



## Characterization of boro rice (*Oryza sativa* L.) varieties of Assam (India) based on their morphological traits

Mehzabin Rehman, Sabnoor Yeasrin Jyoti, Amit Kumar Pradhan, Preetom Regon, Bhaben Tanti\*

Plant Molecular Biology Laboratory, Department of Botany, Gauhati University, Guwahati, Assam, India

### Abstract

In Assam, boro rice is generally cultivated during November/December to May/June. It is grown in low-lying, water-logged areas with high residual moisture. One of the major problems faced by rice cultivation in Assam is flood leading to large scale destruction of the crop during monsoon. Cultivation of boro rice during the dry season in this area is preferable to meet the growing requirement of food by the increasing population. Therefore, a study was undertaken to evaluate the morphometric characteristics of 46 boro rice varieties collected from different agro-climatic zones of Assam. The result of this investigation revealed significant values of different morphometric parameters of the boro varieties which signify the good quality of rice seeds and kernels. A positive correlation of seed size was found at 0.05 level with seed length ( $r=0.591^*$ ), seed width ( $r = 0.671^*$ ) and seed thickness ( $r = 0.743^*$ ). The kernel thickness and kernel length to width ratio ( $r=0.619^*$ ) also showed a significant positive correlation at  $P<0.05$  level. Thus, characterization of boro rice is a necessary step for future breeding programmes along with providing breeders with sufficient information in selecting relevant traits.

**Keywords:** boro rice (*Oryza sativa* L.), morphometric characterization, correlation coefficient

### Introduction

Rice (*Oryza sativa* L.) cultivation is carried out across all the continents of the world. However, Asia holds the highest position in rice cultivation. China, India, Indonesia, Bangladesh, Philippines, Vietnam, Thailand, and Myanmar are known for large scale production of rice which covers almost 80% of the rice cultivating areas (Prasad *et al* 2017) [1]. Rice is associated with cultural identities of many countries in the world. In Indian rice holds a sacred place in different social and cultural practices. Apart from the cultural value, rice has a great importance in world's economy. According to Food and Agriculture Organization (FAO), rice contributes an amount of 500.5 million metric ton in total global cereal production, during months of April to June in 2015. The contribution of India in case of rice export is also huge. In 2014 the contribution of India towards global rice export was 32% which brought the country into the top ten rice exporters of the globe (Workman 2015; Prasad *et al* 2017) [2, 1]. There are five rice growing regions in India namely, eastern region, north-eastern region, northern region, southern region and the western region. Assam lies in the north-eastern region, which is an important contributor of rice towards the economy of India. Almost 70% of the total cultivable lands in Assam are used in rice cultivation (Singh *et al* 2003) [3]. The favorable agro-climatic and physiographic conditions make this region a wonderful place for rice cultivation in different time period or seasons throughout the year which *viz.*, Ahu (Feb /March - June /July), Sali (June /July - Nov /December) and Boro (Nov /December -May /June) (Ahmed *et al* 2011; Rehman and Tanti 2021) [4, 5].

Based on the growing season and high capability of moisture retention, Boro rice (the summer rice) has a remarkable and significant place in the rice cultivation scenario of Assam.

Boro rice (*O. sativa* L.) is a rabi season crop which is generally cultivated from November to May in the eastern states of India like Assam, West-Bengal and Eastern Uttar Pradesh (Lal *et al* 2013) [6]. The boro rice varieties are sown in winter in the low-lying, water-logged areas and harvested during the early summer. In this period flood is not observed in Assam which serves to be the major problem of the state especially in different "char" areas and is responsible for the destruction of hundreds of hectares of crop. Because of this unique feature boro rice can be considered as the ideal crop for growing in the areas affected by flood and prevailing in the submerged conditions during the monsoon. Every year flood causes severe devastations all over Assam which leads to a remarkable destruction of the arable areas. As a consequence the production and the yield of rice are reduced. As per the record, a total of about 47.9 thousand hectares cultivable land falls under chronically flood prone areas (Gogoi and Bordoloi 2011) [7]. Generally the problem of flood arises in the monsoon which is characterized by heavy rainfall. During this period, *kharif* crops are planted which makes these crops more susceptible to flood. But the rabi crops are safe from the problem of flood because of their dry growing season. Thus, rabi season indicates a suitable season for cultivation of rice and other crops in Assam. So cultivation of boro rice in this season will increase the yield of rice which has every possibility to contribute to the economy of our country and meet the growing demand of the increasing population (Gogoi and Bordoloi 2011) [7]. The growing season of boro rice experiences different ranges of temperature i.e. a lower temperature in the first growing period and a higher temperature during its harvesting period. Tolerance to a vivid range of temperature is another superior character of boro rice as compared to the rice grown in other seasons. Also this temperature variation helps the boro rice varieties

to accumulate photosynthates (Lal *et al* 2013) [6]. All these characters of boro rice make it an exemplary crop to be employed for future breeding programs for increasing the production of rice.

Nearly half of the world's population is using rice as the staple food. So in addition of high yield, a rice variety with superior quality should possess several other nutritional properties. In today's world, where the lifestyle of people is changing day by day, the health issue is also growing. As a result, the concern regarding a healthy diet is gaining attention throughout the world. Therefore a rice variety of better quality is essential for all the consumers. Rice is a crop possessing diverse nutrient components which has a great importance in improving a country's economic condition (Otegbayo *et al* 2001) [8]. Most of the rice nutrition contains carbohydrate, the main part of which is starch. The rice grains are also high in proteins which possess a higher concentration of lysine (4%). It is also a moderate source of fat and vitamin B-complexes. In addition to these minerals like calcium, phosphorus, magnesium are also obtained in this crop with a trace of copper, zinc, manganese and iron (Oko *et al* 2011; Verma 2017) [9, 10]. Rice supplies more than one-fifth of the calories consumed by the people around the world, 40-80% of which contribute to the diet of Asian people. (Smith 1998; Paramita *et al* 2002; Singh *et al* 2005; Hossain *et al* 2009) [11, 12, 13, 14]. In addition to the nutritional characteristics, the selection preference of rice often depends on various

physical, morphological and functional properties. Morphometric characters such as the length, width and thickness of grain or kernels influence the physical properties including the properties of the milling and the recovery of head rice. Generally, majority of the consumers prefer well-milled white rice with no bran layer, but the choices vary depending upon the place and requirements of the diet (Lyon *et al* 1999) [15]. Besides physical characteristics, morphometric characteristics also affect the genetic diversity of rice plants (Lahkar *et al* 2018) [16]. These characteristics collectively affect the price of rice and hence the commercial value alongwith customer taste. Therefore, in light of the above mentioned views a study was undertaken to estimate the morphometric characters of 46 boro rice varieties of Assam, India.

## Materials and Methods

### Collection of plant sample

The present study was carried out with 46 boro rice varieties collected from different agro-climatic zones across the state Assam, India. The rice samples were stored in paper bags at room temperature until further use. Each experiment was conducted with five replicates in laboratory condition for authentication and the data obtained were recorded for further evaluation. Table 1 shows the names of collected 46 boro rice varieties, their laboratory assigned codes, sites of collection, latitude, longitude and their respective elevation above sea level.

