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Morpho-agronomic Evaluation of Rice (*Oryza sativa* L.) Variety IR28 in Wangdue-Punakha Valley

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Abstract

Rice is a staple food in Bhutan, which provides 55% of the dietary calorie supply. However, domestic rice production meets only 45% of the total requirement. One of the ways to achieve rice self-sufficiency level is to cultivate high yielding varieties, which play a crucial role in enhancing production and livelihoods of farmers. In 2008, 78 entries of rice germplasm, including IR28, were introduced from the International Rice Research Institute in the Philippines. IR28 underwent seven years of vigorous evaluation both on-station and on-farm. On-station evaluation was done at RDC Bajo research farm followed by on-farm trials in the mid-altitude geogs of Wangdue-Punakha valley. The main objective of such evaluation was to screen and select potential rice varieties for release and promotion in the country. Currently, Bhutan has only 23 released varieties and there is a need to identify more through research and extension. With emerging threats from the vagaries of climate change and associated risks, there is a need to increase the genetic base of rice in the country. IR28 was evaluated both on-station and on-farm using RCBD with three replications. IR28 was assessed as the best entry in terms of yield, grain quality, and overall farmers' acceptance. The evaluation trials at RDC Bajo showed that it produced grain yield of 4–6 t/ha. From the agronomic, morphological, and grain quality aspects, IR28 was rated as the best variety by farmers. Therefore, IR28 is now proposed for release in the mid-altitude regions of the country.

Keyword: Evaluation, germplasm, grain yield, introduction, on-station, on-farm

Introduction

Among the cereals, rice is the most important food crop grown in Bhutan and in order to raise its production and productivity, the Department of Agriculture (DOA) has initiated a number of initiatives (Chhogyel *et al*., 2015). The need to raise rice production and productivity lies in the fact that 55% of the rice requirement is met through imports, which impinge on the national food security. Therefore, the country needs to enhance rice production by introducing high yielding varieties to reduce import. Currently, various agencies within the Department and the Dzongkhag extension offices are engaged in research and development of rice commodity. The Renewable Natural Resources Research and Development Centre–Bajo (RNR RDC–Bajo) is the leading centre for breeding and development of rice varieties in the country. Annually, the centre introduces and evaluates hundreds of rice germplasms, most of which come as part of the International Network for Genetic Evaluation of Rice (INGER) of the International Rice Research Institute (IRRI) in the Philippines. IRRI, in its endeavour to support global rice research and development, provides rice germplasms to many countries and partner institutes across the globe, and Bhutan receives IRRI's germplasms annually. The introduced germplasms undergo vigorous six to seven years of testing, both on-station and on-farm, to identify germplasms with desirable traits under spe-

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cific environments. The testing and screening procedures are defined and data are collected based on the IRRI's Standard Evaluation System (SES) for rice (IRRI, 1996). SES was developed to enable rice scientists from all over the world to speak a common language on evaluation of rice characters.

The rice variety IR28 was introduced in Bhutan in 2008 from IRRI and it underwent vigorous five years of evaluation at the RDC–Bajo farm followed by two years of on-farm evaluation in four different *geogs* of Wangdue-Punakha valley. IR28 was one of the three best varieties identified for testing further in farmers' field after passing screening evaluations at RDC–Bajo in 2012 (Chhogyel *et al*., 2013). Records from the RNR RDC–Bajo showed that IR28 has consistently performed well in the mid -altitude geogs of Wangdue and Punakha Dzongkhags yielding in the range of 4–6 t/ha, which is much higher than the national average of 3.2 t/ha (Chhogyel *et al*., 2013; RNR RDC–Bajo, 2014). The variety has the potential to replace IR64 whose resistance against rice blast is observed to be breaking down. IR64 is one of the mega-rice varieties responsible for fuelling the green revolution in 1960s (Hargrove and Coffman, 2006) and is also one of the most widely adapted mid-altitude varieties in the country (Ghimiray, 2012; Chhogyel and Bajgai, 2014). However, IR64 losing its resistance to blast diseases has been a concern for the DOA. Thus, IR28 could be an alternative variety for farmers of the same agro-ecological zone. Literatures show that IR28 has multi-resistance against diseases and pests and is also one of the mega-varieties of IRRI in the 1970s and 1980s (Khush and Verk, 2005). IR28 also has cooking and eating qualities that are acceptable to Bhutanese people who prefer rice that stick together and remain soft when cooled. Such a trait is attributed to amylose content of the grain assessed through laboratory tests.

