



## Identification of Wheat Cultivars by CART Analysis

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Author US designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MH managed the analyses of the study. Author MOK managed the literature searches. All authors read and approved the final manuscript.*

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## **ABSTRACT**

This experiment was conducted at the Research Farm of the Department of Genetics and Plant Breeding of Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh to develop biometrical methods based on some morphological traits for characterization of the selected wheat varieties. Among the selected wheat varieties BARI Gom 26 requires comparatively fewer days and BARI Gom 27 requires more days for 50% heading than other varieties. The BARI Gom 28, BARI Gom 29 and BARI Gom 30 are comparatively short (< 90 cm) whereas others are medium-sized (> 90 cm) plants. BARI Gom 27 has narrow flag leaf than others. BARI Gom 28 show short spike length while BARI Gom 22, BARI Gom 26 and BARI Gom 30 show nearly a similar length of the spike. The BARI Gom 25 is large-sized in length and breadth but the grain of BARI GOM 27 is comparatively small sized. BARI Gom 22, BARI Gom 23, BARI Gom 24, BARI Gom 25 and BARI Gom 26 are classified which have <7.5 mm length of the grain. The 1000 grain weight of BARI Gom 24 is more than other wheat varieties and comparatively less in BARI Gom 22 and BARI Gom 27. BARI Gom 24 can be identified with the height of >90 cm, breath of flag leaf is >1.2 cm, spike length is >10 cm and yield per plant is >20.196 g. Based on these variations, a classification and regression tree (CART) has been developed to identify the wheat variety easily and quickly.

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## 1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is known as “king of cereal” is one of the major cereal crops of the world ranking second both in acreage and production among the seed crops [1]. In Bangladesh, wheat is the second important cereal crop next to rice [2] which was grown in about 4,44,805 hectares of land producing 13,48,186 metric tons grain with an average yield of 3.031 metric tons hectare<sup>-1</sup> in 2015-2016 [3]. Farmers grow it mainly as a cash crop here.

Bangladesh Wheat and Maize Research Institute (BWMRI) has released 34 wheat varieties up to now. Among the released varieties BARI Gom 22 (Shatabdi), BARI Gom 23 (Sufi), BARI Gom 24 (Prodip), BARI Gom 25 (Bijoy), BARI Gom 26 (Hasi), BARI Gom 27 (Tista), BARI Gom 28 (Francoline), BARI Gom 29 (Ug 99 resistant variety), BARI Gom 30 are popular for cultivation. The farmers get the seed (40-50%) of these varieties from BADC, DAE, Seed Dealers, NGOs, etc. The farmers homegrown wheat seeds had low yielding ability compared to the seeds provided by BADC/Research organizations (increase on average 23.5% of wheat yields, respectively compared to homegrown seed) [4]. Most of the stakeholders in Bangladesh cannot identify the desirable variety easily and quickly. When they produce seed, they mix the seed of different varieties and fail to maintain the quality of seed. As a result, the production and quality of wheat are decreasing day by day. Moreover, many officers of the BADC, DAE, and NGOs cannot recognize the seed of wheat varieties properly.

They sell one variety of seeds with the name of another variety. As a result, the farmers sometimes do not get their desired cultivar's seed and are deceived by using those seeds. Since variety identification and characterization are the first steps of any crop introduction, improvement program and parameters for the suitability of a specific region and specific purpose, rapid identification, and characterization of varieties would, therefore, provide valuable information for their introduction and genetic improvement. Moreover, the correct identification of wheat variety is also important in research where a specific variety may be chosen as a parent for a crossing program. For this, a biometrical method that is rapid, easy and inexpensive would be useful for the agriculturist,

seed dealers, and the farmers, in maintaining the required quality of the wheat varieties.

For morphological characterization of wheat varieties by biometrical method DUS test and CART analysis is very helpful. But the measurement of morphological traits by the DUS test is comparatively expensive, requiring more space, time-consuming [5] and in some cases, it is difficult to identify the varieties easily. On the other hand, CART analysis is very simple to understand and interpret, able to handle both numerical and categorical data, requires little data preparation, possible to validate a model using statistical tests and mirrors human decision making more closely than other approaches and can identify the cultivars easily.

Keeping this point in mind a study was conducted to identify the different varieties of wheat easily and quickly and to study the variability among the wheat variety.

