RESEARCH ARTICLE

PHENOLOGICAL CHARACTERIZATION AND YIELD PERFORMANCE OF HILLY BLACK RICE CULTIVARS UNDER YEAR-ROUND CULTIVATION IN PLAIN LAND ECOSYSTEM OF BANGLADESH

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ABSTRACT

Black rice is considered as super food due to its various health benefits to the human being. In Bangladesh this rice is cultivated in a very limited area of Chittagong hill tracts and its cultivation technique in plain land ecosystem is still unknown. Therefore, a study was undertaken to evaluate the performance of few black rice cultivars cultivated year-round in plain land environment. The experiment was performed at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh. The experiment comprised two factors viz. A) three rice cultivars: Kongnam ene, Gelong ni and Gelong se; and B) Twelve date of transplanting starting from 01 July 2018 to 01 June 2019. The experiment was laid out in a split plot design where date of transplanting was distributed in main plots and rice cultivars were allocated in sub plots. It has been found that cultivar Kongnam ene can be cultivated as a short duration variety as it required only 40 days to panicle initiation, 60 days to flowering and 80 days to harvesting after transplanting. All the three cultivars can be cultivated in all the three seasons viz. aus, aman and boro. The cultivar Gelong ni produced significantly highest grain yield (4.0 t/ha) among the cultivars when transplanted in January (boro season).

KEYWORDS

Phenology, yield performance, black rice, plain land ecosystem Bangladesh

1. INTRODUCTION

Black rice is a type of the rice species *Oryza sativa* L. which is glutinous, packed with high level of nutrients and mainly cultivated in Asia. The pericarp (outer part) of kernel of this rice colour is black due to a pigment known as anthocyanin, an antioxidant. Many people assume this rice as a panacea of many culinary diseases because of its high nutritive value and curative effect. This rice is supposed to enhance the longevity of life, hence it is also known as long life rice. Black rice is known as forbidden rice which is an ancient grain that has even more impressive health benefits. Ancient Chinese history claims that black rice was solely for the Emperor and the Royal family due to its nutritional and healing abilities (Oikawa, 2015).

This rice includes several varieties with a long history of cultivation in Southeast Asian countries such as China, India and Thailand (Kong et al., 2008). Nutrients such as protein, minerals (Ca, P, Fe, and Zn) and dietary fiber contents are higher in black rice compared white rice. Demand for this rice is growing fast in the USA and European countries due to its value as a healthy food and its attractive organic food color. A study reported that black rice is efficient, and two fold stronger with respect to antioxidant activities of blueberries (Ichikawa et al., 2001).

There exists no other rice with a higher nutritional spectrum near blackrice. This rice is free of gluten, free of cholesterol, low in sugar, salt and fat. Black rice is a whole grain, super nutritious type of rice that is high in fiber, anthocyanin, antioxidants, vitamins B and E, iron, thiamine, magnesium, niacin and phosphorous (Ling et al., 2002). The anthocyanin components in BRACs are about 26.3 %, and cyaniding-3-O-glucoside and peonidin-3-O-glucoside are the main effective constituents accounting for about 90 % (Chang et al., 2010). Among different compounds of black rice, anthocyanin is the one which mop up harmful molecules and help to protect arteries and prevent the DNA damage. Anthocyanins are the flavonoid pigments of black rice and are the source of antioxidants that have the ability to inhibit the formation or to reduce the concentrations of reactive cell damaging free radicals (Adom and Liu, 2002). Black rice extracts could scavenge superoxide anions more effectively than hydroxyl radicals (Nam et al., 2006). This rice has long been consumed in Korea, Japan and China (Ryu et al., 2000; Han et al., 2004). This rice help to prevent headaches, relieve symptoms of constipation, prevent colon cancer, adjust blood sugar levels, prevent heart disease, lower blood pressure and prevent Alzheimer's disease (Kayahara and Tsukahara, 2000).