**Table 1:** Collected boro rice varieties, laboratory assigned codes, collection sites alongwith their latitudes and longitudes and their respective altitudes

Sl. No.	Lab assigned codes	Rice varieties	Site of collection	Latitude	Longitude	Altitude (m)
1	PMB/BT/R212	China Boro	Kamrup	26°15'15"N	91°33'51"E	43
2	PMB/BT/R213	N.K. Paddy	Nagaon	26°21'42"N	92°38'38"E	63
3	PMB/BT/R214	15 No. Aijung	Nagaon	26°21'42"N	92°38'38"E	63
4	PMB/BT/R215	Local Sarno Masuri	Nagaon	26°21'55"N	92°47'39"E	75
5	PMB/BT/R216	Swarnabh	Nagaon	26°21'42"N	92°38'38"E	63
6	PMB/BT/R217	Laal bihari	Morigaon	26°07'45"N	92°12'02"E	60
7	PMB/BT/R218	Laal paan	Nagaon	26°21'42"N	92°38'38"E	63
8	PMB/BT/R219	Bihari	Lakhimpur	27°18'41"N	94°27'24"E	93
9	PMB/BT/R220	Rampur boro	Nagaon	26°21'42"N	92°38'38"E	63
10	PMB/BT/R221	Jagli boro	Nagaon	26°21'42"N	92°38'38"E	63
11	PMB/BT/R222	Sarno masuri	Nagaon	26°21'55"N	92°47'39"E	75
12	PMB/BT/R177	No. 29	Morigaon	26°07'45"N	92°12'02"E	60
13	PMB/BT/R223	Ukhov aijong	Nagaon	26°21'42"N	92°38'38"E	63
14	PMB/BT/R225	V1	Nagaon	26°21'42"N	92°38'38"E	63
15	PMB/BT/R261	V2	Nagaon	26°21'42"N	92°38'38"E	63
16	PMB/BT/R262	Dinanath	Nagaon	26°21'42"N	92°38'38"E	63
17	PMB/BT/R228	Majuli boro	Majuli	26°58'24"N	94°08'44"E	84
18	PMB/BT/R229	Biplav	Nagaon	26°21'42"N	92°38'38"E	63
19	PMB/BT/R224	Local boro	Nagaon	26°21'55"N	92°47'39"E	75
20	PMB/BT/R226	Kola joha	Nagaon	26°21'42"N	92°38'38"E	63
21	PMB/BT/R232	DRH	Nagaon	26°21'55"N	92°47'39"E	75
22	PMB/BT/R227	Lal ganga	Dhubri	26°12'35"N	89°51'58"E	36
23	PMB/BT/R234	Dhubri boro	Dhubri	26°01'29"N	89°53'10"E	30
24	PMB/BT/R235	Buro	Cachar	24°49'52"N	92°47'57"E	24
25	PMB/BT/R236	Nagarbera I	Kamrup	26°21'42"N	90°58'44"E	43
26	PMB/BT/R237	Nagarbera II	Kamrup	26°21'42"N	90°58'44"E	43
27	PMB/BT/R230	Hybrid boro	Cachar	24°49'52"N	92°47'57"E	24
28	PMB/BT/R231	Artis	Karimgangj	24°51'55"N	92°21'30"E	18
29	PMB/BT/R233	Chatla boro	Karimgangj	24°51'55"N	92°21'30"E	18
30	PMB/BT/R238	Suna Muchuri	Nagaon	26°21'55"N	92°47'39"E	75
31	PMB/BT/R239	Mala	Cachar	24°49'52"N	92°47'57"E	24
32	PMB/BT/R243	Narayan	Karimgangj	24°51'55"N	92°21'30"E	18
33	PMB/BT/R240	Nayanmoni	Karimgangj	24°51'55"N	92°21'30"E	18
34	PMB/BT/R245	Bina	Hailakandi	24°35'54"N	92°35'06"E	103

35	PMB/BT/R246	Chhihattar	Karimgangj	24°51'55"N	92°21'30"E	18
36	PMB/BT/R247	Bosi	Hailakandi	24°35'54"N	92°35'06"E	103
37	PMB/BT/R242	Paan dhan	Nagaon	26°21'55"N	92°47'39"E	75
38	PMB/BT/R249	Moricha	Cachar	24°49'52"N	92°47'57"E	24
39	PMB/BT/R244	Barak aijong	Cachar	24°49'52"N	92°47'57"E	24
40	PMB/BT/R241	8 no. eri	Cachar	24°49'52"N	92°47'57"E	24
41	PMB/BT/R248	Kokuwa	Nagaon	26°21'12"N	92°40'46"E	68
42	PMB/BT/R250	Basful	Cachar	24°49'52"N	92°47'57"E	24
43	PMB/BT/R251	Heera	Cachar	24°49'52"N	92°47'57"E	24
44	PMB/BT/R255	Luit	Nagaon	26°15'15"N	91°33'51"E	43
45	PMB/BT/R256	Kolong	Nagaon	26°15'15"N	91°33'51"E	44
46	PMB/BT/R257	Disang	Nagaon	26°15'15"N	91°33'51"E	45

## Morphometric Characterization

### Seed length

The distance between the base of the lowermost sterile lemma to the tip of the lemma or palea was measured in millimeter (mm) using a centimeter scale. The method of Rosta (1975) <sup>[17]</sup> was used to categorize varieties based on seed length. The varieties were categorized based on seed length as follows: Very short (< 6), short (6.1-8.5), medium (8.6-10.5), long (> 12.5) and very long (> 10.0).

### Seed width

The distance between the lemma and the palea (the broadest point) was measured using a centimeter scale, and the mean of seed width was represented in mm. The varieties were classified by Ramaiah and Rao (1953) <sup>[18]</sup> based on the mean seed width: 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

Seed thickness was measured in mm and given as the height of the seed when positioned horizontally. The seed's profile value is also calculated using the thickness.

### Seed size

Based on length (L), width (W) and thickness (T) the seed size was calculated using formula as below:

$$\text{Seed size (mm}^3\text{)} = (L \times W \times T)^{1/3}$$

### Seed length to width ratio

Length to width ratio of the *boro* rice varieties were determined by simply dividing the length value by seed width. Based on this ratio, the shape of rice seeds were grouped into different categories following the method of Rosta (1975) <sup>[17]</sup> i.e. Spherical (< 2.0), semi-spherical (2.0-2.4), semi-long (2.4-3.0) and elongated (> 3.0).

### Seed grade

Five different grades were assigned to each rice varieties based on their average length-width ratio (Ramaiah Committee 1969) <sup>[19]</sup>: Long slender (Length > 6.00mm, L/B > 3.0), short slender (Length 6.00mm, L/B > 3.0), long bold (L > 6.00mm, L/B 3.0), medium slender (L 6.00mm, L/B > 3.0).

### Kernel length

The lemma and palea of seeds were dehulled carefully and the length was taken from the base to the tip of the kernel and expressed in mm. Based on the mean length, varieties were classified into four categories according to Rosta (1975) <sup>[17]</sup>: Short (< 7.5), medium (7.5-9.0), long (9.0-10.0), very long (> 10.0).

### Kernel width

The lemma and palea of the grain were removed carefully and the width was measured across the seed at the widest point and expressed in mm.