## 2. MATERIALS AND METHODS

The experiment was conducted at the research field of Hajee Mohammad Danesh Science & Technology University (HSTU), Dinajpur during the period of November 15, 2016, to March 30, 2017. For the construction of decision tree, nine cultivars (BARI Gom 22, BARI Gom 23, BARI Gom 24, BARI Gom 25, BARI Gom 26, BARI Gom 27, BARI Gom 28, BARI Gom 29 and BARI Gom 30) of wheat were grown at a different plot. Plants were selected randomly from each plot. For the development of biometrical methods of identification in wheat different characters was observed like 50% germination days, 50% heading days, plant height, number of tiller, internodes distance, flag leaf angle, length and breadth of flag leaf, awn length, number of spikelet per spike, maturity day, length and breadth of grain, yield per plant, 1000 grain weight etc. For statistical analysis R software 3.3.4 (R Core Team, 2017) and construction of random decision tree Classification and regression-tree (CART) analysis was used.

## 3. RESULTS

### 3.1 Mean Performance of Different Wheat Variety on the Studied Traits

Variation with respect of days to 50% germination was observed among the selected wheat varieties. Further, days to 50%

germination of genotypes ranged from 6-8 days). Among the tested varieties, BARI Gom 22 (8 DAS) required the highest day for 50% germination, this was followed by BARI Gom 30, these two are statistically not different. On the other hand, lowest days required for BARI Gom 23 (6 DAS) and BARI Gom 24 (6 DAS). 50% heading days showed significant variation among the genotypes. It ranged from 61 to 68 days among the genotypes. The highest heading days were recorded in the cultivar BARI Gom 27 (68 DAS) followed by BARI Gom 23 (66 DAS) and BARI Gom 24 (66 DAS). In contrast, the lowest heading days were found in the genotype BARI Gom 26 (61 DAS) (Table 1). A considerable variance was shown among the variety in the number of tillers plant<sup>-1</sup> and the range was 5.4 to 9.3 (Table 1). The highest number of tillers plant<sup>-1</sup> was found in BARI Gom 27 and then followed by BARI Gom 28 and BARI Gom 24. The lowest number of tillers plant<sup>-1</sup> was found in BARI Gom 29. The BARI Gom 23 is comparatively tall variety and BARI Gom 29 and BARI Gom 30 are comparatively dwarf variety while the rest varieties are semi-dwarf. The range of the variation in plant height was 86.8 to 101.7 cm. The highest internode distance was found in BARI Gom 27 (23.4) while the lowest one in BARI Gom 29 (16.75). The longest awn found in BARI Gom 24 (9.575 cm) and shortest awn found in BARI Gom 22 (7.3 cm) (Table 1).

Long spike was found in BARI Gom 24 (13.55 cm) followed by BARI Gom OM 29, BARI Gom 25, BARI Gom 23, BARI Gom 27, BARI Gom 26 while short spike was found in BARI Gom 28 (9.975). A wide range of variation was found among the genotypes about the number of spikelet spike<sup>-1</sup>. It ranged from 16.55 to 20.80 (Table 1). The BARI Gom 24 produces the highest number of spikelet spike<sup>-1</sup>(20.8) ranges from 21-25 followed by BARI Gom 25 and BARI Gom 29. The BARI Gom 28 produces the lowest number of spikelet spike<sup>-1</sup>(16.55). The number of grains spike<sup>-1</sup> was ranged from 38.5 to 55.2 (Table 1). The maximum number of grains spike<sup>-1</sup> was recorded in the genotypes BARI Gom 22 (55.2) followed by the genotype BARI Gom 26 and BARI Gom 24 while the lowest from the BARI Gom 30 (17.3). The range of spike weight (g) was reported between 2.6465 to 4.382. The highest spike weight (4.382 g) was found in BARI Gom 24 followed by BARI Gom 29 (3.661 g) and BARI Gom 26(3.449 g). The lowest spike weight was found in BARI Gom 27 (1.90 g). The highest seed weight spike<sup>-1</sup> was found in BARI Gom 24 (3.203 g) followed by BARI Gom 29, BARI Gom