This paper provides information on the evaluation and performance of IR28 rice variety leading up to the release proposal. The paper also compiles the basic morphological and agronomic characters and grain quality aspects of IR28 for future use and reference. The research has policy implications leading towards enhanced rice production and food self-sufficiency through the adoption and cultivation of improved varieties with proven yield potential and desired grain quality.

Materials and Method

Evaluation trial sites

The trial was conducted at the RNR RDC–Bajo research farm for five years after which it was evaluated in the farmers' fields for two years in Wangdue and Punakha Dzongkhag (Figure 1). The on-farm trials were conducted in Thetsho geog in Wangdue and Guma, Kabjisa, and Dzomi geogs in Punakha Dzongkhag. All these geogs or the trial sites are within the altitude range of 1200–1400 m above mean sea level. The Wangdue-Punakha valley is the major rice growing areas in the mid-altitude zone. The research sites represent the main rice growing area with high rice yield potential.

Evaluation procedure and methods

The standard variety evaluation system of RDC –Bajo was followed, which evaluates new materials in Introduction nursery, Observation nursery, Initial Evaluation Trial, and Advanced Evaluation Trial at the station. On-farm trials include Pre-Production Evaluation and Production Evaluation Trials for a minimum of two seasons. Introductory and observation nurseries were done in 2008–2009 and 2009–2010 respectively. Replicated trials were done using randomised complete block design (RCBD). For controlling weeds, butachlor (5G) was used as pre-emergence herbicide at the rate of 1.5 kg a.i. per ha followed by manual weeding. Fertilizer rate followed was 70:40:30 NPK (NSSC, 2009). The crop growth was monitored fortnightly and all the pre-harvest agronomic and post-harvest grain quality traits were measured following a standard protocol described below.

1. Plant heights were measured and tillers counted at the heading stage wherein ten random hills per plot were selected for measurement in all the sites.
2. Other plant morphological traits such as leaf pubescence, ligule colour, and basal leaf sheath colour were observed between active tillering to heading stages, while the panicle length, and grains per panicle were measured at maturity. Panicle type and panicle exsertion were observed after complete panicle emergence stage. Prominence of apiculus and awns and their colours were observed at crop

maturity.

3. Grain yield was taken at maturity when 85% of the grains turned golden yellow. Yield was estimated from three 5 m^2 plots and the average was taken. Moisture content was adjusted to 14% following the standard formula:

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

Where MC = moisture coefficient adjusted to 14% derived from the formula:

$$MC = \frac{(100 - GM)}{100 - 14}$$

4. For post-harvest milling recovery analysis, a sample of 300 g paddy was taken and de-hulled using a table mill. All input and output products such as brown rice, total polished rice, head rice, and broken percentages were weighed using digital balance. The brown rice so obtained was subjected to polishing for 4 minutes and the polished rice (both broken and head rice) were measured and the milling recovery (MR) was calculated in the following way:

$$MR = \frac{Wh + Wb}{Wt}\ X\ 100$$

Where Wt = total paddy milled (300g), Wh = Weight of head rice, and Wb = Weight of broken rice obtained after polishing

Grain categorisation was done after the crop harvest taking the length-breadth ratio (l/b ratio) of grains using vernier caliper. Scale for grain category was based on the table developed by IRRI (IRRI, 1996). The kernel colour of milled rice was also assessed at the same time.

In order to further provide weightage to the test variety IR28, a simple organo-leptic test was performed involving the staff and field workers of RDC–Bajo. IR28 and IR64 rice were cooked and tested by the evaluators based on basic eating quality parameters such as softness when cooked and cooled, aroma, and fluffiness when cooked. The evaluators provided their overall ratings on the eating quality of IR28 in comparison to IR64.