### Kernel length to width ratio

Kernel length to width ratio was determined similarly as seed. The shape of the dehusked grain was determined based on the mean dehusked grain length to width ratio and the varieties were classified into four groups according to Rosta (1975) <sup>[17]</sup>: Spherical < 2.0, semi-spherical (2.0-2.4), semi-long (2.4-3.0), elongated (> 3.0).

### Seed and kernel colour

The colour of the husk was recorded under day light condition. The kernel colour was determined using RHS colour chart (2015) and FAN number was assigned.

### Statistical Analysis

The experiments were conducted in a completely randomized design and results were calculated as mean  $\pm$  SE with five replicates from each rice variety taken during the study period. Pearson's correlation coefficient analysis was conducted using the Microsoft Excel data sets and statistical significance was considered for *p* values <0.05 (Shandilya and Tanti 2019) <sup>[20]</sup>. Heatmaps were also constructed for the chosen 46 *boro* rice varieties on the basis of the considered morphometric parameters. From the results so generated, hierarchical clustering was performed with ComplexHeatmap package of R (R Core Team, 2013) <sup>[21]</sup>.

## Results

### Morphometric characterization of *boro* rice varieties

The seeds of the *boro* varieties were evaluated for different morphometric characters like length, width, length to width ratio and thickness. Based on these observations, several other properties, such as seed size, shape and grades were determined. The evaluation was based on the method of Rosta (1975) <sup>[17]</sup>, Ramaiah committee (1969) <sup>[19]</sup>; and Raamaiah and Rao (1953) <sup>[18]</sup>. Depending on the types of length, width and length to width ratio, the seeds and kernels were also classified into different categories.

### Characteristics of Rice Seeds

#### Seed length

The length of the grains ranged between 5.6mm in Mala to 10.7mm in Bina (Fig 1). The size of the seeds also varied from very short, short to medium. Mala and Bina were found to show very short and medium sizes respectively. The seeds were categorized according to the method of

Rosta (1975) [17]. 33 boro varieties were placed under medium category, whereas 12 came under short and 1 under

very short category (Table 2).

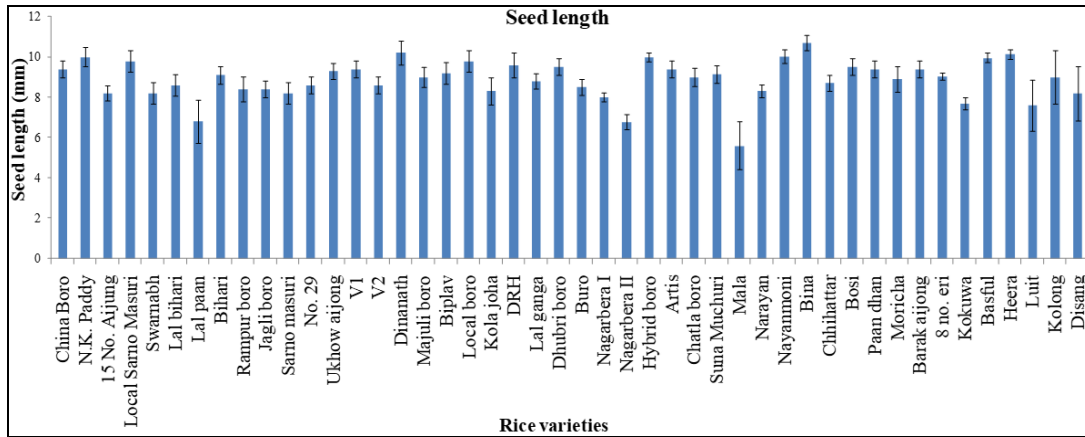


Fig 1: Morphometric characterization of seeds of the boro rice varieties: Seed length

**Seed width**

Among all the varieties the highest width was found to have by Chatla boro (4.54mm) and the lowest was found in Nagarbera II (2.18mm) (Fig 2). Considering the width of

boro varieties, the grains were again categorized into three categories, out of which 39 varieties were placed under very broad category, 6 under broad and 1 variety came under the category narrow (Table 2).

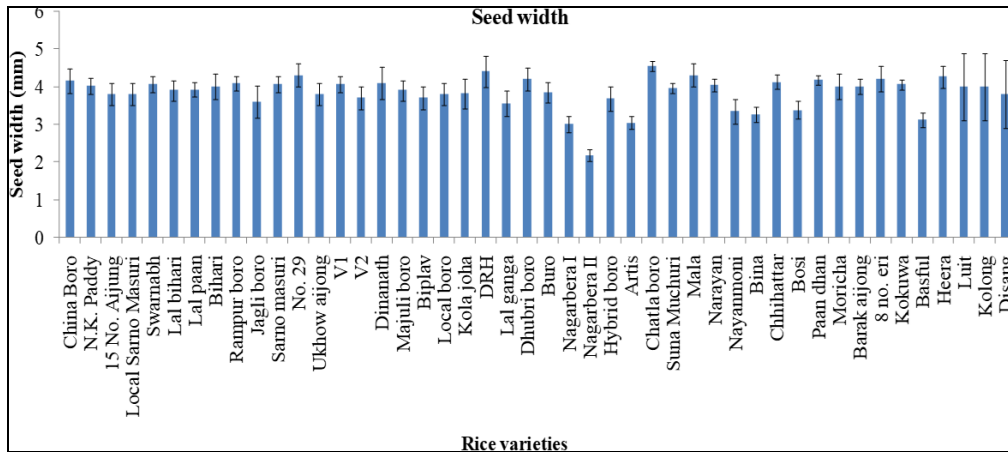


Fig 2: Morphometric characterization of seeds of the boro rice varieties: Seed width

**Seed length to width ratio**

Grain length to width ratio determines an important characteristic of rice, known as grain shape. Bina was recorded to be highest in case of grain length to width ratio (3.28) having an elongated seed shape (Fig 3). On the other hand, Mala was found to have length to width ratio of 1.29 with a spherical shape. The rest of the boro varieties were in between this range. The shape of the varieties on the basis

of grain length to width ratio were classified as semi-spherical (26), spherical (6), semi-long (9) and elongated (5). Considering the length and length to width ratio of the grains, the rice grains were also categorized into different grades. In the present investigation all the boro varieties could be placed in the long slender (3), long bold (42) and short bold (1) categories (Table 2).

