Evaluation of Genotypic Performances in Native Rice Landraces of Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Field experiments were carried out at Dinajpur, Nilphamari and Faridpur from July, 2017 to March, 2018 to evaluate the performance of native land races of rice *viz*., Chinigura, Kataribhog, Radhunipagol, Badshabhog, Kalozira, Uknimadhu, Dudshar, Salna, Shitabhog and Zirashail to assess G x E interaction against five quantitative characters, plant height (cm), productive tillers/hill, 1000-grain weight (g), grain yield/m^2 and days to maturity, and three qualitative characters, proline (%) as µmol/g fresh weight, aroma from green leaves and cooked rice. The field experiment was conducted in Randomized Complete Block Design with three replications. The highest grain yield (390.25 g/m^2) was obtained from Radhunipagol at Dinajpur. Next to Radhunipagol, Kataribhog produced higher grain yield (350.00 g/m^2) which was significantly higher than that of Nilphamari and Faridpur but Radhunipagol was suited both for Dinajpur and Nilphamari. The cultivar, Kalozira was adapted to three locations as reflected by its regression coefficient very close to unity (b=0.92) and deviation from the coefficient estimated very near to zero (s^{2}d=0.16). Maximum proline was estimated (18.7 µmol/g fresh weight) from Chinigura cultivated at Dinajpur. The proline (%) estimated average from Kalozira at three locations and the range varied from 14.00 -15.90 µmol/g fresh weight. Dinajpur appeared as the best and Faridpur as an unfavorable location for local aromatic rice cultivars. Since, aroma was assessed through

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sensory method the maximum aroma was assessed from Chinigura under Dinajpur but its content gradually decreased at Nilphamari and Faridpur. The aroma assessed from cooked rice ranged from 7.05-8.90 over three locations but maximum aroma was assessed under Dinajpur. Chinigura, Radhunipagol and Kataribhog found suitable for Dinajpur, and Kalozira and Badshabhog might suggest cultivating over the locations of Bangladesh.

1. INTRODUCTION

Worldwide population growth necessitates a pace to increase the yield potential of cereal like rice to meet out the global food security. Most of the Asian people consume rice as their staple food and rapid growth of population demands 60-70% increase rice production by 2050 but gradual decrease of arable land with corresponding increase of population creates a threat in Asian agriculture. The exploitation of primitive diverse rice genetic resources may expand and enrich the base materials for future breeding [1]. Improvement in plant breeding programs primarily depends upon genetic variability pertains in the domestic genetic resources [2]. Moreover, narrow genetic variability limits expected to gain even from simple selection [3]. Therefore, popular land races may be exploited to evolve new outstanding fine rice varieties. Rice breeders are always interested to develop high yielding varieties with desirable agronomic characters but the expression of grain yield enhancing characters is influenced by prevailing growing conditions. So, the selection criteria for production high yield, one or more of the morphological components of yield, especially plant height, productive tillers/hill, days to maturity, 1000-grain weight and grain yield/m^2 are the most important [4], therefore grain yield might be increased in small grain by measuring the such component attributes. Nonetheless, [5,6] reported that the components of yield are influenced greatly by environment. The presence of G x E interactions is characterized by the differentiation response of genotypes due to variation of the environmental conditions, which can cause an alteration in the performance ordering of the genotypes in the environmental gradient [7]. The G x E interactions can be expressed in different ways and with different intensities and are of fundamental importance in genetic evaluations [8]. According to [9], variance component of the G x E interactions can be deployed into a simple part from the interactions, explained by the change in genetic heterogeneity of the genotypes in different environments, and into a complex part from the interactions arising from a lack of genetic correlation between the genotypic performances from one environment to another. This is the problematical part of the interactions, meaning that the good genotype in one environment may not be in another. According to [10], a genotype is considered stable when it presents small variation in its overall behavior under various environmental conditions. Another important concept is the adaptability or responsiveness to environmental improvement. This concept is associated with the plasticity of genotypes. In these terms, an ideal genotype is one that responds predictably or proportionally to environmental stimulus. There are several procedures to evaluate the effects of G x E interactions in plant breeding [11]. One of the main methods used in rice is based on simple linear regression analysis, proposed by [12]. This method considers the coefficients of linear regression of the phenotypic values from each genotype concerning the environmental index and the deviations of this regression to select genotypes with stability and adaptability to favorable and unfavorable environments.

Quality is one of the selection principles prioritized by farmers and consumers of fine rice; thus farmers choose rice with characters that are needed for consumption as well as production and sale [13]. Consumer preference is based on appearance (milling quality, grain length and width), cooking and eating quality. The quality of a rice grain is determined by its physicochemical and physical properties. Rice grain quality is one of the major concerns in rice production [14]. Cooking and eating qualities are controlled by biochemical components such as aroma, amylose content, gel consistency, alkaline spreading value/gelatinization temperature, and paste viscosity profiles [15]. Keeping eyes on the above aspects this study was conducted to determine the stability and response to varying environments based on agro- morphological and quality characters like proline and aroma contents in primitive cultivars of rice.