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Though Bangladesh is self-sufficient in rice production, most of the people suffer from hidden hunger due to lack of essential vitamins and minerals (e.g. vit-A, Zinc, Iron, Iodine) in rice (Harding et al., 2017). This problem might be eliminated by consumption of Black rice in people's daily diet. It has been found that black rice has zinc content of about 65 mg/Kg than that of zinc enriched rice varieties developed by Bangladesh Rice Research Institute (BRRI, 2016; Rahman et al., 2019). In Bangladesh, the black rice is being cultivating in the remote hilly areas including Bandarban district as shifting cultivation crop without any agronomic management practices and hence giving very low yield. The climate of Bangladesh is suitable for growing rice in year-round and there are three distinct rice growing season namely aus (pre-monsoon season), aman (monsoon season) and boro (winter season) (Rahman et al., 2020). Planting date is a very crucial factor in yield formation. Transplanting dates have significant effect on growth conditions of rice plant and therefore, contribute a lot on the yield response of a variety (Kabir et al., 2014; Islam et al., 2015).

Different authors reported the benefits of choosing optimum planting dates in rice and in most of the cases, neither too early or too late transplanting proved to give better yield by offering prolonged or shorter growth period (Safdar et al., 2008). Rice varieties were shown to respond differently to the seasonal variation in their grain quality as well as yield. A group researchers found that the variation in grain yield was associated with differential effects of season on grain filling in different varieties (Laenoi et al., 2017). However, the cultivation procedure of hilly black rice under plain land condition is still unknown in Bangladesh. Therefore, this study intends to explore the suitability of black rice cultivation under plain land condition to increase its productivity through different agronomic practices. In this connection the present study was set to identify the suitable growing season and seasonal variation in growth and yield

performance of three hilly black rice cultivar under plain land ecosystem of Bangladesh.

2. MATERIALS AND METHODS

2.1 Description of experimental site

The study was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from June 2018 to October 2019. The experimental site is located at 24° 75' N latitude and 90° 50' E longitude in the south-west part of Brahmaputra at an elevation of 18 m above the sea level. This site belongs to non-calcareous dark grey floodplain soil under the agro-ecological zone Old Brahmaputra Floodplain. The experimental area was a fairly leveled well drained medium high land belonging to the Sonatola series of non-calcareous dark grey floodplain soil under the Old Brahmaputra Floodplain agro-ecological zone (UNDP and FAO, 1988). The experimental soil was silt loam having bulk density of 1.35 g cc⁻¹ and pH 5.70. The soil contained 0.09% total nitrogen, 1.02% organic matter, 5.68 ppm available phosphorus, and 49.12 ppm exchangeable potassium and 8.28 ppm available sulphur.

2.2 Agro-climatic condition of the site

Bangladesh is located in the tropical monsoon region. It has hot and humid summer season starting from March to October and a cool winter season from November to February. Rice can be grown year-round in Bangladesh. There are three rice growing season in Bangladesh name Aus, aman and boro. The comparative characteristics of these three seasons is presented in the Table 1. Monthly weather data during the experimental period (June 2018 to October 2019) is presented in Table 2.

Table 1: Comparative characteristics of Aus, aman and boro season

Aus season	Aman season	Boro season
The word is derived from the Sanscrit <i>ashu</i> meaning quick or early.	The word is derived from Arabic <i>aman</i> meaning safety which indicates stability of the crop.	Boro rice refers to the crop grown in land lower in elevation with <i>boring</i> (ground) water.
The season designates the cultivation of rice varieties that are planted in mid March-April and harvested in June-July.	The season describes the cultivation of the rice varieties which are planted in mid July and harvested in mid November-December.	The season defines the cultivation of the rice varieties which are planted in November-December and harvested in March-April.
The season is synonymous to <i>Kharif-I</i> .	The season is synonymous to <i>Kharif-II</i> .	The season is synonymous to <i>Rabi</i> .
The sky is cloudy, mainly in the late season.	The sky is cloudy.	Clear and cloud free sunny day, but little cloud in the late season.