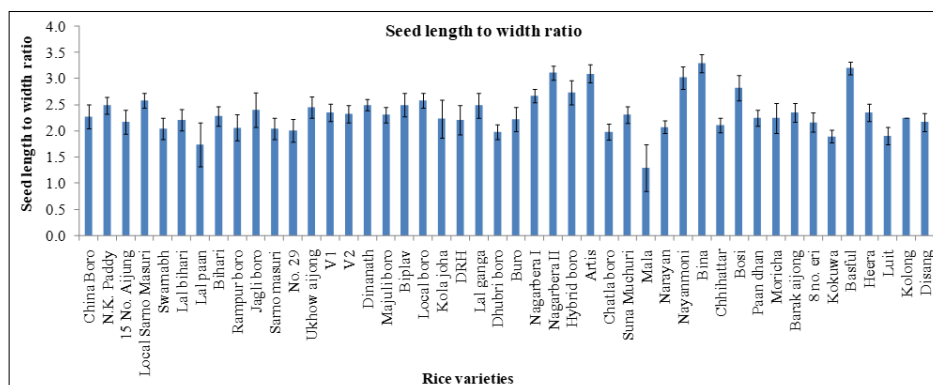
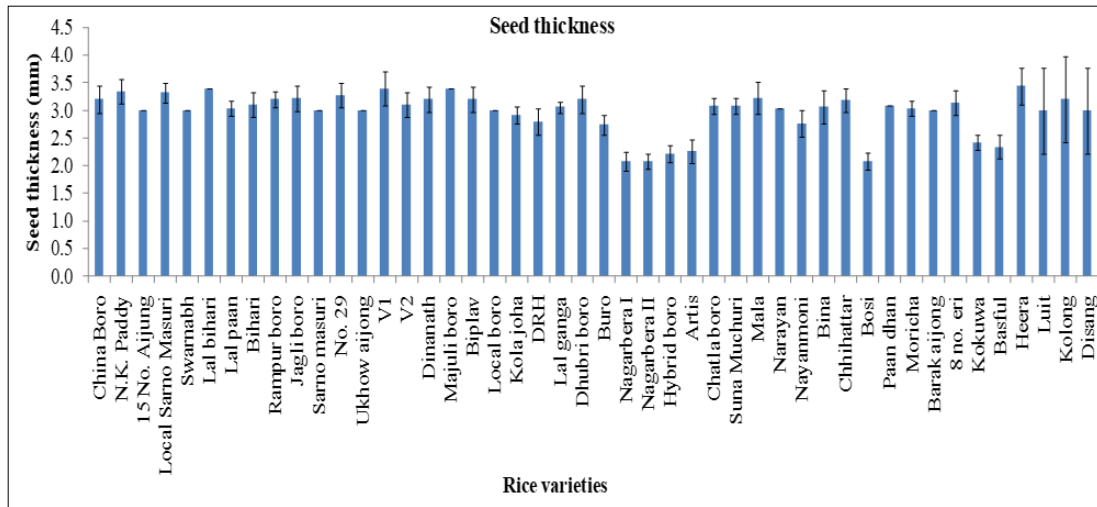


Fig 3: Morphometric characterization of seeds of the boro rice varieties: Seed length to width ratio

**Seed thickness**

Seed thickness of the rice varieties ranged from 2.08 mm in Nagarbera I, Nagarbera II and Bosi to 3.44mm in Heera.

Other varieties were also found to have grain thickness in between this range (Fig 4).

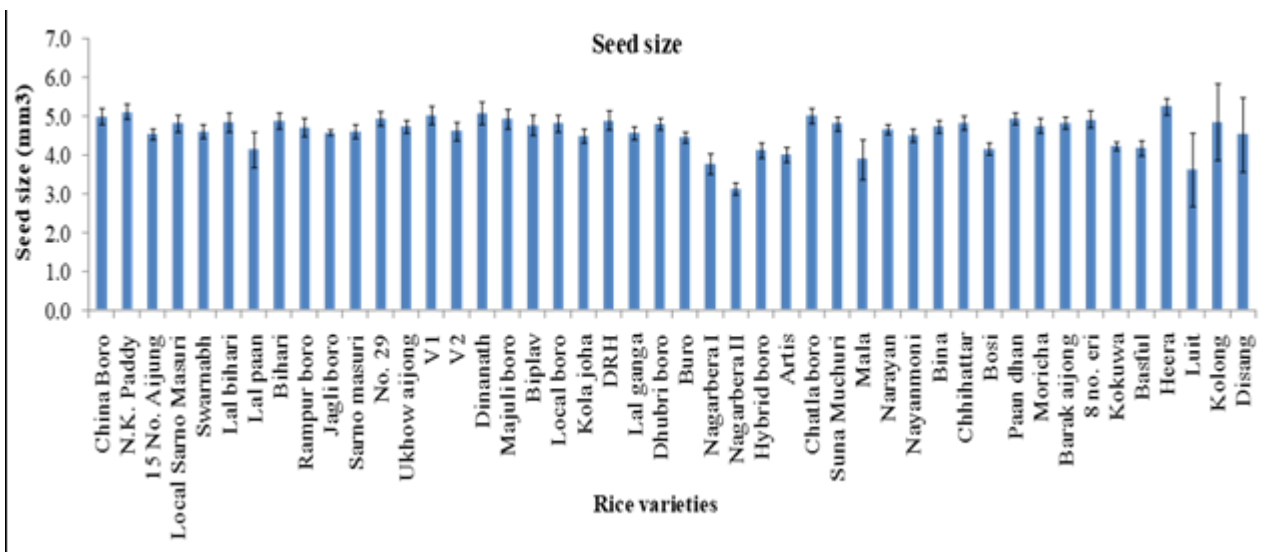


**Fig 4:** Morphometric characterization of seeds of the boro rice varieties: Seed thickness

**Seed size**

Seed size was highest in Heera (5.26 mm<sup>3</sup>), whereas Nagarbera boro

2 showed the lowest value of grain size among all the boro varieties (3.13 mm<sup>3</sup>) (Fig 5).



**Fig 5:** Morphometric characterization of seeds of the boro rice varieties: Seed size

**Table 2:** Collected boro rice varieties alongwith their seed categories based on length and breadth, seed shape and grade

Sl. No.	Rice varieties	Seed category (based on length)	Seed category (Based on width)	Seed shape (based on l/w)	Grade (Based on L and l/w)
1	China Boro	Medium	Very broad	Semi-spherical	Long bold
2	N.K. Paddy	Medium	Very broad	Semi-long	Long bold
3	15 No. Aijung	Short	Very broad	Semi-spherical	Long bold
4	Local Sarno Masuri	Medium	Very broad	Semi-long	Long bold
5	Swarnabh	Short	Very broad	Semi-spherical	Long bold
6	Laal bihari	Medium	Very broad	Semi-spherical	Long bold
7	Laal paan	Short	Very broad	Spherical	Long bold
8	Bihari	Medium	Very broad	Semi spherical	Long bold
9	Rampur boro	Short	Very broad	Semi-spherical	Long bold
10	Jagli boro	Short	Very broad	Semi-long	Long bold
11	Sarno masuri	Short	Very broad	Semi-spherical	Long bold
12	No. 29	Medium	Very broad	Semi-spherical	Long bold
13	Ukhow aijong	Medium	Very broad	Semi-long	Long bold
14	V1	Medium	Very broad	Semi-spherical	Long bold