2. MATERIALS AND METHODS

2.1 Experimental Materials and Design of Experiment

The experiment was conducted from July, 2017 to March, 2018 in three locations *viz*., Plant Breeding Research Farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Seed Multiplication Farm, Nilfamari and Seed Multiplication Farm, Faridpur.

The farms are under BADC (Bangladesh Agricultural Development Corporation). Ten native land races of rice such as Chinigura, Kataribhog, Radhunipagol, Badshabhog, Kalozira, Uknimadhu, Dudshar, Salna, Shitabhog and Zirashail were integrated in the study. The seedlings were raised at three locations and 25 days old seedlings were transplanted with the spacing of 20 cm x 20 cm.

Recommended doses of fertilizers such as cowdung (5 t/ha), 100 kg/ha Urea, 25 kg/ha TSP and 45 kg/ha MOP were applied. The experimental design was randomized complete block design with three replications. The individual plot size was 2 m x 3 m. Ten plants were randomly selected at maturity and five quantitative characters *viz*., plant height (cm), productive tillers/ hill, days to maturity, 1000-grain weight and grain yield/m^2 were recorded.

2.2 Estimation of Proline

To estimate proline from each landrace, fresh green leaves (0.5 g/sample) were collected location and plot basis and carried in 70% ethanol to the Genetics and Plant Breeding Laboratory, HSTU, Dinajpur. The leaves were grounded to powder and then homogenized with 10 ml of 3% (w/v) sulpho salicylic acid and passed through a Whatman 2 filter paper. A reagent, 2 ml ninhydrin and 2 ml glacial acetic acid were added to 2 ml filtrated extract. The mixture was incubated at 100°C in a water bath for one hour. The reaction mixture was placed on ice and excreted with 4 ml toluene. Absorption of chromospheres were read at 250 nm using Perkin's lambda 900 uv/vis spectrophotometer. Toluene was used as blank. The proline concentration was calculated using L-proline corresponding to aroma content as suggested by [16].

The proline content on fresh-weight-basis as:

$$\mu \text{ moles per g tissue} = \mu g \text{ proline/ml} \times \text{ml toluene}/115.5 \times 5/\text{g sample}$$

2.3 Assessment of Aroma

Aroma characteristics of the fine rice cultivars were measured by tasting individual plant leaves and cooked rice. Following the

Table 1. Agro-ecological description of the experimental sites

Experimental site	Soil type	Soil pH and fertility	Name of the AEZ*	Location
HSTU	Medium high with sandy clay loam texture	5.5 to 6.00 with medium fertility level and low organic matter content	Old Himalayan Piedmont Plain (AEZ 1)	Located at 25°13´ N latitude and 88°23´E longitude and it is situated at elevation 42 meters above sea level.
Nilphamari	Medium high with sandy clay loam texture	6.00 to 6.5 medium fertility level and low organic matter content	Active Tista Flood Plain (AEZ 2)	25°48' N latitudes and 88°44' E longitude and it is situated at elevation 40 meters above sea level.
Faridpur	Medium high with clay loam texture	6.5 to 7.0 medium fertility level and low organic matter content	Active Ganges Floodplain (AEZ 10)	Located at 23.5958°N latitudes 89.84°E longitudes and it is situated at elevation 15 meters above sea level.

AEZ = Agro-ecological zone

method used by [17] one gram of the first green leaf blades at heading stage was cut into small pieces and put into Petri dishes with 5 mL of 1.7% KOH solution at room temperature. Similarly, 200 g of milled grain was taken and cooked over a mini rice cooker. For both treatments, after 30 minutes, the dishes were opened and immediately smelled by individual member of six-member panel and aroma content was assessed through 1-9 scale [18].

2.4 G x E Interaction Analysis

The stability of yield performance for each cultivar was calculated by regressing the mean grain yield of individual genotypes on environmental index and calculating the deviations from regressing of the mean yield against individual cultivar on environmental index as suggested by [12]. Regression coefficient (bi) was considered as an indication of the stability of the cultivars while deviation of from regression coefficient (s^2di) as response of the cultivars over the three locations.

The data obtained for different characters were recorded first on MS excel sheet. Afterwards, the data were analyzed using the software package R of version 3.4.2 and Statistical Tools for Agricultural Research (STAR) Version: 2.0.1.