26, BARI Gom 28, BARI Gom 30 and BARI Gom 23 and lowest in BARI Gom 27 (2.64 g) (Table 1). The highest flag leaf angle was found in BARI Gom 25 (35.50) followed by BARI Gom 29 (34.50), BARI Gom 26 (33.0) and the lowest in BARI Gom 22 (27.50) (Table 1). The long flag leaf was found in BARI Gom 26 (33.54) followed by BARI Gom 25, BARI Gom 22, BARI Gom 23, BARI Gom 24 and short flag leaf was found in BARI Gom 30 (22.06). The highest value in the breadth of flag leaf (cm) was found in BARI Gom 23 (1.91 cm) followed by BARI Gom 24, BARI Gom 25, BARI Gom 22 and the lowest was found in BARI Gom 27 (0.96 cm) (Table 1). A wider range of variation was observed among the genotypes about days to maturity. Among the genotypes, BARI Gom 28 matured earlier (104) while the BARI Gom 27 (110) takes more time to mature. The long-grain was found in BARI Gom 25 (8.35) followed by BARI Gom 24, BARI Gom 29, BARI Gom 30, BARI Gom 23 and small grain was found in BARI Gom 27 (6.3). The range of grain breadth varies from 3.45 to 4.1. The highest value was found in BARI Gom 29 and BARI Gom 30 while the lowest value was found in BARI Gom 22 (3.45) (Table 1). The highest thousand-grain weight was recorded in the genotype BARI Gom 24 (60.99) followed by BARI Gom 25, BARI Gom 26, BARI Gom 23 and lowest was found in BARI Gom 27(40.33). A wide variation found among the varieties about yield plant<sup>-1</sup> and it was ranged from 11.8035 to 24.67388. The highest yield plant<sup>-1</sup> found in BARI Gom 24 (18.735) followed by BARI Gom 28. The lowest yield plant<sup>-1</sup> found in BARI Gom 25 (11.804) (Table 1).

### 3.2 CART (Classification and Regression Tree) Analysis

The classification tree produced by CART analysis used five morphological variables to distinguish selected wheat varieties in Fig. 1. The variables are plant height, breadth of flag leaf, spike length, yield per plant and length of grain and the mean variation of these characters is given in Table 2.

In node1 varieties are classified based on plant height. All the varieties which are equal or shorter than 90 cm are identified by CART analysis in node 2. Here, BARI Gom 28, BARI Gom 29 and BARI Gom 30 are classified. Among these, BARI Gom 29 is the shortest variety and BARI Gom 30 moderately shorter than BARI Gom 28 according to Table 2. The variety longer than 90 cm is classified in node 3