Adapted from Bhuiya et al., 2005

Table 2: Monthly average weather data during experimental period (May 2018 to October 2019) of the experiment site

Month	Air temperature (°C)	Relative humidity (%)	Total rainfall (mm)	Total sunshine (hrs)
May 2018	26.8	83.2	488.5	144
June 2018	29.2	84.9	302.9	99
July 2018	29.9	84.0	299.6	161
August 2018	29.4	84.4	216.6	152
September 2018	29.4	84.4	145.9	147
October 2018	23.9	83.3	05.6	195
November 2018	20.35	80.4	37.2	228
December 2018	18.0	83.6	2.6	202
January 2019	19.2	75.4	0.0	226
February 2019	21.3	75.9	29.8	177
March 2019	24.3	73.0	51.6	208
April 2019	27.0	78.5	69.8	195
May 2019	36.2	80.4	334.8	189
June 2019	29.2	84.4	422.3	111
July 2019	29.6	84.5	582.9	121
August 2019	30.2	81.6	117.5	198
September 2019	29.3	84.6	207.0	147
October 2019	27.3	87.3	201.5	164

Source: Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh

2.3 Characteristics of test varieties

Three hilly rice cultivars named Kongnam ene, Gelong ni and Gelong se, were used as the test crop in this experiment. The seeds of the three black rice varieties were collected from Bandarban hill district of Bangladesh. The main characteristic features of the rice cultivars are discussed below: Kongnam ene is a black rice variety which includes a long history of cultivation in Southeast Asian countries such as China, India and Thailand (Kong et al., 2008). The pericarp (outer part) of kernel of this rice color is black due to a pigment known as anthocyanin, an antioxidant. Brown rice has also many health benefits. It is a transplant aman rice cultivar and matures after 90 days after transplanting with average yield 3.0-3.5 t ha⁻¹. Life cycle of this variety ranges from 95-105 days, which however may vary due to changes in climatic condition. The plant height is 90-95 cm and the cultivar is of non-lodging type. It is somewhat resistant to pests and diseases and especially blast disease.

Gelong ni and Gelong se are rice variety traditionally cultivated in hilly upland area. This rice varieties are short duration variety. It matures after 110-120 days of transplanting when planted in summer season in hilly areas. Plant height is usually around 120 cm. The hull and bran around the kernel are brown in color. Yield is about 3.5 t ha⁻¹. Both these rice varieties are a good source of magnesium, phosphorus, selenium, thiamin, niacin and vitamin B6, and an excellent source of manganese, with 88 percent of our daily manganese in just one cup cooked. The morphological and nutritional characteristics are almost same for these two varieties except the thousand grain weight. The thousand grain weight of variety Gelong ni is little higher than that of Gelong se.

2.4 Experimental treatment and design

The experiment was comprised of two factors viz. A) Three rice cultivars: Kongnam ene, Gelong ni and Gelong se; and B) Twelve date of transplanting: The transplanting of rice seedlings was done at the beginning of every month starting from 01 July 2018 to 01 June 2019. The experiment was laid out in a split plot design where date of transplanting was distributed in main plots and rice cultivars were allocated in sub plots. Thus, the total number of plots were 108 (12×3×3). The size of each plot was 10 m² (4 m × 2.5 m).

2.5 Preparation of the experimental land and layout

The land was first opened with a tractor drawn disc plough on 01 June 2018. After two days, the land was irrigated slightly and subsequent ploughings and cross ploughings were given and leveled by laddering. The field layout was made on 01 July 2018 according to experimental specification immediately after final land preparation.

2.6 Crop husbandry

After the layout of the experiment was completed the rice seedlings were carefully uprooted from nursery bed and transplanted in the plots maintaining a spacing of 25 cm × 15cm. First and last transplanting of rice seedlings were done on July 01, 2018 and June 01, 2019, respectively, according to the experimental treatments. Three healthy seedlings were transplanted in each hill. The experimental plots were fertilized with urea (200 kg ha⁻¹), triple super phosphate (100 kg ha⁻¹), muriate of potash (70 kg ha⁻¹), gypsum (60 kg ha⁻¹) and zinc sulphate (10 kg ha⁻¹). The full dose of triple superphosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate was applied at the time of land preparation. Urea was top dressed in three equal splits, at 15, 30 and 45 days after transplanting. Various intercultural operations viz. irrigation, weeding, disease and pest management etc. were done as and when necessary to ensure and maintain the favorable condition for normal plant growth and development of crop.