3. RESULTS AND DISCUSSION

3.1 Expression of Different Characters over the Locations

Though aromatic rice contributes to a small share in the world markets, but it is valued at the highest price among all types of rice. The demand for aromatic rice is expected to increase due to increasing consumer preference and excellent premium in national and international markets. Nevertheless, traditional aromatic rice varieties low yield potential compared to other varieties, the breeding of new aromatic rice is to be increasingly more competitive rather than exploitation primitive aromatic rice cultivars of our country. Therefore, the experiments were undertaken to improve the aromatic rice cultivation scenario and the results are discussed below-

As grain yield in rice is an interactive quantitative character, selection on performance in single environment is not effective for genotype identification [19], therefore the cultivars were evaluated over three locations to measure grain

yield stability [20,21,22]. Since the cultivars under study had different adaptable behavior, such stability and adaptability analysis was performed prior to recommendation to grow in diverse eco-zones of Bangladesh [23]. Ten native land races of rice, such as Chinigura, Kataribhog, Radhunipagol, Badshabhog, Kalozira, Uknimadhu, Dudshar, Salna, Shitabhog and Zirashail were selected to study G x E interaction following by the model proposed by [12] in three locations, Dinajpur, Nilphamari and Faridpur. The cultivars were differently responded in changing of growing conditions as projected by significant mean square values for each of the selected characters like plant height, productive tillers/hill, 1000-grain weight, grain yield/m^2 and days to maturity were significantly responded across the three locations. In general, performance of land race was superior in Dinajpur as compared to other two locations but Nilphamari was better than that of Faridpur (Table 2). The highest grain yield, 390.25 g/m^2 was recorded from Radhunipagol but it was not significantly differ from the grain yield obtained at Nilphamari (385.28 g/m^2) and not only that the grain yield potential was statistically same of Kataribhog (350.00 g/m^2) at the same location and for Badshabhog at three locations. The grain yield of Kalozira was medium both at Dinajpur and Nilphamari and significantly higher than that of Faridpur. The grain yield of this cultivar varied from 279.43 to 314.75 g/m^2 over the three locations. The popular cultivar, Chinigura produced average grain yield of 300.00 g/m^2 at Dinajpur and the potential of this cultivar was very poor at other two locations. The grain yield potential of other five cultivars, Uknimadhu, Dudshar, Salna, Shitabhog and Zirashail were medium but fluctuated over the three locations.

3.2 G x E Interactions for Adaptability and Stability of the Cultivars

It was evident that the model of analysis proclaimed significant genetic basis of response and stability for the evaluated cultivars. Besides, significant differential changes were displayed by the cultivars due to environmental variation in three locations. In breeders' eyes in three locations, the performance of ten native rice cultivars on the quantitative and qualitative characters' remarkable superiority were observed at Dinajpur location, even the inputs like fertilizer, irrigation and pesticide application, and other management practices were utmost appropriate and judicious in three locations. The interactions of G x E for quantitative and

qualitative characters were significant across the three locations in ten land races of fine rice. [24,25,26,27,28,29,30,31] reported differential behavior of rice genotypes in changing environments. However, [12] defined a stable genotype as the one which showed high mean yield, regression co-efficient (bi) around unity and deviation from regression (s^2di) near to zero. Accordingly, the mean along with corresponding regression coefficient and deviation from respective regression coefficient were considered to evaluate the cultivars for response and stability. Considering response and stability of the cultivars based on [12] model, the cultivar, Kalozira with average grain yield, had regression coefficient very closed to unity (bi=0.92) and deviation from regression coefficient (s^2di=0.16) closed to zero, suggests general adaptation over the locations (Table.4). The regression coefficient against Chinigura was around the unity (0.90) but the deviation from regression coefficient measured highly away from zero (s^2di=5.23) indicates highly sensitive while changing the favorable location, like Dinajpur. The sensitiveness of Kataribhog was lower than Chinigura but due to its low grain yield potential only suitable to cultivate at Dinajpur. The response and stability of Radhunipagol and Badshabhog were unpredictable because lack of co-linearity between regression coefficients and deviations from regression coefficients. Other five cultivars, Uknimadhu, Dudshar, Salna, Shitabhog and Zirashail showed unpredictable relationship between two parameters of G x E interaction, regression coefficient and its deviation against each of the cultivars. Therefore, these cultivars may cultivate irrespective environmental fluctuation (Fig. 1). The effects of genotypes, environments and G x E interactions provided prediction on performance of genotypes overall and specific adaptation to different environment conditions [32], which is essential in selection strategies to stable genotype with suitable environment for grain yield [33,34]. Similar results were reported by [21,34,35,36,37, 38,39,40] over different ecosystems for grain yield in rice.

3.3 Estimation of Proline from Green Leaves

Proline and aroma from green leaves and aroma of cooked rice were estimated in each of the cultivars for each of the locations (Table 3). Considering the range of proline, aroma from green leaves and cooked rice in three locations, it is revealed that Chinigura and Kataribhog

produced high proline at Dinajpur; high aroma from green leaves at Dinajpur and Faridpur and aroma from cooked rice only at Dinajpur. For Radhunipagol, Dinajpur was suitable as compared to other two locations for the three qualitative characters. Badshabhog produced high aroma from green leaves, while aroma was assessed from cooked rice was not remarkable. The amino acid, proline is the precursor of 2AP (2-acetyl-1-pyrroline) reported by [41], a potent flavor compound of an aromatic rice cultivars [42], hence high proline content indicates high aroma content but volatilization of aromatic compounds during storage and cooking are the great concerned to maintain the quality of the local rice cultivars. The proline accumulation in plants is affected by water deficit [43] and temperature [44] in field conditions. [45] mentioned that sensory characterization undoubtedly provides a more complete and accurate information than the instrumental method for assessment of aroma in native rice cultivars.

