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Morphometric characterization of seeds of Deep Water Rice varieties of Assam

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Abstract
The significance of rice in Assam is recognized by every individual living here. The dietary carbohydrate requirement of the population is met primarily by rice. However, many districts of Assam such as Lakhimpur are heavily affected by flood during the monsoon season due to which the fields are submerged with water. During this period, conventional rice varieties cannot withstand the water stress and thus cannot be cultivated successfully. Therefore, local farmers of highly flood affected areas cultivate Deep Water Rice varieties during this season. DWR serves as an alternate crop for the farm dependent inhabitants of the district. DWR varieties not only display an incredible ability to tolerate and escape submergence caused by flood, they are also found to be enriched with various nutrients, vitamins, minerals as well as antioxidants. The present study focuses on the characterization of 21 deep water rice landraces based on morphometric parameters that are locally cultivated in Lakhimpur district of Assam. This study will inculcate plant breeders with necessary information for selecting desired traits in future breeding programmes.
Keywords: Deep water rice, morphometric, characterization

INTRODUCTION

Rice serves as a significant contributor to the global calories demand for human, a vital commodity in international trade, and plays an essential role in ensuring food security (Tolba et al., 2020). Rice cultivation is the third most significant agricultural commodity produced, following sugarcane and maize. It serves as the primary source of dietary energy for 17 nations in Asia and the Pacific, 9 nations in North and South America, and 8 nations in Africa (Rathna et al., 2019). Approximately 90% of the global rice supply, amounting to nearly 640 million tons, is sourced from Asia, with China and India being the primary contributors. These varieties are suited to varied climatic conditions and can thrive in both arid and aquatic environments across a range of altitudes. In Bhutan and Nepal, rice cultivation is possible at elevations exceeding 300 meters above sea level, while in India (specifically Kerala), it can be grown at 3 m below sea level (Khush, 1984). Globally, *Oryza glaberrima* (Steudel) and *Oryza sativa* (L.) are widely grown rice species (Fahad et al., 2019). India ranks second in rice production, following China (Rathna et al., 2019).

Rice exhibits a vast genetic diversity, with thousands of varieties cultivated globally, and India currently boasts 6,000 of these varieties. Historically, India had over 110,000 rice varieties prior to 1970, but many were lost during the Green Revolution, which prioritized monoculture and hybrid crops. Rice comes in various colors, such as brown, red, purple, and black, and these colorful varieties are regarded as beneficial for health (Rathna et al., 2019). The various rice varieties cultivated in distinct areas of the North Eastern Region of India represent significant genetic resources that could be beneficial for future crop enhancement (Hore, 2005; Sarma and Pattanayak, 2009; Das and Ghosh, 2010). Understanding the physical characteristics of seeds is crucial for the development of agricultural machinery and equipment used in planting, harvesting, processing, packaging, and storage (Bashar et al., 2014). The capacity to differentiate and accurately identify the various cultivated species is essential for the operational elements of the seed trade.

North Lakhimpur district, situated in Assam, India, is located within the Northern bank plain zone of the North Eastern region of Assam, lying between latitudes 26°48' and 27°53' N, and longitudes 93°42' and 94°20' E with an average elevation of 101 m (331 ft) above sea level. On an average, Lakhimpur receives 2,850 mm of rainfall each year, which frequently leads to significant flooding of the tributaries originating from Arunachal Pradesh, often resulting in the submersion and consequent damage to sali rice (winter rice). The agricultural practices in Lakhimpur and its surrounding districts are marked by monocropping, subsistence farming, and a system characterized by low inputs and low outputs. Since Lakhimpur district faces heavy rainfall during the monsoon season, many regions of the district suffer from floods which stands as a major constraints for farm families. Rice is the staple food for the inhabitants of Lakhimpur, people are highly dependent on the production of rice. In the period of 2009-2010, Lakhimpur experienced crop damage spanning 21,241 hectares as a result of flooding, which impacted 68,901 farming households (Sharma, 2013). To address the challenges posed by flooding during the monsoon season and to sustain the local population, deep water rice varieties are cultivated in several regions of the district.

