should be the most important trait for a varietal evaluation and screening processes. This is in agreement with the IRRI's report on adoption of improved rice varieties in Asia (Wang, *et al*. 2012). Crop varieties with ideal agronomic traits such as plant height, maturity duration, tillering ability, resistance to diseases and insect pests, should produce good levels of yield for promotion. Therefore, based the two season's evaluation result, the four BRRI varieties (BRRI Dhan 26, BRRI Dhan 28, BRRI Dhan 56 and BRRI Dhan 58) were assessed to be the best performing ones. Thus, these four BRRI varieties, based on preliminary evaluation showed potential for promotion in the Southern Bhutan which has large rice areas. Grain yielding ability is one important varietal characteristic in rice (IRRI, 1965), and therefore, varieties with yield potential and other basic traits provide basis

for large scale promotion. According to the rice breeding history (Hargrove and Coffman 2006), a semi-dwarf higher yielding rice variety, IR 8 was a prototype for all the modern varieties grown today. Under best management, IR8 yielded 9.4 t/ha grain yield and was the first higher yielding rice variety that changed the world food situation. Therefore, the ultimate goal of breeding and varietal improvement work is to get varieties producing higher yield. The evaluations would be continued for few more years before actual promotion in the farmers' field. Regular field observations have also showed that these varieties had good crop stand with about 14-15 tillers per hill and produced disease free clean grains.

Conclusion

Under normal level of cultivation practices, four BRRI varieties viz. BRRI Dhan 26, BRRI Dhan 28, BRRI Dhan 56 and BRRI Dhan 58 were assessed to have performed well as both Spring and main season crops. Based on the two seasons' evaluation result, these varieties have qualified for further screening processes for few more years. It has been reported that BRRI Dhan28 with maturity duration of 140 d is a mega variety in Bangladesh and is one of the most popular higher yielding 'Boro' varieties in the country. Both from the view point of crop intensification drive as well as climate change, there is a need to have rice varieties which could mature early without much penalty on yield. Rice production in Bhutan is largely rain fed and with increased frequencies of weather extremes, use of short maturity varieties should be emphasized and promoted. Growing short duration varieties of rice has other advantages like fitting other crops in between. It has been reported that, adoption of short duration rice varieties is one of the strategies to mitigate emission of methane and nitrous oxide which are greenhouse gases. Since, rice crop is said to be one of the major contributing factors to global warming, growing short duration varieties is one way of reducing such emissions. In the context of Bhutan, short duration varieties would also reduce exposure of crops to pests such as wild animals thereby reducing probability of crop damage due to shortened cropping period. Thus, more emphasis must be given on the development and release of short maturity varieties for both Spring and main season crop. This way, research on evaluation of short duration varieties will go a long way in contributing to the national crop production as well as in reducing the factors affecting the global climate change. It is hoped that one of the four selected BRRI varieties will pass the subsequent screening processes giving a varietal choice for the farmers in Southern Bhutan. Currently, the only short duration variety that we have is IR-20913 and through vigorous evaluation and testing, more promising new varieties must be released and promoted.

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