ANOVA was conducted using statistical software R version 3.2.5 for the data compiled in Microsoft Excel spreadsheet. Graphs were plotted using the software R as well as Microsoft Excel. Elevation map was generated using ArcGIS software version 9.3.

Results and Discussion

On-farm evaluation

In 2014 and 2015, IR28 produced an average grain yield of 5.31 t/ha and 5.35 t/ha, while the local check (Ngabja) yielded 3.54 t/ha and 3.53 t/ha respectively (Table 1). Comparison between the mean yields were done using Tuk-

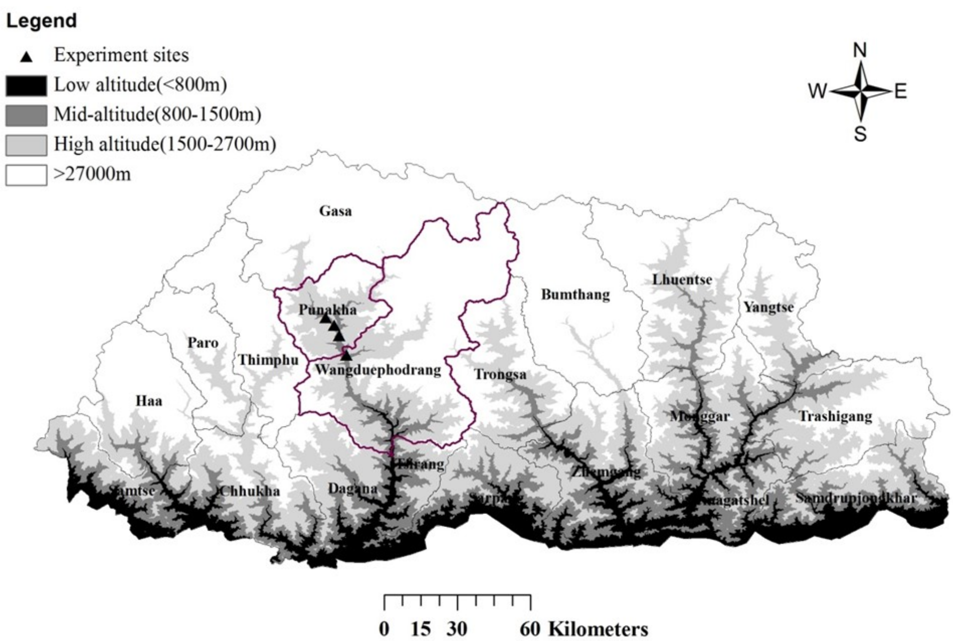

Figure 1: Elevation map of Bhutan indicating the on-farm trial sites (representing mid-altitude regions) in Wangdue and Punakha where IR28 was tested

eyHSD test. The two year's on-farm yield compared with Ngabja showed that IR28 yielded 34% more than the check. The yield difference was significant (*Pr* > *F* = 0.0070) indicating that IR28 could be one of the best improved variety choices for farmers in similar agro-ecosystems of the country. Yield from different trial locations showed that the highest yield was obtained from Dzomi geog (6.14 t/ha) and the lowest at Kabjisa (4.20 t/ha) in Punakha (Figure 2). Higher yield in Dzomi compared to Kabjisa was due to better fertility management by farmers who applied 10 t/ha of FYM basally and top dressed with 40 kg N per ha at booting stage. There was no urea topdressing at Kabjisa although 7–8 t/ha FYM was applied basally. Hence, yield difference was attributed to nutrient management. Among the four different trial sites, the yield variation was less at Thetsho and Dzomi, while Kabjisa had the largest variation (Figure 2). At Thetsho the yield varied between 4.8 to 5.7 t/ha, whereas at Kabjisa the yield fluctuated between 6.21 t/ha to 3.11 t/ha. The wider yield variation at Kabjisa could be attributed to wider altitude range which extends from about 1200 m to 1450 m above mean sea level. IR28, being a tropical variety, would not do well in higher elevation areas.In general, the average on-farm yield was above the national average of 3.20 t/ha (Chhogyel *et al.,* 2013). These results corroborated with the findings of Hussain *et al*. (2014) who also worked on the yield and characteristics of four rice varieties involving IR28 as one of the test materials.