In Assam among the locals, deep water rice is known as Bao Dhan. Significant rice cultivation regions in the state are predominantly low-lying, where only bao dhan rice, which is capable of surviving submersion in water depths of 3 to 4 meters, can be cultivated. This type of rice can endure water stagnation exceeding 50 cm for over a month during the growing season. In flooded conditions, DWR can reach a height of up to 2 m. During the early vegetative phase, specifically 4 to 6 weeks post-germination, the plant's height increases significantly in reaction to the rising flood water levels. Conversely, in the late vegetative phase, the rate of elongation gradually slows down. The maximum daily growth can reach 25 cm, although this is contingent upon both the water level and the specific genotype of the DWR. Most DWR varieties exhibit red kernels, which may result from varying levels of anthocyanin accumulation in both the starchy endosperm and the aleurone layer. Typically, the mature seed features a long awn. Apart from their flood tolerance and antioxidant property, the seeds of the varieties possess various nutrients, minerals, vitamins as well. Although Bao rice varieties are recognized for their high mineral content, their yield remains relatively low, ranging from 1.6 to 3 tons per hectare.

Physical seed characters such as seed size, shape are based on the length, breadth, thickness, length to breadth ratio etc. These physical characteristics are important aspects for consumers along with their cooking properties. To meet the increasing human demand, certain key attributes, including ease of harvest, high yield, and low toxicity, are prioritized in the selection process. The presence of awns, which is considered a disadvantage during harvesting and processing, has been specifically addressed by selection programs (Ishii and Ishikawa, 2018). Some of the wild DWR varieties are reported to have awn. The purpose of this study is to analyze and quantify the physical morphometric characteristics of twenty one deep water rice or Bao dhan varieties such as seed length, seed breadth, seed length to breadth ratio and based on these parameters the seeds can be categorized and the shape of the seeds can be determined, as well as seed colour and the presence (along with their length) or absence of awn are important attribute for commercialization of any rice variety.

MATERIALS AND METHODS

Collection of plant sample

The present study was carried out for twenty one deep water rice varieties that were collected from local farmers of Lakhimpur District of Assam, India. The rice seed samples were kept in paper bags at ambient temperature until they were needed for further use. All the morphometric analysis were carried out in the Department of Botany, North Lakhimpur College (Autonomous), Lakhimpur, Assam. Each experiment was performed under controlled laboratory conditions with five replicates to ensure accuracy, and the resulting data were documented for subsequent analysis.

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MORPHOMETRIC CHARACTERIZATION

Seed length

Length of the seeds were measured in millimeters (mm) using a centimeter scale. The measurement of the distance from the base of the lowermost sterile lemma to the tip of the lemma or palea was considered for measuring the length of rice seed (Singh et al., 2005; Rehman et al., 2021). The classification approach established by Rosta in 1975 was employed to categorize varieties according to seed length. The varieties were classified into the following categories based on seed length: very short (< 6), short (6.1-8.5), medium (8.6-10.5), long (> 12.5), and very long (> 10.0).

Seed breadth

The seed width was determined by measuring the distance between the lemma and the palea at their broadest point using a centimeter scale, with the average seed width expressed in millimeters (mm) (Singh et al., 2005; Rehman et al., 2021). Ramaiah and Rao (1953) classified the varieties according to the average seed width into the following categories: very narrow (< 2), narrow (2.1-2.5), medium (2.6-3.0), broad (3.1-3.5), and very broad (> 3.5).

Seed thickness

The thickness of the seed was measured in millimeters and represented as the height of the seed when placed in a horizontal position.

Seed Length/Breadth ratio

The L/B ratio was calculated by dividing the length by the breadth of each seed.

Seed size

The seed size was determined in cubic millimeters (mm^3) using the formula based on its length (L), width (W), and thickness (T) as follows:
Seed size (mm^3) = $(L \times W \times T)^{(1/3)}$

Seed awn

The length of awn (if present) was measured in mm using a centimeter scale.

Results

The experiments were carried out using a fully randomized design, and the results were expressed as average or mean, based on five replicates from each rice variety collected throughout the study period.