3.4 Selection of Desirable Cultivars in Relation to Yield and Aroma Content

Water to uncooked rice ratio and heat controlling during cooking are two primary factors determining the quality of cooked rice [46]. Cooking through rice cooker is considered as the most acceptable for cooking in the urban areas of Bangladesh, because it causes minimum loss of nutrients as compared to other methods [47]. Hence, sample rice from each cultivar was cooked in mini rice cooker. The texture of cooked rice was apparently soft and sticky for all ten cultivars suggests high percentage amylopectin and low amylose content [48]. However, the maximum aroma was assessed from cooked rice over the three locations in Chinigura and the range varied from 8.64-9.00. The cultivar Kataribhog also showed remarkable aroma in cooked rice taken from Dinajpur (8.30) and it was significantly higher than that of Nilphamari and Faridpur. The potential of Radhunipagol for the character was same at Dinajpur and Nilphamari but significantly higher than that of Faridpur. Other cultivars were not appeared as outstanding for aroma production irrespective of locations. These findings would provide a guideline for selection from the available cultivars for overall as well as specific environment [49].

What may be aroma content, the cultivars exhibited stable performance in regard to sensitiveness and stability over three environments are presented (Table 4 and Fig. 2).

Table 2. Means of growth, yield attributes and yield of native rice landraces of Bangladesh

Cultivars	Plant height (cm)			Productive tillers/hill(no.)			1000-grain weight (g)			Days to maturity(no.)			Grain yield/m^2(g)		
	Dinajpur	Nilphamari	Faridpur	Dinajpur	Nilphamari	Faridpur	Dinajpur	Nilphamari	Faridpur	Dinajpur	Nilphamari	Faridpur	Dinajpur	Nilphamari	Faridpur
Chinigura	140.75 d	137.88 de	135.70 e	15.65 a	12.87 ab	10.66 c	11.51 c	11.10 c	11.34 d	142.22 c	140.42 d	139.46 e	300.00 c	295.00 f	173.50 g
Kataribhog	144.53 c	142.89 bc	139.33 de	13.28 b	10.00 c	8.55 d	15.47 a	14.95 a	14.98 a	144.52 bc	142.81 c	137.68 e	350.00 ab	302.75 ce	285.60 cd
Radhunipagol	152.74 a	149.31 ab	149.90 ab	14.44 b	12.12 bc	10.97 c	12.78 b	12.54 b	11.46 d	151.13 a	148.75 a	144.72 bc	390.25 a	385.28 a	281.00 e
Badshabhog	148.06 b	144.29 c	143.58 bc	13.04 b	9.88 c	9.78 cd	13.33 ab	11.17 e	12.32 bc	146.97 b	145.40 b	148.48 a	360.00 ab	352.75 ab	348.00 ab
Kalozira	143.09 c	139.68 de	137.83 ce	13.42 b	10.54 c	8.53 d	13.83 ab	11.65 c	12.62 b	145.5 b	142.71 c	141.98 d	310.00 bc	314.75 bc	299.43 c
Uknimadhu	135.06 e	132.18 f	134.16 ef	16.65 a	14.90 a	12.25 a	12.61 bc	13.88 ab	11.87 bc	146.41 b	143.10 c	144.62 bc	298.25 d	297.75 c-f	284.25 cd
Dudshagor	139.08 de	135.66 ce	133.86 f	13.91 b	12.05 bc	11.03 c	12.26 bc	11.20 d	11.90 bc	147.25 ab	145.00 b	145.57 b	325.5 bc	321.5 b	315.60 bc
Salna	144.35 c	142.15 c	140.25 d	13.4 b	11.12 c	10.49 c	13.87 ab	12.75 b	11.99 bc	146.25 b	144.36 bc	143.64 bc	223.75 e	204.25 ef	191.00 f
Shitabhog	142.62 c	138.71 de	135.67 e	16.55 a	12.04 bc	11.76 bc	12.54 b	11.12 b	11.04 d	146.68 b	144.65 bc	141.21 d	310.25 bc	300.75 c	291.50 ce
Zirashail	138.41 de	135.37 e	136.62 e	12.71 b-c	10.05 c	8.32 d	13.15 a	14.15 a	12.40 bc	145.18 b	144.20 bc	140.82 d	312.50 bc	304.5 c	297.75 c
CV	9.35	9.02	8.84	12.73	12.44	11.85	6.83	7.19	6.70	9.85	9.70	10.00	13.50	14.03	13.85
LSD (0.05)	2.25	2.10	2.30	1.20	1.26	1.23	0.80	0.76	0.74	3.45	3.70	3.90	10.25	10.10	9.95

The mean values having same letter (s) did not significantly differ at 5% level of probability

Table 3. Estimation of proline, aroma in fresh leaves and cooked rice in native rice landraces of Bangladesh