2.7 Observation and data collection

The crop was harvested at full maturity. The date of harvesting was confirmed when 90% of the grain became golden yellow in color. Five rice hills were selected randomly from each individual plot and uprooted before harvesting for recording data. During the growth period the data collected were days required to panicle initiation, flowering and harvesting after transplanting. Total growth duration from seed to seed

was also recorded. After harvesting the data on plant height (cm), number of total tillers per hill, number of effective tillers per hill, number of non-effective tillers per hill, panicle length (cm), number of sterile spikelets per panicle, number grains per panicle, 1000-seed weight, grain yield (t/ha) and straw yield (t/ha) was collected.

2.8 Statistical analysis of data

Data were compiled and tabulated in proper form for statistical analysis. The recorded data were statistically analyzed to find out the significance of variation resulting from the experimental treatments. All the collected data were analyzed using the statistical software R.

3. RESULTS AND DISCUSSION

3.1 Phenological characteristics

Days required to panicle initiation, flowering and harvesting was recorded. These three phenological characteristics were significantly affected by black rice varieties and date of transplanting. Figure 1 shows that variety Kongnam ene required minimum number of days to panicle initiation (40 days after transplanting) while the variety Gelong ni required maximum number of days to panicle initiation (54 days). For flowering, the similar trend was found in case of variety i. e. Kongnam required shortest time and Gelong ni required longest time to flower. However, for harvesting it has been found that the black rice variety Kongnam ene took only 80 days after transplanting while the other two varieties viz. Gelong ni and Gelong se took the same times (92 days) for harvesting (Figure 1). It is also found that total growth duration (TGD in days) from seed to seed, cultivar gelong ni required the maximum number of days (114 days).

Time of transplanting also have significant effect on phenological characteristics. It appears in the table 1 that minimum number of days required to panicle initiation (40 days), flowering (60 days) and harvesting (82-83 days) when transplanted in aman season (July-September) and maximum number of days required to panicle initiation (50-53 days), flowering (75-77 days) and harvesting (105-107 days) when transplanted in boro season (Dec-Feb). Total growth duration was found highest when the seedlings of rice was transplanted in boro season (December and January).

Figure 1: Varietal difference on crop phenology of black rice (days required to panicle initiation, flowering, harvesting and total growth duration)

3.2 Crop characteristics

Different crop characters like plant height, total number of tillers hill⁻¹, number of non-effective tillers hill⁻¹, panicle length and sterile spikelets panicle⁻¹ differed significantly at 1% level of probability among different varieties of black rice (Table 2). Significantly Tallest plant (115.34 cm) smallest plant (87.94 cm) were found in the variety named Gelong ni and Kongnam ene, respectively. Maximum number of total tillers (15.99), non-effective tillers (5.27), longest panicle length (25.59 cm) and highest number of sterile spikelets panicle⁻¹ was found in Gelong ni (Table 2). These superior plant characters of the cultivar Gelong ni over the other two cultivars might be due to the genetic makeup of the cultivar.