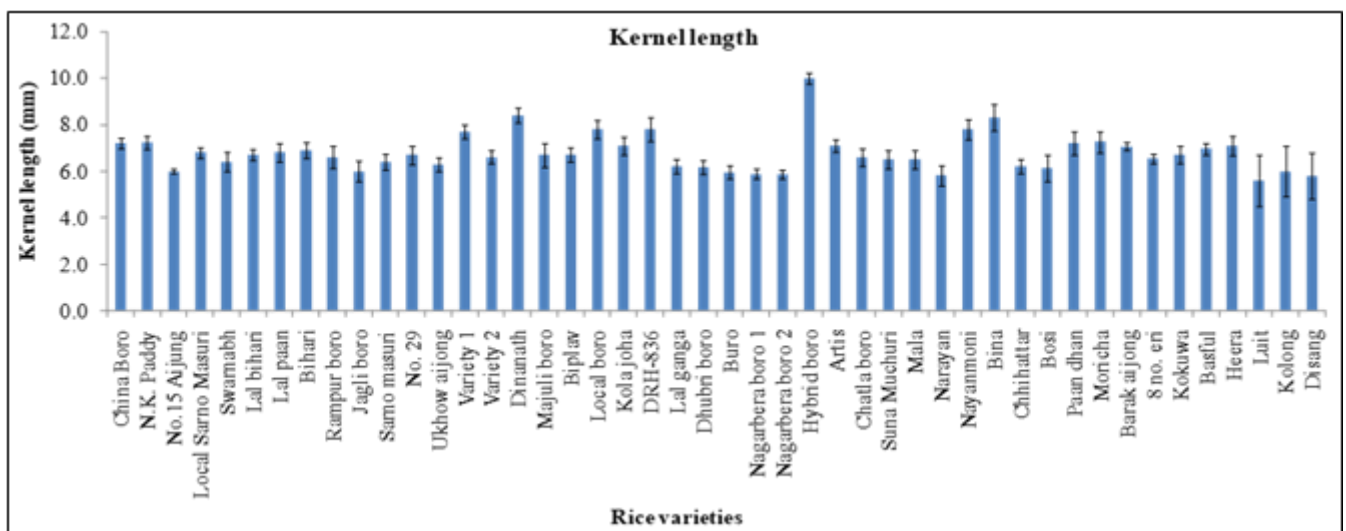
15	V2	Medium	Very broad	Semi-spherical	Long bold
16	Dinanath	Medium	Very broad	Semi-long	Long bold
17	Majuli boro	Medium	Very broad	Semi-spherical	Long bold
18	Biplav	Medium	Very broad	Semi-long	Long bold
19	Local boro	Medium	Very broad	Semi-long	Long bold
20	Kola joha	Short	Very broad	Semi-spherical	Long bold
21	DRH	Medium	Very broad	Semi-spherical	Long bold
22	Lal ganga	Medium	Very broad	Semi-long	Long bold
23	Dhubri boro	Medium	Very broad	Spherical	Long bold
24	Buro	Short	Very broad	Semi-spherical	Long bold
25	Nagarbera I	Short	Broad	Semi-long	Long bold
26	Nagarbera II	Short	Narrow	Elongated	Long bold
27	Hybrid boro	Medium	Very broad	Semi-long	Long bold
28	Artis	Medium	Broad	Elongated	Long slender
29	Chatla boro	Medium	Very broad	Spherical	Long bold
30	Suna Muchuri	Medium	Very broad	Semi-spherical	Long bold
31	Mala	Very short	Very broad	Spherical	Short bold
32	Narayan	Short	Very broad	Semi-spherical	Long bold
33	Nayanmoni	Medium	Broad	Elongated	Long Slender
34	Bina	Medium	Broad	Elongated	Long Slender
35	Chhihattar	Medium	Very broad	Semi-spherical	Long bold
36	Bosi	Medium	Broad	Semi-long	Long bold
37	Paan dhan	Medium	Very broad	Semi-spherical	Long bold
38	Moricha	Medium	Very broad	Semi-spherical	Long bold
39	Barak aijong	Medium	Very broad	Semi-spherical	Long bold
40	8 no. eri	Medium	Very broad	Semi-spherical	Long bold
41	Kokuwa	Short	Very broad	Spherical	Long bold
42	Basful	Medium	Broad	Elongated	Long bold
43	Heera	Medium	Very broad	Semi-spherical	Long bold
44	Luit	Short	Very broad	Semi-spherical	Long bold
45	Kolong	Medium	Very broad	Semi-spherical	Long bold
46	Disang	Short	Very broad	Spherical	Long bold

**Characteristics of kernel**

**Kernel length**

This study showed that the length of the kernels of the boro varieties have a distinct range of variation, but the width of the kernel were found to be present within a more or less same range. The kernels were grouped on the basis of the

kernel length according to the method of Rosta (1975) [17]. Most of the varieties showed short kernels, whereas only a few of them were observed to have medium kernels (Table 3). Kernel length was found highest in Hybrid boro (10mm) and lowest in Luit (5.6 mm) (Fig 6).



**Fig 6:** Morphometric characterization of the kernels of the boro rice varieties: Kernel length

**Kernel width**

The kernel width of all the boro rice varieties was recorded in the range of 2.02 mm (Nagarbera II) to 3.8 mm (China

boro). Others varieties also exhibited more or less similar values (Fig 7).

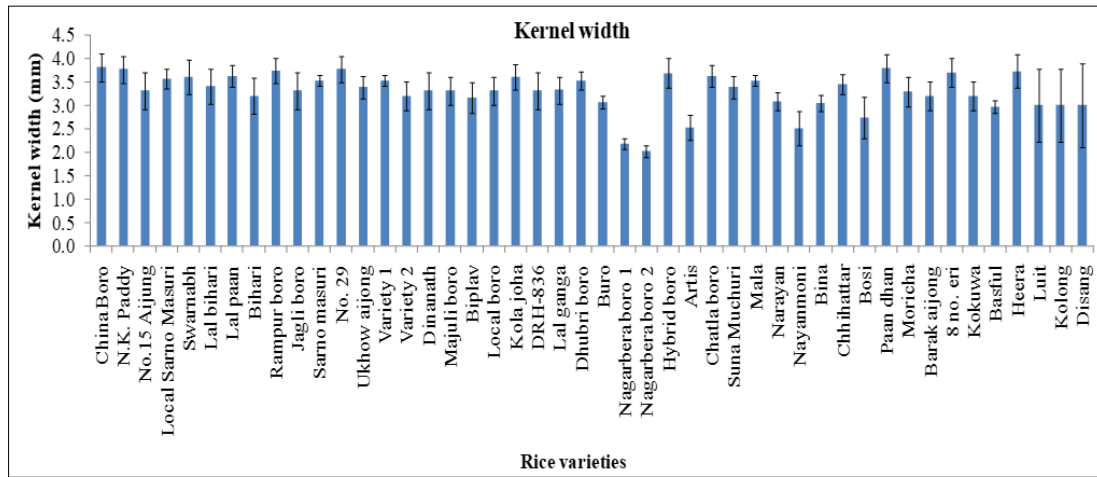


Fig 7: Morphometric characterization of the kernels of the boro rice varieties: Kernel width

**Kernel length to width ratio**

The highest value of length to width ratio was recorded in Nayanmoni (3.21 mm) and the lowest in Hybrid boro (1.10 mm) (Fig 8). The shape of the kernels were categorized as semi-spherical, spherical and elongated groups on the basis

of the ratio between length and width of the kernels following the method of Rosta (1975) [17]. Among the 46 varieties, only Nayanmoni exhibited elongated kernels. Rest of the varieties was found to be of spherical (24), semi-spherical (17) and semi-long (4) categories (Table 3).