Seed length

In the present study, the seeds of Jalpriya bao and Borehha bao were found to be the longest *i.e.* 10.6 mm whereas the seeds of Kola Bao were found to be the shortest *i.e.* 6.5 mm among all the twenty one deep water varieties. Regarding the seed category based on length, the longest seeds *i.e.* seeds of Jalpriya and Borehha falls under 'very long' category whereas the shortest seed *i.e.* the seeds of Kola bao falls under 'short' category.

Seed breadth

Significant variation in breadth was noted. Maguri Bao has the broadest seeds with 4 mm breadth followed by Kola Bao which measured 3.7 mm in width whereas Biroi has the narrowest seeds with a width of 2.4 mm.

Table 1: Seed length and breadth of DWR and their respective seed categories

Sl. No.	DWR	Length (mm)					Average	Seed category (based on length)	Breadth (mm)					Average	Seed category (Based on width)
		R1	R2	R3	R4	R5			R1	R2	R3	R4	R5		
1	Kola Bao	7	7	6	6	6.5	6.5	short	3.5	3.5	3.5	4	4	3.7	very broad
2	Jalpriya	11	11	11	10	10	10.6	very long	2.5	2.5	2.5	2.5	2.5	2.5	narrow
3	Sonjul	8	7.5	7.5	7.5	7.5	7.6	short	3.5	3	3	3.5	3	3.2	broad
4	Maguri	8	8	7	8	7	7.6	short	4	4	4	4	4	4	very broad
5	Palia	9	9	8	8	8	8.4	short	2.5	2.5	2.5	2.5	2.5	2.5	narrow
6	Ikora	10	11	10	10	9	10	medium	3	2.5	3	2.5	2.5	2.7	medium
7	Tulsi	7	7.5	7	7	7	7.1	short	3	3	3	3	3	3	medium
8	Dubori	9	8.5	9	8	8	8.5	short	3	3	3	3	3	3	medium
9	Ramdulari	9.5	9	9	8.5	8.5	8.9	medium	2.5	2.5	2.5	2.5	2.5	2.5	narrow
10	Rangadhar kekowa	8	8	7.5	7	7	7.5	short	3	3	3	3	3	3	medium
11	Adoliya	8.5	8.5	8	8	8	8.2	short	3	3	3	3	3	3	medium
12	Panchanan	8.5	8	8	8	8	8.1	short	3	2.5	2.5	2.5	2.5	2.6	medium
13	Mirem	8.5	8	8	8	8.5	8.2	short	3.5	3	3	3	3	3.1	broad
14	Borehha	11	11	10	11	10	10.6	very long	2.5	2.5	2.5	2.5	2.5	2.5	narrow
15	Boola	8	8	8	7	7.5	7.7	short	3	3.5	3	3.5	3.5	3.3	broad
16	Negheri	7	7	7.5	7.5	7	7.2	short	3	3.5	3	3	3	3.1	broad
17	Amona	7.5	7.5	7.5	7.5	7	7.4	short	3.5	3	3.5	3.5	3	3.3	broad
18	Panikekowa	8	8	7.5	8	7	7.7	short	3	3	3.5	3	3	3.1	broad
19	Biroi	8	8	8	8	7.5	7.9	short	2.5	2.5	2.0	2.5	2.5	2.4	narrow
20	Biria bhonga	7	7	7	7	7	7	short	3.5	3.5	3.5	3	3	3.3	broad

21	Zeng bao	9	9	8	8.5	8.5	8.6	medium	3	3	3	3.5	3.5	3.2	broad

Seed thickness

In the current study regarding the thickness of DWR seeds it was observed that, the values ranged from 2 mm to 2.5 mm. Out of the 21 DWR varieties, 11 has a mean thickness of 2 mm whereas, Maguri Bao has the highest thickness *i.e.* 2.5 mm.

Seed length to breadth ratio

The ratio of grain length to its width is a crucial factor that defines a significant characteristic of rice, which is referred to as grain shape. In this study, it was seen that the seeds of Jalpriya Bao and Borehha Bao recorded the highest length to breadth ratio *i.e.* 4.2 having an elongated shape whereas Kola Bao has the lowest length to breadth ratio which is 1.8 with spherical shaped seeds. The varieties were categorized based on their grain length to width ratio into four shapes, *viz.* semi-spherical (6), spherical (2), semi-long (6), and elongated (7).