**Table 1. Mean performance of different cultivars on different character**

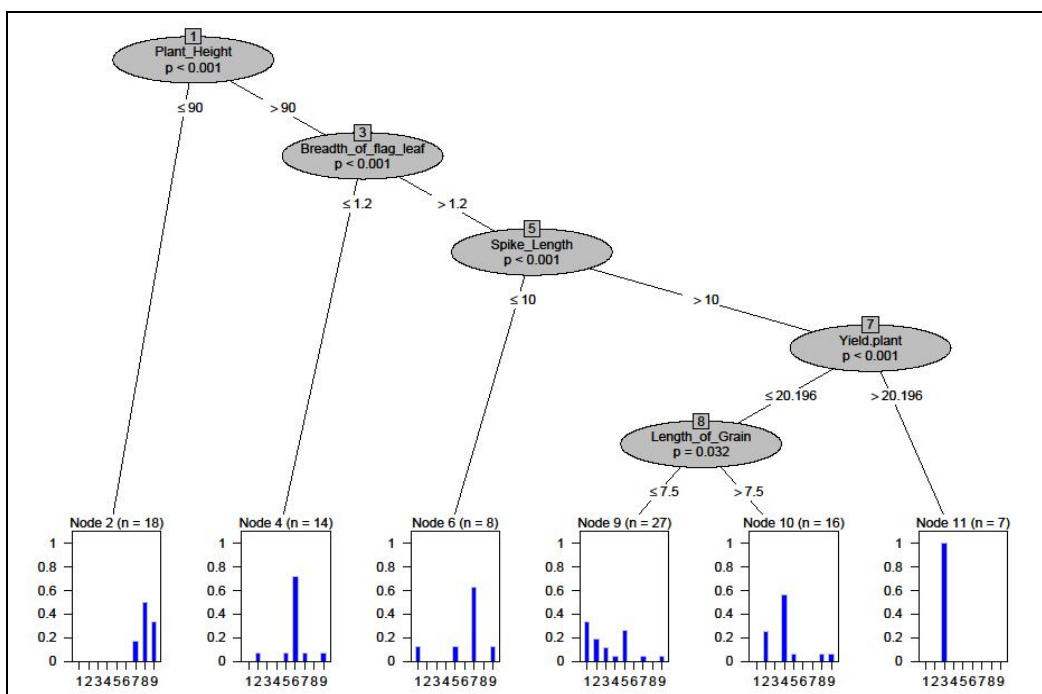
Characteristics	BARI Gom 22	BARI Gom 23	BARI Gom 24	BARI Gom 25	BARI Gom 26	BARI Gom 27	BARI Gom 28	BARI Gom 29	BARI Gom 30
Days to 50%germination	8	6	6	7	7	7	7	7	8
Days to 50% heading	64	66	66	64	61	68	62	64	62
Number of tillers plant <sup>-1</sup>	6	6.7	7.7	6.1	6.8	9.3	8.1	5.4	6.6
Plant height (cm)	99.8	101.7	99.8	99.7	95.3	94.6	91	86.8	89.4
Internode distance (cm)	21	22.25	22.35	20.15	20.75	23.4	20.55	16.75	19.65
Awn length (cm)	7.3	7.975	9.575	7.675	8.575	7.775	7.65	8.3	8.1
Spike length (cm)	10.4	11.425	13.55	12.75	11.125	11.225	9.975	12.125	10.25
Number of spikelet spike <sup>-1</sup>	18.5	17.5	20.8	19.1	17.75	17.8	16.55	19.1	17.3
Number of grains spike <sup>-1</sup>	55.2	39.65	50.15	42	51.1	43	47.1	47.9	38.5
Spike weight (g)	2.66225	2.7854	4.382	2.7308	3.4494	2.6465	3.0062	3.6611	2.9525
Seed weight spike <sup>-1</sup> (m)	1.9	2.0423	3.2038	1.9346	2.4553	1.9139	2.3126	2.5338	2.0697
Flag leaf angle (°)	27.5	30.5	32	35.5	33	30.5	32.5	34.5	31
Length of flag leaf (cm)	32.04	31.08	30.03	32.66	33.54	22.57	28.73	25.59	22.06
Breadth of flag leaf (cm)	1.72	1.91	1.83	1.81	1.57	0.96	1.49	1.3	1.14
Days to maturity	106	108	106	106	107	110	104	105	106
Length of grain (mm)	6.6	7.3	8.25	8.35	7.1	6.3	7.15	7.95	7.9
Breadth of grain (mm)	3.45	3.85	3.95	4.1	3.95	3.65	3.6	4.05	4.05
Number of spikes m <sup>-2</sup>	410	430	445	360	455	490	485	425	465
Yield m <sup>-2</sup>	0.625	1.025	1.2	0.37	0.65	0.495	1.105	0.925	0.54
1000 seed weight (g)	40.73	50.59	60.99	55.58	53.61	40.33	43.89	47.15	46.06
Yield plant <sup>-1</sup> (g)	11.808	13.681	24.674	11.804	16.701	17.801	18.735	13.684	13.669

**Table 2. Means, ranges, standard deviations and Co-efficient of variation for morphological traits of the selected wheat varieties**

Variety		Plant height	The breadth of flag leaf	Spike length	Yield plant <sup>-1</sup>	Length of grain
BARI Gom 22	Mean	99.8	1.72	10.4	11.808	6.6
	Range	94-105	1.14-2.1	10-13	7.02-17.22	6-7.5
	SD	3.6147	0.2201	0.8755	3.3972	0.5676
	CV	3.62	12.79	8.41	28.77	8.6
BARI Gom 23	Mean	101.7	1.91	11.425	13.681	7.3
	Range	95-110	1.2-2.4	11-15	10.586-18.358	6-9