Even in terms of other agronomic characters such as plant height and number of tillers, IR28 was better with shorter and sturdy culms. Modern rice varieties have shorter height with sturdier culms to carry heavier panicle bearing heads. Plant height is one of the breeding objectives in the development of rice varieties (De Datta, 1981). This is technically superior and makes it lodge resistant in a windy place like Wangdue and Punakha. IR28 plant grew to about 95-100 cm and produced about 10–14 tillers as against 145 cm height and 6–7 tillers by Ngabja (Table 2). Based on TukeyHSD test, IR28 outperformed the local check in terms of yield, numbers of tillers, and plant height.

Table 1: Performance of IR28 in Wangdue and Punakha in 2014 and 2015

Variety	Yield (t/ha)		Tillers/hill		Plant height (cm)	
	2014*	2015*	2014*	2015*	2014*	2015*
IR28	5.31[a]	5.35[a]	11[a]	10[a]	93[b]	96[b]
Local check (Ngabja)	3.54[b]	3.53[b]	7[b]	7[b]	141[a]	145[a]
Pr (> F)	0.00704	0.00708	0.0131	0.0484	0	0.00002

*significant at 0.05 level

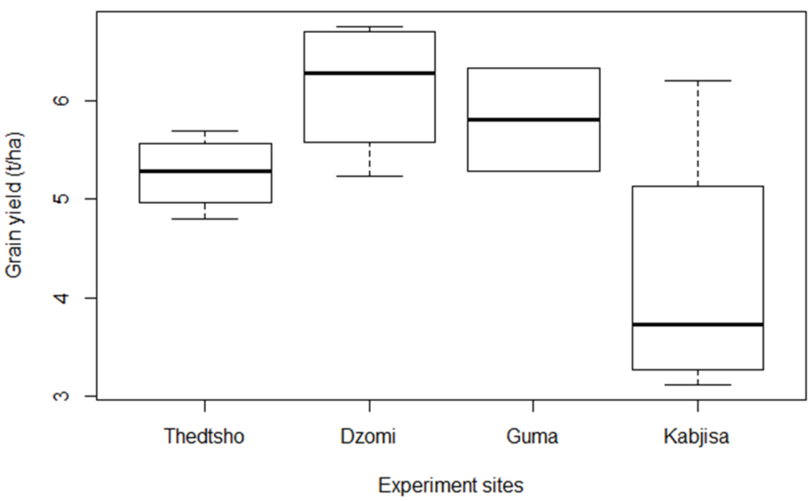

Figure 2: Grain yield variation among the trial sites (geogs) in Wangdue–Punakha valley

On-station evaluation

After introduction in 2008 (RNR RDC–Bajo, 2009), IR28 has undergone vigorous on-station evaluation and screening processes. Records maintained with RDC–Bajo showed that IR28 has consistently performed well and out yielded the best local check (Table 2). The seven year's trial data maintained by RDC–Bajo showed that IR28 produced 48% more yield than the local check. It is one of the eight elite advanced entries which further graduated to on-farm trials in the mid-altitude geogs of Wangdue and Punakha. The other selected varieties from the same introduction lines were BP-176 and PSB RC60, which were also superior when tested in farmers' field. Crop performance in terms of grain yield showed that IR28 was one of the highest yielding varieties introduced in the recent years. Data from 2009 to 2015 showed that its average grain yield stood between 3.90 t/ha to 6.7 t/ha with an average of 5.43 t/ha, whereas the average yield from the local check was 3.61 t/ha. Additionally, IR28 has other favourable agronomic traits such as plant height and tillering ability (Table 1). Bhutan's farmers prefer plants of medium height, medium maturity, and good yield (Ghimiray *et al.*, 2008). Medium height or tall plants provide more straw which is important to feed cattle during winter when green fodder is scarce. Varieties with medium maturity (about 150 days) fit well in farmers' cropping systems. IR28 meets these criteria and was selected for further testing in the following two years (2014 and 2015).