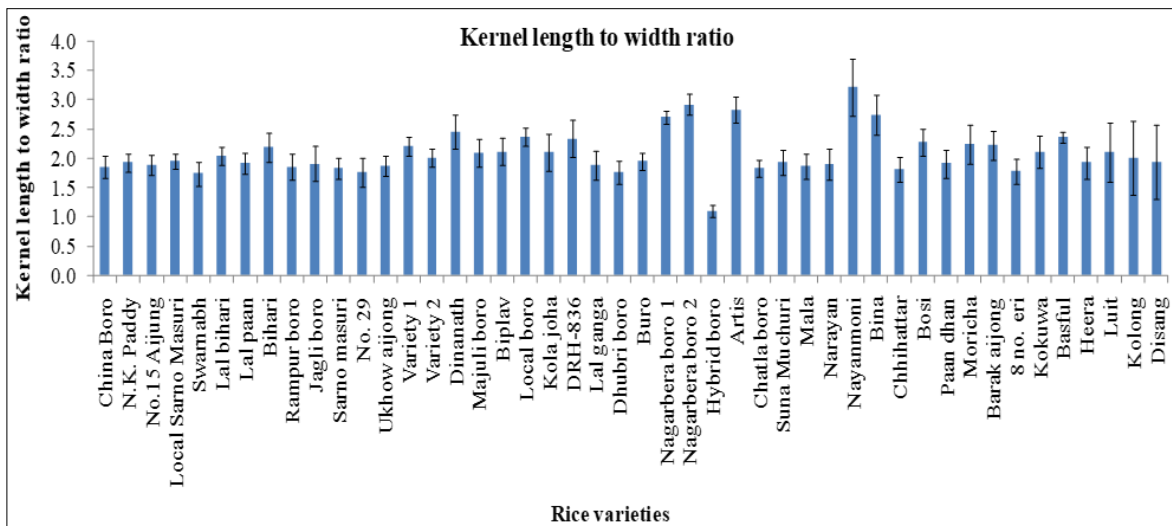


Fig 8: Morphometric characterization of the kernels of the boro rice varieties: Kernel length to width ratio

**Kernel thickness**

A distinct variation was found in case of kernel thickness. The lowest value was recorded from Swarnabh (1.74),

whereas the highest was recorded from Naynamoni (3.21 mm). All other varieties were found in between this range (Fig. 9).

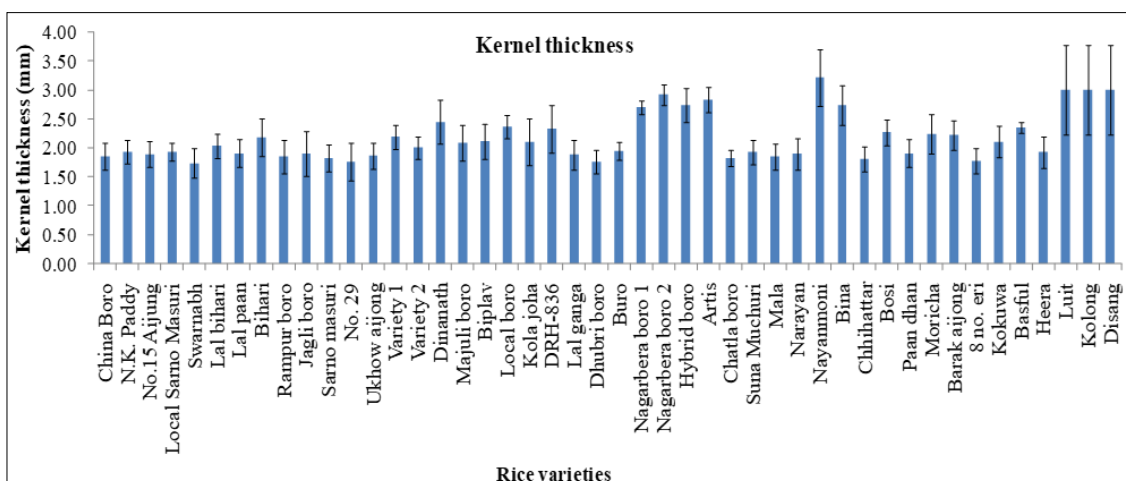


Fig 9: Morphometric characterization of kernels of the boro rice varieties: Kernel width

**Table 3:** Collected boro rice varieties and their respective kernel length type and shape

Sl. No.	Rice variety	Kernel length type	Kernel shape
1	China Boro	Short	Spherical
2	N.K. Paddy	Short	Spherical
3	15 No. Aijung	Short	Spherical
4	Local Sarno Masuri	Short	Spherical
5	Swarnabh	Short	Spherical
6	Laal bihari	Short	Semi-spherical
7	Laal paan	Short	Spherical
8	Bihari	Short	Semi-spherical
9	Rampur boro	Short	Spherical
10	Jagli boro	Short	Spherical
11	Sarno masuri	Short	Spherical
12	No. 29	Short	Spherical
13	Ukhow aijong	Short	Spherical
14	V1	Medium	Semi-spherical
15	V2	Short	Semi-spherical
16	Dinanath	Medium	Semi-spherical
17	Majuli boro	Short	Semi-spherical
18	Biplav	Short	Semi-spherical
19	Local boro	Medium	Semi-spherical
20	Kola joha	Short	Semi-spherical
21	DRH	Medium	Semi-spherical
22	Lal ganga	Short	Spherical
23	Dhubri boro	Short	Spherical
24	Buro	Short	Spherical
25	Nagarbera I	Short	Semi-long
26	Nagarbera II	Short	Semi-long
27	Hybrid boro	Long	Spherical
28	Artis	Short	Semi-long
29	Chatla boro	Short	Spherical
30	Suna Muchuri	Short	Spherical
31	Mala	Short	Spherical
32	Narayan	Short	Spherical
33	Nayanmoni	Medium	Elongated
34	Bina	Medium	Semi-long
35	Chhihattar	Short	Spherical
36	Bosi	Short	Semi-spherical
37	Paan dhan	Short	Spherical
38	Moricha	Short	Semi-spherical
39	Barak aijong	Short	Semi-spherical
40	8 no. eri	Short	Spherical
41	Kokuwa	Short	Semi-spherical
42	Basful	Short	Semi-spherical
43	Heera	Short	Spherical
44	Luit	Short	Semi-spherical
45	Kolong	Short	Semi-spherical
46	Disang	Short	Spherical

### Seed coat and kernel colour

The seed coat colour of the 46 boro varieties were evaluated and could be categorized into different categories- yellow seed coat (5 varieties), pale yellow (9 varieties), yellowish brown seed coat (8 varieties), flaxen yellow with black shades (1 variety), black(1 variety), light brownish yellow (1 variety), brownish yellow (2 varieties), yellow with black shade (1 variety), greyish yellow (1 variety), greyish brown (1 variety), dark greyish brown (1 variety), light brown (1 variety), dark brown (1 variety) and light brownish yellow (1 variety), dark greyish reddish brown (1 variety), strong brown (1 variety), pale brown (1 variety), moderate yellow (4 varieties), yellowish grey (1 variety), moderate brown (1

variety), light brownish grey (1 variety) and golden (2 varieties) (Table 4).

On the other hand, it was found that 12 varieties exhibited yellowish white (NN155A) kernels, 14 exhibited white (NN155B) kernels, 2 varieties strong brown (172 A), 2 pale yellow (8D), 1 moderate brown (165A), moderate red (N 34C), 1 light greenish grey (202D), 2 vivid reddish orange (N 30) and greenish white (192D). Apart from these colors, the kernel of boro varieties were also exhibited moderate reddish orange (179C), moderate reddish brown (177A), light grey (N200D) and yellowish grey (194C) colors (Table 4).