Cultivars	Proline(µ mol/g)			Aroma in fresh leaves			Aroma in cooked rice		
	Dinajpur	Nilphamari	Faridpur	Dinajpur	Nilphamari	Faridpur	Dinajpur	Nilphamari	Faridpur
Chinigura	18.75 a	16.05 a	15.39 ab	8.75 a	8.20 a	7.89 a	9.00 a	9.05 a	8.64 a
Kataribhog	17.00 a	15.92 ab	14.79 b	7.63 ab	6.92 bc	6.77 c	8.90 a	8.16 b	7.05 b
Radhunipagol	16.89 a	14.07 b	12.78 cd	7.53 b	6.96 bc	6.76 c	8.75 ab	8.13 cd	7.29 b
Badshabhog	15.90 ab	12.19 d	11.88 de	7.41 bc	7.18 a	7.05 ab	7.00 c	6.92 e	6.28 c
Kalozira	15.90 ab	14.28 b	14.00 b	7.19 b-d	6.85 bc	6.65 c	8.85 ab	7.92 cd	6.93 bc
Uknimadhu	14.85 b	13.67 c	12.80 cd	6.97 fg	6.55 c	6.28 ef	5.27 ef	4.30g	4.00 f
Dudhshar	10.54 e	9.87 ef	9.02 ef	7.19 b-d	6.85 bc	6.57 cd	5.54 e	5.60 f	4.28 e
Salna	9.75 e	10.75 e	8.70 f	7.16 e	6.52 c	6.39 e	6.20 d	6.15 ef	5.88 d
Shitabhog	8.68 e	9.69 ef	10.06 e	6.86 g	6.24 d	6.18 f	3.84 g	3.40 h	3.00 g
Zirashail	13.47 c	12.60 d	12.01 cd	7.19 b-d	6.75 ab	6.52 c	5.22 f	5.10 ef	4.90 d-f

Table 4. Response and stability parameters of native rice landraces of Bangladesh

Cultivars (Place of collection)	Item	Plant height (cm)	Productive tillers/hill (no.)	1000-grain weight (g)	Grain yield/hill (g)	Days to maturity (no.)	Proline (µ mol/g)	Aroma in fresh leaves	Aroma in cooked rice
Chinigura	bi	0.41	4.12	0.83	0.90	0.73	0.81	0.84	0.91
	s^2di	0.90	-2.51	0.58	5.25	0.40	0.09	0.12	0.10
Kataribhog	bi	0.62	0.64	0.33	1.41	0.36	0.93	0.91	0.93
	s^2di	0.24	0.73	0.20	0.69	0.54	0.07	0.09	0.11
Radhunipagol	bi	0.29	0.84	0.02	0.87	0.93	0.90	0.97	0.96
	s^2di	4.88	0.90	0.87	1.03	3.86	0.11	0.13	0.11
Badshabhog	bi	0.22	0.28	0.85	1.38	0.74	0.98	1.08	1.05
	s^2di	0.25	-0.25	0.46	0.40	2.97	0.07	0.13	0.11
Kalozira	bi	0.10	0.88	0.52	0.92	0.88	0.87	0.92	0.95
	s^2di	0.65	0.07	0.41	0.16	0.86	0.12	0.08	0.05
Uknimadhu	bi	0.45	0.09	0.80	0.59	0.27	0.95	0.92	0.94
	s^2di	0.13	0.17	0.61	0.08	0.42	0.10	0.12	0.10
Dudshar	bi	0.75	0.23	0.63	0.70	0.85	0.86	0.90	0.89
	s^2di	0.62	0.02	0.27	0.13	0.10	0.12	0.11	0.15
Salna	bi	0.58	0.92	0.38	1.11	0.61	1.03	1.01	1.04
	s^2di	0.39	0.13	0.34	0.46	0.39	0.06	0.10	0.11
Shitabhog	bi	0.65	1.50	0.30	0.74	0.14	0.90	0.84	0.88
	s^2di	3.51	0.03	0.21	1.55	2.62	0.11	0.15	0.08
Zirashail	bi	0.90	0.52	0.31	0.28	0.57	0.89	0.88	0.90
	s^2di	0.10	0.39	0.75	0.65	0.33	0.12	0.15	0.09