Table 2: Grain yield and agronomic attributes of IR28 from 2009 to 2015

Year	Grain yield (t/ha)		Difference (%)
	IR28	Local Check	
2009	4.91	3.45	42
2010	6.9	3.65	89
2011	4.7	3.6	31
2012	3.9	3.71	5
2013	5.25	3.8	38
2014	6.7	3.8	76
2015	5.69	3.73	53
Average	5.43	3.61	48

Source: RNR RDC Bajo, annual report (2009 to 2015)

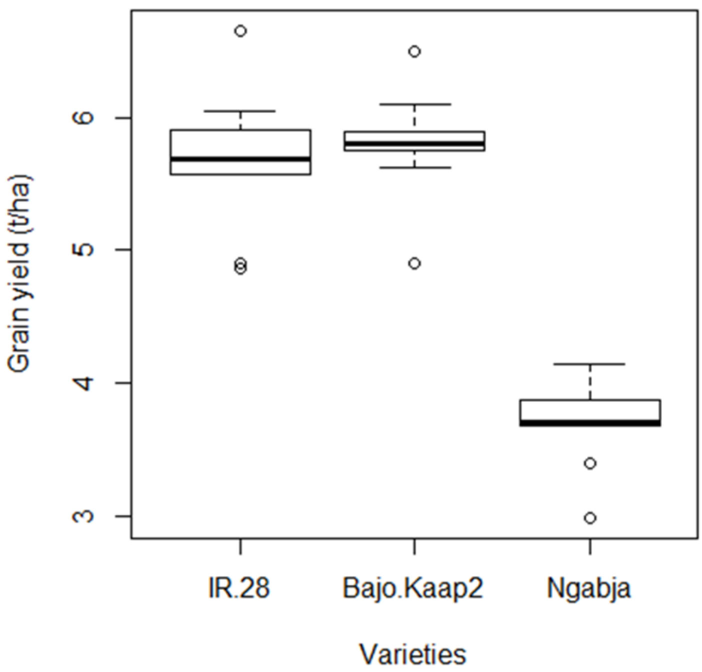

Figure 3: Boxplot of yield difference between IR28, Bajo Kaap2 and Ngabja rice varieties. The two dissimilar letters (a and b) denotes significant difference while similar letters (a) denotes no statistical difference

Data recorded with the RNR RDC–Bajo proved it has consistently performed well in all stages of evaluation (Chhogyel *et al.*, 2013; RNR RDC–Bajo, 2013–2014; RNR RDC–Bajo, 2014–2015). Khush and Virk (2005) reported that IR28 was a mega rice variety and was released in 12 countries of South and South East Asia with the first release in the Philippines in 1974. Its average yield potential in dry season was about 5.33 t/ha, which is within the range evaluated in Bhutan.

In order to confirm its potential and validate the crop performance, IR28 was tested against the high yielding improved variety (Bajo Kaap2) and the most popular local check (Ngabja) in 2015. The evaluation on larger plots in 2015 showed that there was a significant difference ($Pr > F = 3.86 \times 10^{-6}$) in yield among IR28 (5.69 t/ha), Bajo Kaap2 (5.71 t/ha), and Ngabja (3.73 t/ha). IR28 produced comparable yield to Bajo Kaap2 which is considered to be one of the best varieties promoted in the region (Figure 3). The yield of IR28 was slightly lower with the difference of just 0.02 t, but statistically similar ($Pr > F = 0.8496$). The higher yield of IR28 compared to other varieties could be due to its high genetic potential as growing conditions were more or less similar. Yoshida (1981) mentioned that the grain yield of rice ranges between 3–10 t/ha depending on management practices and crop variety.