**Table 4:** Rice varieties and their seed and kernel colour alongwith RHS code and FAN numbers

Sl. No.	Rice variety	Seed coat colour	Kernel colour with RHS code	FAN
1	China Boro	Yellowish brown	White NN 155B	4
2	N.K. Paddy	Yellowish brown	White NN 155B	4
3	15 No. Aijung	Yellow	Yellowish white NN 155A	4
4	Local Sarno Masuri	Yellowish brown	Yellowish white NN 155A	4
5	Swarnabh	Yellow	Yellowish white NN 155A	4
6	Laal bihari	Yellowish brown	Yellowish white NN 155A	4
7	Laal paan	Dark brown	White NN 155B	4
8	Bihari	Light brownish yellow	Yellowish white NN 155A	4
9	Rampur boro	Brownish yellow	Strong brown 172A	4
10	Jagli boro	Yellow with black shade	Strong brown 172A	4
11	Sarno masuri	Yellowish brown	Yellowish white NN 155A	4
12	No. 29	Yellow	Yellowish white NN 155A	4
13	Ukhow aijong	Light brown	Yellowish white NN 155A	4
14	V1	Yellowish brown	White NN 155B	4
15	V2	Yellow	Yellowish white NN 155A	4
16	Dinanath	Yellow	Pale yellow 8D	4
17	Majuli boro	Brownish yellow	Yellowish white NN 155A	4
18	Biplav	Brownish yellow	Yellowish white NN 155A	4
19	Local boro	Flaxen yellow with black strips	Moderate brown 165A	4
20	Kola joha	Black	Light greenish grey 202D	4
21	DRH	Yellowish brown	White NN 155B	4
22	Lal ganga	Dark greyish reddish brown	Greenish white 192D	4
23	Dhubri boro	Greyish yellow	Vivid reddish orange N 30C	1
24	Buro	Greyish brown	Moderate reddish orange 179 C	4
25	Nagarbera I	Dark greyish brown	Moderate reddish brown 177A	4
26	Nagarbera II	Strong brown	Vivid reddish orange N 30C	1
27	Hybrid boro	Pale yellow	Greenish white 192D	4
28	Artis	Pale yellow	Pale yellow green 192 A	4
29	Chatla boro	Pale brown	White NN 155B	4
30	Suna Muchuri	Moderate yellow	White NN 155B	4
31	Mala	Pale yellow	Pale yellow green 192 A	4
32	Narayan	Yellowish grey	Strong reddish orange 31A	1
33	Nayanmoni	Moderate brown	Pale yellow 8D	4
34	Bina	Pale yellow	White NN 155B	4
35	Chhihattar	Pale yellow	Vivid reddish orange N 30C	1
36	Bosi	Pale yellow	White NN 155B	4
37	Paan dhan	Pale yellow	Greenish white 192D	4
38	Moricha	Pale yellow	White NN 155B	4
39	Barak aijong	Moderate yellow	White NN 155B	4
40	8 no. eri	Moderate yellow	White NN 155B	4
41	Kokuwa	Moderate brown	Moderate red N 34C	4
42	Basful	Light brownish grey	White NN 155B	4
43	Heera	Pale yellow	White NN 155B	4
44	Luit	Golden	Yellowish White N 155D	4
45	Kolong	Golden	Light Grey 188D	4
46	Disang	Golden with brown	Yellowish Grey 198C	4

**Pearson's correlation coefficient**

Pearson's correlation coefficients for comparisons between different seed morphometric parameters are shown in Table 5. The results showed significant positive relationships between seed length-length:width ( $r = 0.58$ ;  $P < 0.05$ ); seed length-grain size ( $r = 0.59$ ;  $P < 0.05$ ); seed width-length:width ( $r = -0.77$ ;  $P < 0.05$ ); seed width-grain thickness ( $r = 0.67$ ;  $P < 0.05$ ); seed width-grain size ( $r = 0.67$ ;  $P < 0.05$ ) and seed thickness-grain size ( $r = 0.74$ ) (Table 5). On the other hand, the Pearson's correlation coefficients for kernel morphometrics are tabulated in Table 6. The results showed significant positive relationships between kernel width-length: width ( $r = -0.77$ ;  $P < 0.05$ ); kernel width-kernel thickness ( $r = -0.71$ ;  $P < 0.05$ );

length:width-kernel thickness ( $r = 0.61$ ;  $P < 0.05$ ) (Table 6).

**Table 5:** Pearson's correlation matrix showing correlation among the analyzed morphometric parameters of the seeds in the experimental boro rice varieties

Parameters	Seed length	Seed width	Length:width	Seed thickness	Seed size
Seed length	1				
Seed width	0.035	1			
Length:width	0.587*	-0.776*	1		
Seed thickness	0.100	0.679*	-0.494	1	
Seed size	0.591*	0.671*	-0.173	0.743*	1

Levels of significance: \*\* $P < 0.01$  level (2-tailed); \* $P < 0.05$  level (2-tailed)

**Table 6:** Pearson’s correlation matrix showing correlation among the analyzed morphometric parameters of the kernels in the experimental boro rice varieties

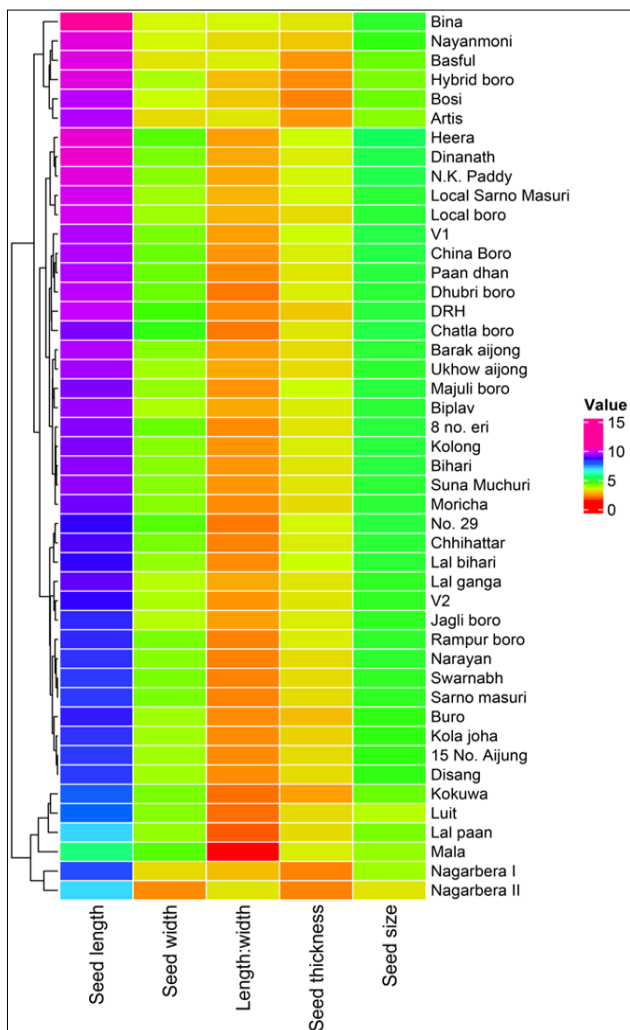
Parameters	Kernel length	Kernel width	Length:width th	Kernel thickness
Kernel length	1			
Kernel width	0.251	1		
Length:width	0.061	-0.770*	1	
Kernel thickness	0.210	-0.713*	0.619*	1