Table 2: Seed thickness and length to breadth ratio of DWR and their respective shapes based on L/B ratio

Sl. No.	DWR	Thickness (mm)					Average	Length Breadth ratio (L/B)	Seed shape (based on l/w)
		R1	R2	R3	R4	R5			
1	Kola Bao	2.5	2	2.5	2.5	2.5	2.4	1.8	spherical
2	Jalpriya	2	2	2	2	2	2	4.2	elongated
3	Sonjul	2	2	2	2	2	2	2.4	semi-spherical
4	Maguri	2.5	2.5	2.5	2.5	2.5	2.5	1.9	spherical
5	Palia	2	2	2	2	2	2	3.4	elongated
6	Ikora	2	2	2	2	2	2	3.7	elongated
7	Tulsi	2	2.5	2	2	2.5	2.2	2.4	semi-spherical
8	Dubori	2.5	2	2	2	2	2.1	2.8	semi-long
9	Ramdulari	2	2	2	2	2	2	3.6	elongated
10	Rangadhar kekowa	2	2	2	2	2	2	2.5	semi-long
11	Adoliya	2	2	2.5	2	2	2.1	2.7	semi-long
12	Panchanan	2	2	2	2	2	2	3.1	elongated
13	Mirem	2.5	2	2.5	2	2.5	2.3	2.6	semi-long
14	Borehha	2	2	2	2	2	2	4.2	elongated
15	Boola	2.5	2	2.5	2	2.5	2.3	2.3	semi-spherical
16	Negheri	2	2	2	2	2	2	2.3	semi-spherical
17	Amona	2	2	2	2	2.5	2.1	2.2	semi-spherical
18	Panikekowa	2	2	2	2	2	2	2.5	semi-long
19	Biroi	2	2	2	2	2	2	3.3	elongated
20	Biria bhonga	2.5	2.5	2	2.5	2.5	2.4	2.1	semi-spherical
21	Zeng bao	2.5	2	2	2	2.5	2.2	2.7	semi-long

Seed awn

Out of the twenty one DWR varieties, seeds of only seven varieties were found to possess awn, of which the longest awn were recorded in Panikekowa with a mean awn length of 43.4 mm and the shortest awn were found to be in Biria bhonga seeds with a mean awn length of 23.8 mm.

Table 3: Presence or absence of awn in DWR seeds and length of Awn (if present)

Sl no.	DWR varieties	Seed colour	Awn length (if present) (mm)					Average (mm)
			R1	R2	R3	R4	R5	
1	Kola Bao	Slightly dark brown	35	34	31	31	29	32
2	Jalpriya	Golden	-	-	-	-	-	-
3	Sonjul	Brown	-	-	-	-	-	-
4	Maguri	Brown	-	-	-	-	-	-
5	Palia	Bronze	-	-	-	-	-	-
6	Ikora	Pale yellow	-	-	-	-	-	-
7	Tulsi	Dark brown	-	-	-	-	-	-
8	Dubori	Brown	-	-	-	-	-	-
9	Ramdulari	Straw	-	-	-	-	-	-
10	Rangadhar kekowa	Slightly dark brown	40	32	27	20	18	27.4
11	Adoliya	Golden	-	-	-	-	-	-
12	Panchanan	Brown	-	-	-	-	-	-
13	Mirem	Brown	-	-	-	-	-	-
14	Borehha	Bronze	-	-	-	-	-	-
15	Boola	Brown	41	42	33	31	24	34.2
16	Negheri	Brown	45	43	29	20	15	30.4
17	Amona	Brown	-	-	-	-	-	-
18	Panikekowa	Brown	71	52	41	31	23	43.6
19	Biroi	Straw	-	-	-	-	-	-
20	Biria bhonga	Brown	27	26	26	21	19	23.8
21	Zeng bao	Bronze	39	29	31	29	22	30