None of the cultivars resulted extreme deviation from unit regression coefficient and deviation from the corresponding coefficient. The results suggested that grain yield potential of a cultivar is not influencing factor for aroma content, rather itself is a quality character in domestic fine rice cultivars. Therefore, farmers should be critical in accepting cultivar that may not be comparably outstanding in yield but also in aroma content and cooking quality [50]. Moreover, the deviation from respective regression confident from zero was very negligible, therefore, the aroma content in cooked rice was least sensitive to locations which indicated that aroma content in cooked rice may not be improved through changing the locations.
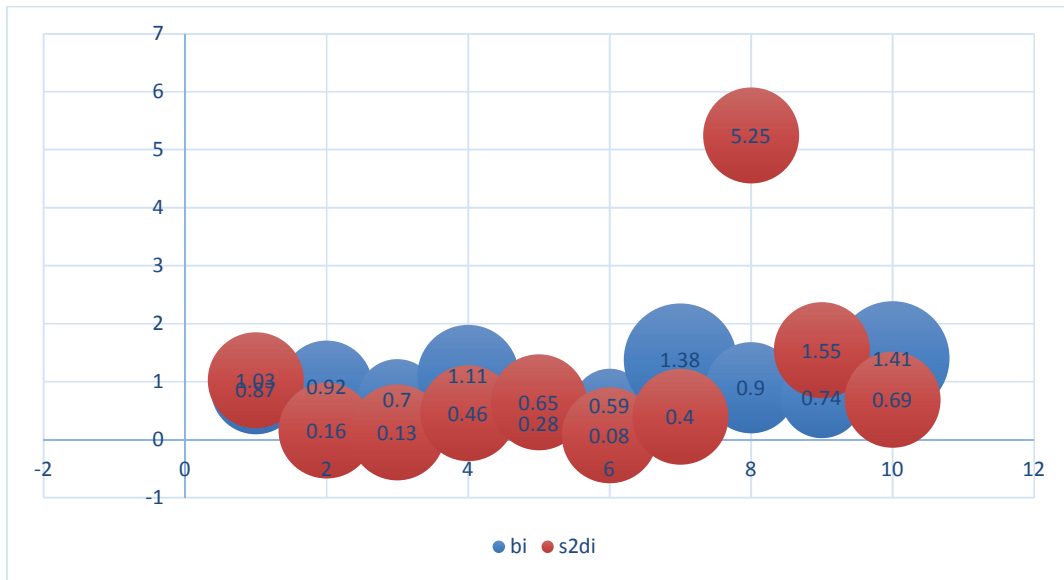
Fig. 1. Distribution of regression coefficient (bi) and deviation from regression (s^2di) in relation to grain yield/m^2
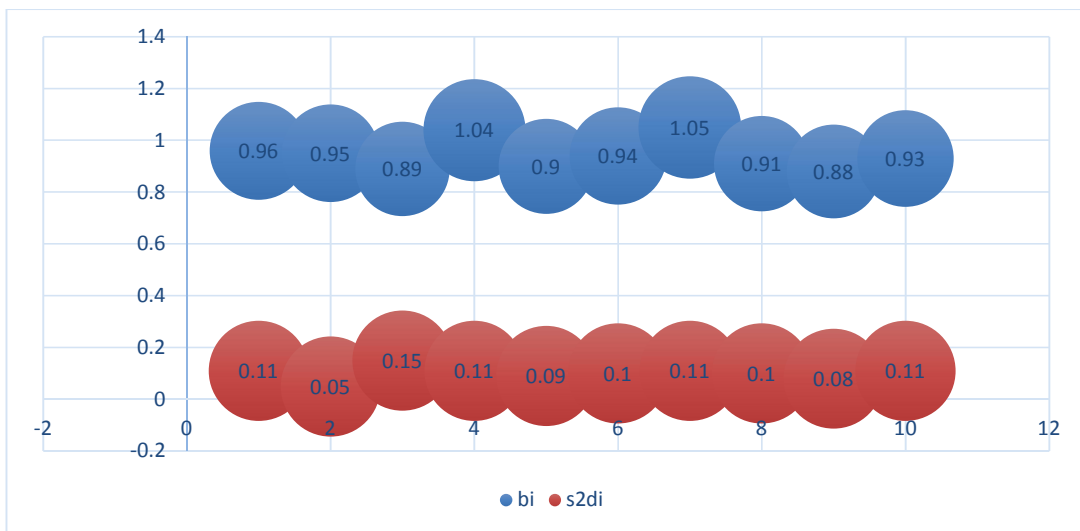
Fig. 2. Distribution of regression coefficient (bi) and deviation from regression (s^2di) in relation to aroma content in cooked rice