Organo-leptic test
The organo-leptic test, which refers to sensory evaluation of taste, odour or texture of food, is one of the easiest and popular tests for food and wine industries. For rice, it is important as it determines the acceptability of a product by consumers. In the current test, the ratings were based on overall taste of cooked rice sample based on softness, hardness when cooled, texture, aroma, fluffiness, and visual appearance. The overall ratings indicated that IR28 was better than IR64 and scored 60% (better than IR64), 27% (similar to IR64), and 13% (not better than IR64) as detailed in Table 3. However, responses from the two amateur groups of respondents – field workers and professionals showed some variations on comparison. Overall, more number of field workers were in favour of the new variety with 12 of the 15 people reporting "better than IR64" as against 8 out of 15 in case of the physical attributes and eating qualities are some of the varietal traits considered in breeding programme. In milling recovery analysis, 300 g of randomly sampled paddy were milled using table mill (Satake) in three replications. Each replication consisted of dehulling, polishing, and grading at 30% milling degree. The rice grain milling recovery of IR28 after the processes of dehulling, polishing, and grading was comparable to IR64. Measurements such as brown rice recovery, total rice recovery, head rice recovery, and broken percentages were comparable to IR64 (Figure 4). The brown rice recovery was close to 80% while the total rice recovery stood at about 74%. Both IR64 and the test variety showed similar values in all the parameters measured. The milling recovery parameters measured in the current experiment were comparable with those reported by Bhonsle and Sellappan (2010) who reported

Table 3: Organo-leptic test result of IR28 compared with IR64 in a random sample of 30 participants

Respondents	Particulars			Remarks
	Better than IR64	Similar to IR64	Not better than IR64	
Field workers	12	4	1	Ratings based overall traits such as fluffiness, aroma, hardness when cooled, softness
Professional group (staff)	8	4	3	
Count (%)	18 (60%)	8 (27%)	4 (13%)	

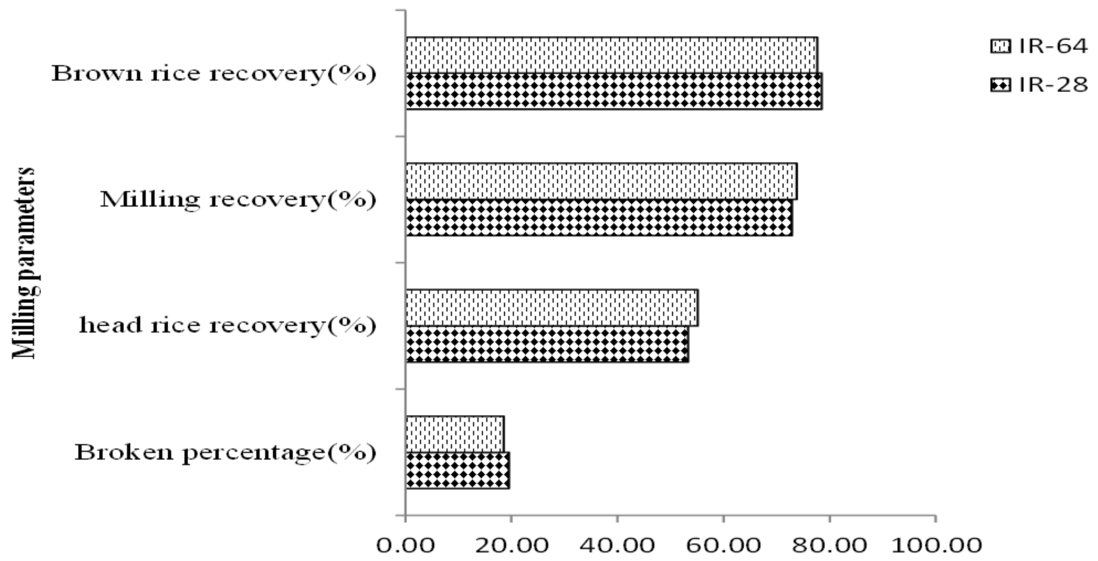

Figure 4: Milling recovery percentages of IR28 compared with that of IR64

Milling recovery analysis

Milling recovery is one of the grain quality traits in rice research and development. Among the post harvest quality traits, milling recovery analysis is the most important parameter. According to Philippine Rice Research Institute (PhilRice) (2013), milling recovery along with