Sl. No.	DWR varieties	Length	Breadth	L:B	Thickness	Size (mm^3)
1	Kola Bao	6.5	3.7	1.8	2.4	19.2
2	Jalpriya	10.6	2.5	4.2	2	17.6
3	Sonjul	7.6	3.2	2.4	2	16.2
4	Maguri	7.6	4	1.9	2.5	19.3
5	Palia	8.4	2.5	3.4	2	14
6	Ikora	10	2.7	3.7	2	18
7	Tulsi	7.1	3	2.4	2.2	15.6
8	Dubori	8.5	3	2.8	2.1	17.9
9	Ramdulari	8.9	2.5	3.6	2	14.8
10	Rangadhar kekowa	7.5	3	2.5	2	15

11	Adoliya	8.2	3	2.7	2.1	17.2
12	Panchanan	8.1	2.6	3.1	2	14
13	Mirem	8.2	3.1	2.6	2.3	19.5
14	Borehha	10.6	2.5	4.2	2	17.7
15	Boola	7.7	3.3	2.3	2.3	19.5
16	Negheri	7.2	3.1	2.3	2	14.9
17	Amona	7.4	3.3	2.2	2.1	17.1
18	Panikekowa	7.7	3.1	2.5	2	15.9
19	Biroi	7.9	2.4	3.3	2	12.6
20	Biria bhonga	7	3.3	2.1	2.4	18.5
21	Zeng bao	8.6	3.2	2.7	2.2	20.2

Fig 1. Heat map (prepared in Microsoft Excel) displaying the mean values of the morphometric characteristics of seeds of 21 DWR varieties (colour gradation is from darkest to lightest representing lowest value to darkest value)

DISCUSSION

Morphometric attributes such as length, width, shape and size of seed plays an indispensable role in evaluating the quality and yield of rice. It has been reported that morphological characters are used to distinguish rice varieties (Bhattacharya and Sowbhagya, 1980; Rajanna et al., 2011) and the yield of rice depends upon these characters like seed length and length to width ratio (Li et al., 2019). After conducting the comparative analysis on the morphometric parameters, a significant variation was seen among the deep water rice varieties. The physical parameters were evaluated in terms of seed length, breadth, thickness, length to breadth ratio, presence or absence of awn. In the present study, the overall length of the seeds ranged from 6.5 mm in Kola Bao to 10.6 mm in Jalpriya bao and Borehha bao. Based on the seed length, majority of DWR seeds (16) fall under short category. In case of breadth of the seeds, the measurements ranged from 2.4 mm in Biroi to 4 mm in Maguri Bao. The data on the thickness of DWR seeds revealed that out of 21 varieties, 11 exhibited an average thickness of 2 mm, while Maguri Bao seeds recorded to have the maximum thickness of 2.5 mm. Length to breadth ratio help to determine the shape of seeds. Therefore, based on the L/B ratio, 6 semi-spherical, 2 spherical, 6 semi-long, and 7 elongated seeds were categorized. Hence the most common shape was found to be elongated seed shape. Regarding awn, only 7 varieties were found to possess awn. Amongst them, Panikekowa has the longest awn of a mean awn length of 43.4 mm. The colour of the seed coats are generally brown.

CONCLUSION

From the perspective of consumers' preferences and aversions, as well as for achieving success in the market and trade, physical parameters are essential. The physical attributes collectively influence the cost of rice and consequently its market value, as well as consumer preferences. Therefore, proper cataloguing of local landraces of rice is very important. The growing demand of the increasing population and climate changing threats are major challenges that humankind has to face in the near future. Rice being the staple food of Assam is highly susceptible to flood, hence new alternatives in farming is now imperative. Lakhimpur district and the peripheral regions are prone to floods during monsoon season. Therefore, during this time of the year, local farmers opt for cultivating flood tolerant rice varieties such as Bao dhan, that serves as a sustenance for them. Although deep water rice varieties are endowed with high nutritional values as well as antioxidants, the yield of the local varieties is reported to be lower than conventional rice breeds. Thus, besides nutritive properties, study on the physical properties of these seed varieties is also crucial for identification of desirable seed qualities and incorporating them in breeding programs or biofortification of rice varieties.

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