Variety		Plant height	The breadth of flag leaf	Spike length	Yield plant <sup>1</sup>	Length of grain
BARI Gom 24	SD	4.8085	0.3541	1.2064	2.3688	0.9486
	CV	4.72	18.53	10.55	17.31	12.99
	Mean	99.8	1.83	13.55	24.674	8.25
	Range	94-106	1.5-2.1	12.5-16	17.633-30.464	6-9
BARI Gom 25	SD	3.7653	0.2002	1.0916	5.1444	1.0606
	CV	3.77	10.93	8.05	20.84	14.62
	Mean	99.7	1.81	11.75	11.804	8.35
	Range	97-105	1.4-2.4	10.5-14	6.405-19.032	7.5-9
BARI Gom 26	SD	2.4966	0.3314	1.1067	4.3190	0.5797
	CV	2.50	18.30	9.41	36.58	6.94
	Mean	95.3	1.57	11.125	16.701	7.1
	Range	91-99	1.1-1.9	10-14	8.024-20.196	6-8
BARI Gom 27	SD	2.6687	0.2406	1.0658	4.0183	0.6146
	CV	2.80	15.32	9.58	24.06	8.65
	Mean	94.6	0.96	11.225	17.801	6.3
	Range	91-99	0.6-1.2	10-12.5	13.578-21.948	5-7
BARI Gom 28	SD	2.4585	0.2011	0.7453	2.8912	0.6324
	CV	2.59	20.94	6.63	16.24	10.03
	Mean	91	1.49	9.975	18.735	7.15
	Range	86-95	1.2-1.7	9-12	10.935-26.406	6-8.5
BARI Gom 29	SD	2.7487	0.1523	0.9442	4.3813	0.8514
	CV	3.02	10.22	9.46	23.38	11.90
	Mean	86.8	1.3	12.125	13.684	7.95
	Range	80-96	1-1.7	10-15	9.072-20.574	6-9
BARI Gom 30	SD	4.7328	0.2449	1.4990	4.2071	0.8959
	CV	5.45	18.838	12.36	30.74	11.26
	Mean	89.4	1.14	10.25	13.669	7.9
	Range	84-98	0.5-1.5	10-12	7.458-21.45	7-9
	SD	4.7888	0.2875	0.7168	3.8457	0.5676
	CV	5.35	25.21	6.99	28.13	7.18

Here, 1=BARI Gom 22; 2= BARI Gom 23; 3= BARI Gom 24; 4= BARI Gom 25; 5= BARI Gom 25; 6= BARI Gom 26; 7= BARI Gom 27; 8= BARI Gom 29; 9= BARI Gom 30



**Fig. 1. Classification tree produced by CART analysis of selected wheat varieties**

based on the breadth of the flag leaf. Here the varieties which are less than 1.2 cm are classified in node 4 and which are equal or more than are 1.2 cm are identified in node 5. The node 4 shows BARI Gom 27 has narrow flag leaf than others. The varieties in which breadth of flag leaf less than 1.2 mm is further classified in node 5 based on spike length. The varieties equal or shorter than 10 cm spike length are shown in node 6. It represents that BARI Gom 28 show short spike length while BARI Gom 22, BARI Gom 26 and BARI Gom 30 show the nearly the same length of the spike. In node 7 the varieties that are more than 10 cm are classified based on yield plant<sup>-1</sup>. Node 8 represents the varieties <math>< 20.196</math> g yield plant<sup>-1</sup> which further classified based on length of grain in node 8. In node 9 BARI Gom 22, BARI Gom 23, BARI Gom 24, BARI Gom 25 and BARI Gom 26 are classified which have <math>< 7.5</math> mm length of the grain. And in node 10 BARI Gom 23, BARI Gom 25 and BARI Gom 26 are classified. Similarly, in node 7 the variety more than 10 cm is classified based on yield plant<sup>-1</sup>. Node 8 represents the variety <math>< 20.196</math> g yield plant<sup>-1</sup> which further classified based on length of grain in node 8. In node 9 BARI Gom 22, BARI Gom 23, BARI Gom 24, BARI Gom 25 and BARI Gom 26 are classified which have <math>< 7.5</math> mm length of the grain. And in node 10 BARI Gom 23, BARI Gom 25 and BARI Gom 26 are classified. Finally, in node 11 BARI

Gom 24 can be identified which height is <math>> 90</math> cm, the breadth of flag leaf is <math>> 1.2</math> cm, spike length is <math>> 10</math> cm and yield plant<sup>-1</sup> is <math>> 20.196</math> g.

#### 4. DISCUSSION

Morphological traits often influence the estimation of genetic variation and relatedness. Agronomical important traits of a species are valuable in cultivation for the breeder's selection of promising plant material because morphological traits are used mainly for the identification of genotypes and variety [6].