Morphological characterisation

Basic morphological characterisation was done by using a standard procedure and protocol of INGER (IRRI, 1996) to provide some distinguishing characters of the test variety. The details provided in Table 4 are the averages of the parameters measured at different times of the crop stages. The values of the parameters correspond to the agro-ecology of RDC–Bajo which is located within mid-altitude region of Bhutan at 1250 m above mean sea level. Among the morphological parameters, it is important to note that IR28 belongs to a long grain category based on the l/b ratio of 3.03. As reflected in

Table 4: Morphological characters of IR28 based on observation and analysis at RDC Bajo

Morphological traits	Values/Units	Remarks
Days to flowering (DTF)	125-130 d	No. of days to 50% flowering
Days to maturity (DTM)	160-165 d	No. of days to 85% maturity
Basal leaf sheath colour	Reddish	Observed during vegetative stage
Plant height at heading	95-100 cm	cm
Panicle exersion	fully exerted	full/moderate/low
Panicle type	compact	compact/open
No. of grains per panicle	123	No.
Panicle length	22.5	Average length (cm)
No. of tillers per hill	10-14	No.
Presence of awn	Yes/No.	Awnless
Prominence apiculus	yes	dark brown in colour
Shattering	medium	Easy/Medium/High
Grain yield at 14% MC	4-6 t/ha	Average yield in t/ha
Milling recovery	74%	%
Hull colour	straw/golden	Colour
Kernal colour	white	colour
Grain length (with hull)	8.66	mm
Grain width (with hull)	2.86	mm
L/B ratio	3.03	Slender grain based on l/b ratio
Grain length (milled rice)	6.33	mm
Grain width (milled rice)	2.57	mm
Scent	Non-scented	Yes/No
1,000 grain weight	26 g	Adjusted to 14% moisture

Table 4, the other distinguishing characters of this variety include: straw coloured paddy grains, rice grains of white kernel, awnless but with a dark brown apiculus, plants with whitish ligule, and grains per panicle of 123 with about 22.30 cm length of panicle. The plants flower in about 120–130 days at mid-altitude condition and leaves are glabrous.

Conclusion

Like in any other Asian society, rice is the most important food for Bhutanese people who derive more than half of their calorie needs from it. However, with increasing non-farming population, urbanisation, and shrinking of limited wetland, rice production has declined over the years leading to increasing dependence on imports from India. The Ministry of Agriculture and

Forests wishes to enhance rice production and thus strengthen food security of the people. Among other technical interventions, the Ministry has prioritised identification and promotion of modern rice varieties that are high yielding, disease resistant, and are acceptable to farmers and consumers in culinary traits. Therefore, RNR RDC–Bajo has introduced and evaluated a number of modern rice varieties from IRRI including IR28 variety.

Following a standard procedure, IR28 was evaluated at the research station for five years and in farmers' fields for another two years. At the station, IR28 yielded an average of 5.43 t/ha, which is higher than the national average of 3.20 t/ha. Similarly, in on-farm trials, IR28 produced an average yield of 5.33 t/ha which was 34% higher than that of Ngabja (3.53 t/ha). The average number of productive tillers was 14 compared to 7 for the local variety Ngabja. In an organo-leptic test conducted at RDC–Bajo, IR28 scored better (60% respondents) than IR64. The milling yield of IR28 was comparable to IR64, with a milling recovery of 74% and head rice recovery of 56%.

Results of the trials showed that IR28 has genetic potential for high yield and is acceptable to Bhutanese farmers and rice consumers. The research has added value and expanded the information base on the suitability of IR28 in specific local growing conditions, in this case the mid-altitude rice ecosystem. However, as growing conditions vary at different agro-ecological zones, testing of any new crop variety including IR28 under varied agro-ecological conditions within a given altitude regime is strongly recommended. There is a need to expand the trials of IR28 to other parts of the country in similar agro-ecological zones. For now, the official release of IR28 needs to be confined to the dry mid-altitude zone of Wangdue-Punakha valley.

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