Table 3: Effect of date of transplanting on number of days required to panicle initiation, flowering and harvesting

Transplanting Date	Days required from transplanting to			Total growth duration (days) from seed to seed
	Panicle initiation	Flowering	Harvesting	
1 st July	40	60	82	107
1 st Aug	40	60	80	105
1 st Sep	40	60	83	108
1 st Oct	42	63	91	107
1 st Nov	50	75	100	135
1 st Dec	53	75	105	138
1 st Jan	52	77	106	138
1 st Feb	50	76	107	140
1 st Mar	42	63	89	114
1 st April	42	64	88	111
1 st May	42	64	87	113
1 st June	41	61	86	112
Level of significance	**	**	**	**
CV	1.86	0.47	1.59	1.60

Note: ** means significance at 1% level

Table 4: Differences in crop characteristics of hilly black rice cultivars

Cultivar	Plant height (cm)	Total tillers hill ⁻¹ (no.)	Non-effective tillers hill ⁻¹ (no.)	Panicle length (cm)	Sterile spikelets panicle ⁻¹
Kongnam ene	87.94b	14.53c	4.76c	23.28b	20.11a
Gelong se	106.32a	15.74b	5.19b	25.58a	20.01a
Gelong ni	115.34a	15.99a	5.27a	25.59a	19.24b
Level of significance	**	**	**	**	**
CV	14.26	1.42	2.37	1.02	1.93

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).** =Significant at 1% level of probability

Time of transplanting had a significant effect on different crop characters such as plant height, number of total tillers hill⁻¹, number of sterile spikelets panicle⁻¹ of black rice at 1% level of probability (Table 3). Significantly the tallest plant (115.20 cm) was found when the rice seedlings were transplanted in the month of August and shortest plant (95.88 cm) was found when transplanted in December. This might be due to the hot and humid environment during aman season (August) that helps in better growth of the rice plant.

Though plant height was maximum in aman season but number total tillers hill⁻¹ (18.99) was found highest in January and the lowest number of total tillers hill⁻¹ (10.02) was found when transplanted in September. Number of non- effective tillers hill⁻¹ and panicle length did not differ significantly due to the variation in time of transplanting. However, significantly the highest number of sterile spikelets panicle⁻¹ was observed when transplanted in November and lowest number was found when transplanted in September (Table 3).

Table 5: Effect of transplanting date on different crop characteristics of black rice cultivars

Date of transplanting	Plant height (cm)	No. of total tillers hill ⁻¹	No. non-effective tillers hill ⁻¹	Panicle length (cm)	No. of sterile spikelets panicle ⁻¹
1 st July	110.00 ab	13.93 c	2.28	23.51	17.00 3 d
1 st August	115.20 a	14.08 c	3.22	24.42	16.32 ef
1 st September	111.80 ab	10.02 e	4.13	24.83	14.99 f
1 st October	100.05 b	12.44 cd	4.78	23.46	21.61 b
1 st November	98.00 c	10.06e	3.26	24.25	22.86 a
1 st December	95.88 cd	17.45 ab	3.75	24.47	20.42 c
1 st January	98.08 c	18.99 a	3.14	25.18	18.09 d
1 st February	98.75 c	18.01 b	3.29	25.89	18.39 d
1 st March	105.41 b	10.88 e	4.23	25.64	17.35 d
1 st April	106.67 b	11.69 d	3.67	22.06	19.83 d
1 st May	105.47 b	11.98 d	4.56	22.66	18.52 d
1 st June	107.80 b	12.75 cd	3.44	23.33	17.75 e
Level of significance	**	**	NS	NS	**
CV (%)	3.74	3.03	5.44	3.48	5.57

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). ** =Significant at 1% level of probability, NS = Not significant

3.3 Yield contributing characters and yield

Different yield contributing characters like number of effective tillers hill⁻¹, number of grains panicle⁻¹ and 1000-grain weight was found significant among different varieties (Table 4). It was observed that the variety Gelong ni produced highest number of effective tillers (10.71) hill⁻¹ and the lowest number was observed in Kongnam ene (9.16). Similarly, maximum number of grains (123.41) panicle⁻¹ was found in the variety Gelong ni

which was statistically at par with the variety Gelong se (123.26). However, opposite scenario was found in case of 1000 grain weight. Maximum weight of 1000 grain (30.82) was observed in case of the variety Kongnam ene and minimum weight of 1000 grain (18.89) was found in Gelong se which was similar to the grain size of fine rice.