4. CONCLUSION

The farmers of Bangladesh are cultivating traditional fine rice cultivars of low yielding and the potential of the land races are mostly location specific, therefore, there is an urgent need to identify the suitable cultivars at least with above average yield and aroma content obtained over the locations, which would fulfil the demand of the farmers for want of superior fine rice cultivars. The growing season of these cultivars are almost rainfed, so farmers merely apply supplementary irrigation into crop fields. If a cultivar showed considerable yield with high aroma would be more beneficial to the farmers because of high market price as compared to coarse rice. In light of the above scenario it may be resolved that aromatic rice cultivars were low yield potential and high aroma content was observed at Dinajpur region whereas, these characters couldn't be improved only through changing the locations. The cultivars, Chinigura, Kataribhog and Radhunipagol were most adaptable to Dinajpur conditions; Kalozira with average aroma content may be recommended to cultivate across the three locations however, Badshabhog suitable for cultivation in both Dinajpur and Nilphamari conditions. Therefore, the cultivars Chinigura, Kataribhog, Radhunipagol, Kalozira and Badshabhog might forward for cultivation at specific locations of Bangladesh.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Lu BR. Diversity of rice genetic resources and its utilization and conservation. Chinese Biodiv. 1998;1:63–72.
2. Rana MK, Bhat KV. A comparison of AFLP and RAPD markers for genetic diversity and cultivar identification in cotton. J. Pl. Biochem. Biotech. 2004;13:19-24.
3. Cornelious BK, Sneller CH. Yield and molecular diversity of soybean lines derived from crosses of Northern and Southern elite parents. Crop Sci. 2002;42: 642-647.
4. Woodworth CM. Breeding for yield in crop plants. J. American Soc. Agron. 1978;23: 388-395.
5. Franke OH. Analytical yield investigation on New Zealand wheat. II. Five years' analytical variety trials. J. Agric. Sci. Canberra. 1935;25:466-509.
6. Adams MW. Basis of yield components compensation in crop plants with special reference to the field bean, *Phaseolus vulgaris*. Crop Sci. 1967;7:505-510.
7. Falconer DS, Mackay TFC. Introduction to quantitative genetics. 4. Ed. London: Longman. 1996;464.
8. Resende MDV. Genética Quantitativa e de Populações. Suprema, Visconde do Rio Branco; 2015.
9. Robertson A. The sampling variance of the genetic correlation coefficient. Biometrics. 1959;15:469-485.
10. Resende MDV. Matemática e estatística na análise de experimentos e no melhoramento genético. Embrapa Florestas, Colombo. 2007;561.
11. Eeuwijk FA, Bustos-Korts DV, Malosetti M. What should students in plant breeding know about the statistical aspects of genotype x environment interactions? Crop Sci. 2016;56(5):2119-2140.
12. Eberhart ST, Russell WA. Stability parameters for comparing varieties 1. Crop Sci. 1966;6(1):36-40.
13. Horna JD, Smale Ma, Von Oppen M. Farmer willingness to pay for seed-related information: Rice varieties in Nigeria and Benin. Washington DC. International Food Policy Research Institute (IFPRI), EPT Discussion. 2005;142.
14. Nanda SJ. Rice breeding and genetics. Science Publishers, New York, USA; 2000.
15. Bergman CJ, Bhattcharya K, Ohtsubo K. Rice end-use quality analysis. In: Champagne, E.T. (Ed.). Rice Chemistry and Technology. American Association of Cereal Chemists C, St. Paul, Minnesota, USA. 2004;24-26.
16. Bates LS, Waldren RP, Teare ID. Rapid determination of free proline for water-stress studies. Pl. Soil. 1973;39(1):205-207.
17. Sood BC, Siddiq EA. A rapid technique for scent determination in rice [India]. Indian J. Genet. Pl. Breed. 1978;38(2):268-271.
18. Hien NL, Yoshihashi T, Sarhadi WA, Hirata Y. Sensory test for aroma and quantitative analysis of 2-acetyl-1-pyrroline in Asian aromatic rice varieties. Pl. Product. Sci. 2006;9(3):294-297.
19. Shrestha S, Asch F, Dusserre J, Ramanantsoanirina A, Brueck H. Climate effects on yield components as affected by genotypic responses to variable

environmental conditions in upland rice systems at different altitudes. Field Crops Res. 2012;134:216–228.

20. Kang MS. Simultaneous selection for yield and stability in crop performance trials: Consequences for growers. Agron. J. 1993;85:754–757.

21. Tariku S, Taddesse L, Bitew M, Asfaw M. Genotype by environment interaction and grain yield stability analysis of rice (*Oryza sativa* L.) genotypes evaluated in North Western Ethiopia. Net. J. Agric. Sci. 2013;1:10–16.

22. Islam M, Sarke MRA, Sharma N, Rahman MA, Collard BCY, Gregorio GB, et al. Assessment of adaptability of recently released salt tolerant rice varieties in coastal regions of South Bangladesh. Field Crops Res. 2015;190:34–43.

23. Balakrishnan D, Subrahmanyam D, Badri J, Raju AK, Rao YV, Beerelli K, Babu VR. Genotype x environment interactions of yield traits in backcross introgression lines derived from *Oryza sativa* cv. Swarna/ *Oryza nivara*. Front. Pl. Sci. 2016;7:1530.

24. Hegde S, Vidyachandra B. Yield stability analysis of rice hybrids. Int. Rice Res. Notes. 1998;23:1-4.

25. Mc Laren CG, Wade LJ. G x E interaction in yield components and their relationship with phenology drought tolerance and grain yield in rainfed lowland rice. In Souvenir on the Rainfed Lowland Drought Workshop. Int. Rice Research Institute, Manila, Philippines. 2000;5.

26. Kishore K, Singh NK, Kumar N, Thakur R. Genotype x environment interaction and stability analysis for grain yields some associated traits in boro rice. Oryza. 2002;39:12-14.

27. Nayak AR, Chaudhary D, Reddy JN. Stability analysis for yield and yield components in scented rice. Oryza. 2003;40:1-4.