Bode et al. [7] planted a total of 100 wheat accessions under field conditions and studied their agro-morphological characters (14 quantitative traits) such as plant height, spike length, 100 kernel weight, days to maturity were recorded. A wide variation among the traits of 100 wheat accessions was found. Similarly, Fikre et al. [8] tested sixty-four bread wheat genotypes to estimate the extent of genetic variability and the genotypes showed significant variation for all the traits studied except for biomass yield ha<sup>-1</sup> and relatively wide range of the mean values for most of the characters indicated the existence of variations among the tested genotypes.

Sabaghnia et al. [9] reported that variation of traits is a primary need of any plant breeding

effort that involves the natural evolution and causes sustainable crop production under different environments. Kumar et al. [10] Also showed a considerable amount of variation among genotypes for each character like 1000 seed weight, plant height and number of effective tillers per plant, spike length and 1000 seed weight in thirty wheat genotypes. Mundiara [11] Reported significant differences among the all characters viz., days to 50 per cent flowering, days to maturity, plant height, number of spikelet spike<sup>-1</sup>, productive tillers plant<sup>-1</sup>, ear length with awn, number of grains spike<sup>-1</sup>, 1000 grain weight, and biological yield plant<sup>-1</sup>, grain yield plant<sup>-1</sup>, harvest index and gluten content in the experimental wheat genotypes. According to Kayess et al. [12] BARI Gom 25 and BARI Gom M 28 considered as semi-dwarf genotypes having the plant height within the range 92.02-116.1 (cm). Mahmood et al. [13] also obtained different results for wheat plant height ranging from 62 cm to 110 cm, while Aliu and Fetahu [14] realized range 71 to 79 cm for plant height in different bread wheat genotypes. Fufa et al. [15] Found high variation for all morphological traits, especially spike length. Zečević [16] also observed genetic and phenotypic variability of the spike length in ten winter wheat variety Nazem and Arzani [17] found variation in many morphological trait-like plant height, spike length, flag leaf width, etc. Pawar et al. [18] Reported wider genetic variation for traits in wheat-like plant height, length of the spike, number of spikelets spike<sup>-1</sup>, grains panicle<sup>-1</sup>, 1000 grain weight, and grain yield. Priya et al. [19] also reported that a wide range of variation was observed for fifteen characters viz. days to heading, days to flowering, plant height, number of tillers plant<sup>-1</sup>, spike length, number of spikelets spike<sup>-1</sup>, number of grains spike<sup>-1</sup> weight of grains spike<sup>-1</sup>, flag leaf area, 1000 grain weight, grain yield plant<sup>-1</sup> etc.

## 5. CONCLUSION

Among the cultivars BARI Gom 23 was tall, nearly followed by BARI Gom 22, BARI Gom 24 and BARI Gom 25, others were medium-sized and BARI Gom 28, BARI Gom 29 and BARI Gom 30 are comparatively short (<90 cm). Spike characteristics like spike length, spike weight, no. of spikelet spike<sup>-1</sup>, number of grains spike<sup>-1</sup>, seed weight spike<sup>-1</sup> showed considerable variance among the wheat variety. The BARI Gom 28 showed short spike length while BARI GOM 22, BARI Gom 26 and BARI Gom 30 showed nearly the same length of the spike. Flag leaf characters

like flag leaf angle, length of flag leaf and breadth of flag leaf also showed variance among the variety. The longest flag leaf was found in BARI Gom 26 followed by BARI Gom 25 and BARI Gom 22. The smallest flag leaf was found in BARI Gom 30 followed by BARI Gom 27. BARI Gom 27 has narrow flag leaf than others.

Moreover, variation was present in the grain size. The variety BARI Gom 25 is large-sized in length and breadth but the grain of BARI Gom 27 is comparatively small sized. BARI GOM 22, BARI Gom 23, BARI Gom 24, BARI Gom 25 and BARI Gom 26 are classified which have <7.5 mm length of the grain. The 1000 grain weight of BARI Gom 24 is more than other cultivars and comparatively less in BARI Gom 22 and BARI Gom 27. BARI Gom 24 can be identified which height is >90 cm, the breath of flag leaf is >1.2 cm, spike length is >10 cm and yield per plant is >20.196 g.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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