Levels of significance: \*\* $P < 0.01$  level (2-tailed); \* $P < 0.05$  level (2-tailed)

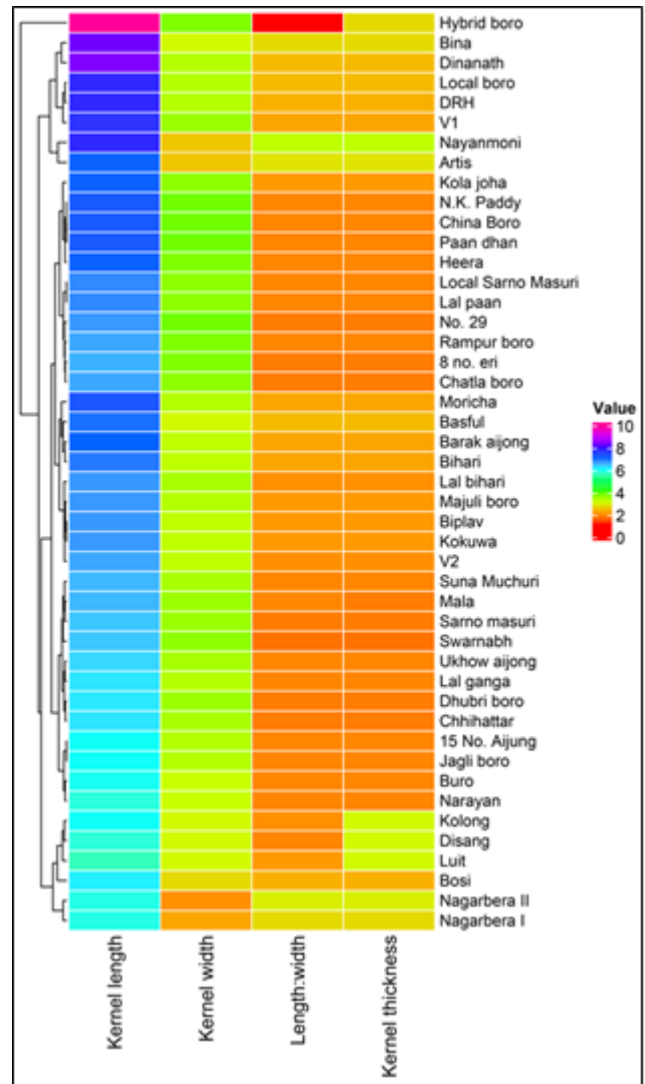
**Hierarchical clustering of morphological parameters**

The heatmap generated for the 46 boro rice varieties based on the considered morphometric parameters revealed that the rice seed characteristics, i.e., seed length, seed width, seed length to width ratio and seed size was highest in Bina, Nayanmoni and Basful. On the contrary, Mala, Nagarbera I and Nagarbera II showed the lowest (Fig 10).

On the other hand, the heatmap generated for the rice kernel characteristics, i.e., kernel length, kernel width, kernel length to width ratio and kernel thickness revealed the highest values in Hybrid boro, Bina and Dinanath; and lowest in Bosi followed by Nagarbera II and Nagarbera I (Fig 11).



**Fig 10:** Heatmap of 46 boro rice varieties based on rice seed characteristics. The parameters were ranked by hierarchical clustering of Complex Heatmap of R program.



**Fig 11:** Heatmap of 46 boro rice varieties based on rice kernel characteristics. The parameters were ranked by hierarchical clustering of Complex Heatmap of R program.

**Discussion**

The length, width, shape and size of seed or kernel are all important morphometric attributes in evaluating rice yield and quality. Various workers have used these characters to distinguish rice varieties (Bhattacharya and Sowbhagya 1980; Rajanna *et al* 2011) [22, 23]. In the current study, each of the morphometric traits revealed a substantial variation between the *boro* rice varieties. According to the results of the morphometric character, nearly equal numbers of boro varieties have comparatively long and medium grains, which are desirable characteristics for consumers in many Asian countries such as India, Bangladesh, Sri Lanka and Indonesia (Calingacion *et al* 2013) [24]. According to the present finding, longer grains tend to be narrower, whereas shorter grains tend to be wider. The morphology of the seed, which was regulated by the length to width ratio, showed a distinctive variation among the boro varieties. The result exhibited an association between the length and the length-to-width ratio. It was seen clearly from the study that, larger the ratio, the longer is the seed and the kernels. The seeds were also found to be finer as their length increased. Therefore, by considering these morphometric factors, it can be contemplated that there is a possibility of the same genes controlling length of the

seed, might control the shape of the seed. Similar results were also reported by Ramaiah and Rao (1953) <sup>[18]</sup> and Rajanna *et al* (2011) <sup>[23]</sup>. Li *et al* (2019) <sup>[25]</sup> reported the dependence of yield of rice upon the morphometric characters like seed length and length to width ratio.

Moreover, the present study showed that there is a positive correlation between seed length and seed length to width ratio (seed shape), which is in accordance with the findings of Patil *et al* (2014) <sup>[26]</sup>. Seed size is a primary factor for weight which is related to grain yield. Rice breeders also consider grain size as a feature for grain quality, as long and slender grains are preferred by rice consumers. A positive correlation of seed size with length, width and thickness signifies its association in determining rice quality. Furthermore, positive correlation was also observed between kernel width and kernel length to width ratio, kernel thickness. The kernel length to width ratio also showed positive correlation with kernel thickness. Therefore, selection based on the kernel characters could prove to be beneficial in bringing concurrent improvement of yield attributes and kernel characters (Sun *et al* 2018) <sup>[27]</sup>. Rice kernel colour is also a significant factor in assessing rice quality. People generally prefer white kernels for consumption (Adair *et al* 1966; Priya *et al* 2019) <sup>[28]</sup>, <sup>[29]</sup>, hence commercializing rice with this type of kernel is more profitable. 28 varieties were discovered to contain white or nearly white kernels in this investigation. However, varieties like Rampur boro and Jagli boro were found to have strong brown colour, which may indicate a high nutrition and antioxidant content (Priya *et al* 2019) <sup>[29]</sup>. Moreover, seed colour can be used to group parental and hybrid lines because of its heritable characters (Gupta and Agarwal 1988; Rajanna *et al* 2011) <sup>[30, 23]</sup>. In this study, although the rice varieties showed a vivid range of seed colour, yet most of the varieties could be grouped under yellow to brown scale, thus suggesting being present in more or less similar groups. One of the probable reasons of the variation of rice seed and kernel colour may be the altitude difference of the area of collection (Siddiqui *et al* 2007; Saikia *et al* 2021; Rehman and Tanti 2020; Bollineni *et al* 2020; Bhukya *et al* 2020) <sup>[31, 32, 33, 34, 35]</sup>.

## Conclusion

Based on the present investigation, we can conclude that the current study offers guidelines for selecting parents for rice development programmes based on morphometric characters. Although boro rice is cultivated in several parts of Assam, yet its extensive cultivation is required. The current research provides the foundation for rice breeders to utilize varieties with one or more desired characteristics. Therefore, characterization of boro rice varieties will be helpful to the breeders in selecting relevant traits.

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