Grain yield and straw yield were also significantly (at 1% level of probability) varied among different varieties (Table 4). The highest grain

yield (4.00 t ha⁻¹) was observed in Gelong ni and the lowest grain yield was observed in Kongnam ene rice variety (3.10 t ha⁻¹). This might be due to the highest number of effective tillers hill and maximum number of grains panicle⁻¹ was produced in Gelong ni rice variety. However, in case of straw yield both the variety Gelong ni and Gelong se produced statistically similar and highest straw yield.

Table 6: Cultivar difference in yield contributing characteristics and yield of hilly black rice

cultivar	No. of effective tillers hill ⁻¹	No. of grains panicle ⁻¹	1000 grain weight	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)
Kongnam ene	9.16 b	82.90 b	30.82 a	3.10 c	5.94 b
Gelong se	10.52 a	123.26 a	18.89 c	3.50 b	6.59 a
Gelong ni	10.71 a	123.41 a	23.95 b	4.00 a	6.50 a
Level of significance	**	**	**	**	**
CV	14.83	12.29	0.67	2.19	7.97

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).

** =Significant at 1% level of probability

Time of transplanting exerted significant differences (at 1% level of probability) in different yield contributing characters and yield of black rice varieties in plain land condition. Highest number of effective tillers hill⁻¹ (13.52) and number of grains panicle⁻¹ (130.3) was observed when seedlings were transplanted on January (Boro season). The lowest number of effective tillers hill⁻¹ (5.01) and number of grains panicle⁻¹ (89.10) was found when transplanted in April (Aus season). However, in case of 1000 grain weight, maximum (28.43 g) was found when transplanted in December and the second highest weight of 1000 grain was observed when the seedlings were transplanted in January (Boro season).

Table 7: Effect of transplanting date on yield contributing characteristics and yield of hilly black rice

Cultivar	No. of effective tillers hill ⁻¹	No. of grains panicle ⁻¹	1000 grain weight (g)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)
1 st July	9.65 bc	104.60 c	24.54 cd	3.50 cd	7.66 a
1 st August	9.85 bc	125.90 b	24.43 cd	3.58 c	6.74 b
1 st September	7.89 c	122.00 a	25.61 c	3.10 d	6.92 b
1 st October	7.61 bc	101.3	25.80f	2.49 f	5.35 d
1 st November	6.79 d	103.9	26.95 ab	2.78 e	6.07c
1 st December	12.70 ab	129.4 ab	28.43 a	3.80 ab	6.61cd
1 st January	13.52 a	130.3a	28.11 b	4.00 a	6.52 b
1 st February	10.72 b	126.3 b	27.71 ab	3.50 c	6.43 bc
1 st March	6.43 d	100.7ab	26.20 c	2.90 e	5.92 c
1 st April	5.01 f	89.10 e	24.13 d	2.61 ef	5.63 f
1 st May	5.42 ef	93.23 d	24.37 d	2.76 e	5.80 e
1 st June	6.31 d	95.38 d	24.25 d	2.80 e	5.84 d
Level of significance	**	**	**	**	**
CV	3.62	3.88	3.64	1.35	1.72

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).

** =Significant at 1% level of probability

Grain yield was found highest (4.0 t/ha) when transplanted in January and lowest grain yield (2.49 t/ha) was observed when the seedlings were transplanted in October. Significantly highest amount of straw yield (7.66 t/ha) was found when the seedlings were transplanted in July (Aman season) and the lowest straw yield (5.63 t/ha) was observed in April (Table 5).

4. CONCLUSION

From the above findings it can be said that all those three cultivars of black rice can be grown in plain land ecosystem where Kongnam ene is desirable because of its short duration ability (80 days to harvest after transplanting). However, the cultivar Gelong ni can be cultivated as it has got the best grain yielding ability (4.0 t/ha) among the three. It can also be concluded that all those three varieties can be cultivated throughout the year where maximum yield can be obtained when the varieties are transplanted in boro season i. e. at the beginning of January in plain land context of Bangladesh.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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