28. Arumugam M, Rajanna MP, Vidyachandra B. Stability of rice genotypes for yield and yield components over extended dates of sowing under Cauvery command area in Karnataka. Oryza. 2007;44:104-107.

29. Panwar LL, Joshi VN, Mashiat Ali. Genotype x environment interaction in scented rice. Oryza. 2008;45:103-109.

30. Sreedhar S, Dayakar Reddy T, Ramesha MS. Genotype X environment interaction and stability for yield and its components in hybrid rice cultivars (*Oryza sativa* L.). Int. J. Pl. Breed. Genet. 2011;5:194-208.

31. Swapna K, Vanisree S, Raju CS, Sreedhar M. Genotype× environment interaction and stability for yield and quality characters in rice (*Oryza sativa* L.). Madras Agril. J. 2014;101(1/3):21-27.

32. Falconer DS, Mackey TFC. Introduction to quantitative genetics, 4ᵗʰ Edn. Harlow: Addison-Wesley Longman; 1996.

33. Gauch GH, Zobel RW. "AMMI analysis of yield trials," in genotype by environment interaction. Eds M. S. Kang and H. G. Gauch (Boca Raton, FL: CRC Press). 1996;85–122.

34. Cooper M, Rajatasereekul S, Immark S, Fukai S, Basnayake J. Rainfed lowland rice breeding strategies for northeast Thailand. I. Genotypic variation and genotype × environment interactions for grain yield. Field Crops Res. 1999;64:131–151.

35. Wade LJ, McLaren CG, Quintana L, Harnpichitvitaya D, Rajatasereekul S, Sarawgi AK. Genotype by environment interactions across diverse rainfed lowland rice environments. Field Crops Res. 1999;64:35–50.

36. Ouk M, Basnayake J, Tsubo M, Fukai S, Fischer KS, Kang S. Genotype-by-environment interactions for grain yield associated with water availability at flowering in rainfed lowland rice. Field Crops Res. 2007;101:145–154.

37. Anandan A, Eswaran R, Sabesan T, Prakash M. Additive main effects and multiplicative interactions analysis of yield performances in rice genotypes under coastal saline environments. Adv. Biol. Res. 2009;3:43–47.

38. Kumar A, Verulkar SB, Mandal NP, Variar M, Shukla VD, Dwivedi JL, et al. High-yielding, drought-tolerant, stable rice genotypes for the shallow rainfed lowland drought-prone ecosystem. Field Crops Res. 2012;133:37–47.

39. Liang S, Ren G, Liu J, Zhao X, Zhou M, McNeil D, et al. Genotype-by-environment interaction is important for grain yield in irrigated lowland rice. Field Crops Res. 2015;180:90–99.

40. Katsura K, Tsujimoto Y, Oda M, Matsushima K, Inusah B, Dogbe W, et al. Genotype-by-environment interaction analysis of rice (*Oryza* spp.) yield in a flood plain ecosystem in West Africa. European J. Agron. 2016;73:152–159.

41. Yoshihashi T, Huong NTT, Inatomi H. Precursors of 2-acetyl-1-pyrroline, a potent

flavor compound of an aromatic rice variety. J. Agril. Food Chem. 2002;50(7): 2001-2004.

42. Bradbury LM. Identification of the gene responsible for fragrance in rice and characterization of the enzyme transcribed from this gene and its homologs. Southern Cross University ePublications@SCU; 2009.

43. Hare PD, Cress WA, Van Staden J. Dissecting the roles of osmolyte accumulation during stress. Pl. Cell Environ. 1998;21:535–53.

44. Naidu BP, Paleg LG, Aspinall D, Jennings AC, Jones GP. Amino acid and glycine betaine accumulation in cold-stressed wheat seedlings. Phytochem. 1991;30: 407–9.

45. Simonelli C, Galassi L, Cormegna M, Bianchi P. Chemical, physical, textural and sensory evaluation on Italian rice varieties. Universal J. Agril. Res. 2017;5(2):104-112.

46. Jamuna P. Physico-chemical and cooking properties of selected rice varieties. Acta Scit. Nutri. Health 3.3. 2019;23-30.

47. Sagum R, Arcot J. Effect of domestic processing methods on the starch, non-starch polysaccharides and *in vitro* starch and protein digestibility of three varieties of rice with varying levels of amylose. Food Chem. 2000;70:107-111.

48. Chrastil J. Protein-starch interactions in rice grains. Influence of storage onoryzenin and starch. J. Agril. Food Chem. 1992;38:1804-1809.

49. Yanjie X, Yining Y, Shuhong O, Xiaoliang D, Hui S, Shukun J, Shichen S, Jinsong B. Factors affecting sensory quality of cooked Japonica rice. J. Rice Sci. 2018;25(6):330-339.

50. Shamim F, Raza MA, Akhtar M. Grain quality attributes of new rice basmati lines of Pakistan. J. Appl. Agric. Biotech. 2017;2(1):37-47.