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Analysis of Morphological, Physiological and Biochemical traits for grain quality and yield in Basmati rice accesions

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ABSTRACT

The knowledge of the extent and pattern of diversity in the crop species is a prerequisite for any crop improvement as it helps breeders in deciding suitable breeding strategies for their future improvement. Rice is the most important staple food crop among the cereals and feeds more than half of the world's population. The wide variety of rice grains, each with its distinct characteristics whether it is size, texture or color ensures that the rice continues to hold a significant place in diverse culinary traditions. As population grows and culinary traditions, rice will remain a wide food source with diverse taste. Therefore, the present study was undertaken with the aim to characterize and assess trends of diversity in a large set of Indian rice genotypes. Fifty germplasm of rice were taken in the experiment which belongs to basmati group. The Basmati rice genotype was collect from ACRIP-Rice, Nagina Research Centre Bijnor U.P. The analysis of 50 rice genotypes reveals that Basmati 5836-E, Basmati 5874-B, and Basmati 5836-C, Basmati 5874-A excel in morphological parameters highlighting the diverse strengths of these genotypes in rice cultivation. Basmati 372-A-E, Basmati 372-A-F, and Basmati 372-A-G, Basmati-375-F excelled in biochemical parameters Basmati-5875-E had the highest chlorophyll content, showcasing the superior performance of specific Basmati genotypes in key agricultural parameters. Diversity is prerequisite for any crop improvement program as it helps in the development of superior recombinants. Diversity offers a range of selections to breeders that may produce superior rice varieties and contribute to targeted crop improvement. The present study aimed to assess the diversity of aromatic rice genotypes and the obtained knowledge which could be utilized further in breeding programme for crop improvement. It will be important in the future of plant breeding as it helps develop crops that can adapt to climate change, agronomical traits, higher yield, speed flower over different aspects and meet food demand with sustainable agriculture.

INTRODUCTION

Rice is one of the world's most important food crops, especially in South East Asia (the eastern hemisphere). More than half of the world's population uses it as a daily source of calories and protein (**Sun et al., 2012**). Due to diverse consumer preferences, quality breeding has gained importance in recent years. The genetic improvement of grain quality and the popularization of high-quality rice are due to the constant growth in the world's population and improvement of people's living standards (**Peng et al., 2014**). Consumer demand for better quality rice has increased recently. As a result, it is now necessary to develop cultivars to produce that consumers like. Consumers usually choose a rice variety based on its physical appearance in the market place, where the rice variety is ultimately tested. While most consumers in the tropics and subtropics prefer long or medium long, slender translucent grains, India prefer long, non-sticky grain and Basmati rice varieties with intermediate amylose and alkali spreading value, intermediate gel consistency, and high-volume expansion of cooked rice.

Grain size, shape, colour, endosperm chalkiness, and translucency are the most important aspects of grain appearance (**Fitzgerald et al., 2009; Oikawa et al., 2015; Sweeney et al., 2006**). Gel consistency (GC), gelatinization temperature (GT), and amylose content (AC) of rice are all dependent on the composition and structure of the starch granules found in rice grains (**Jeon** et al. 2010). It is crucial to translate the physico-chemical and eating quality characteristics that have been used in the laboratory into visual terms that consumers can easily understand. Based on the aroma, rice is classified as aromatic or non-aromatic. Aromatic rice is a small and unique group of rice that are considered the best in quality and are usually used for preparing special dishes. Aromatic rice's fragrance is its key feature, which increases its popularity in global market. Basmati is an Indian rice variety that is well-known worldwide for its flavor. Till now, improvement of basmati rice has been the focus given to the growing demand for aromatic rice in the global market. Thus, the collection and preservation of these special resources is now the focus. Furthermore, in accordance with the provisions laid out in the meeting on Conservation of Biological Diversity (1992), the management of indigenous aromatic rice genetic resources by way of characterization and documentation helps in the protection of these special bioresources.

Rice germplasm diversity can be characterized and studied using a variety of agro-morphological markers. An integrated index for grain length, width, and thickness is grain weight, which is one of the important yield components. This analysis includes six fractions: moisture, ash, crude protein, fat, crude fiber, and carbohydrates. Rice's proximate composition, sensory, gelatinization temperature, and alkali digestion analysis are physicochemical and biochemical analyses that are helpful in producing nutritionally rich varieties of rice. The most crucial characteristic of rice is its eating and cooking quality (ECQ), which determines its price in the market and meets the customer's satisfaction. Physicochemical and biochemical properties of the starch in the endosperm, including gel consistency, gelatinization temperature (GT), pasting properties, and, most importantly, the apparent amylose content, control rice ECQs. As a result, grain quality can be defined as a combination of its physical, chemical, and eating and cooking characteristics.

The comprehensive literature survey demonstrates the importance of an appropriate experimental design for rice crop improvement. In this perspective, the present investigation was planned to work out the following objectives which includes studies of morphological, physiological and Biochemical parameter related to the grain quality of aromatic rice germplasm.

Materials and methods

The present investigation was undertaken based on the studies of rice crop which were grown at different time. First crop was grown in year 2022 and second crop was grown in year 2023 during kharif season. The experimental site's soil profile showed sandy loam with initial pH of 7.3 and EC of 1.38 dSm-1. Fifty germplasm of rice were used in the experiment belongs to basmati group. The Basmati rice genotype was collect from ACRIP-Rice, Nagina Research Centre, (Table 1). Randomized Block Design (RBD) were used, field trial experiment was laid out with three replications over two seasons.

Table 1: Name of the genotypes used in present study

S.no.	Name of genotype	S.no.	Name of genotype
1	BASMATI-372A-E	26	BASMATI-6129-G
2	BASMATI-372A-F	27	BASMATI-6141-A
3	BASMATI-372A-G	28	BASMATI-6141-B
4	BASMATI-375-E	29	BASMATI-6311-C
5	BASMATI-375-F	30	BASMATI-6313-B
6	BASMATI-376-C	31	BASMATI C-621-A
7	BASMATI-377-A	32	BASMATI C-621-B
8	BASMATI-5836-C	33	BASMATI C-621-C
9	BASMATI-5836-E	34	BASMATI C-622-I
10	BASMATI-5836-F	35	BASMATI MEHTRAH-A
11	BASMATI-5853	36	BASMATI NORAT-439-A
12	BASMATI-5874-A	37	BASMATI NORAT-439-B
13	BASMATI-5874-B	38	BASMATI NORAT-439-C
14	BASMATI-5875-C	39	BASMATI-SUFAID-187-A
15	BASMATI-5875-D	40	BASMATI-SUFAID-187-B
16	BASMAT-5875-E	41	BASMATI-SUFAID-187-E
17	BASMATI-5875-G	42	BASMATI SURAKH-A
18	BASMATI-5877-A	43	BASMATI SURAKH-B
19	BASMATI-5877-B	44	BASMATI TALL-C
20	BASMATI-5888-E	45	BASMATI TALL-D
21	BASMATI-6113-A	46	PAK BASMATI-A
22	BASMATI-6113-B	47	SATHI BASMATI-B
23	BASMATI-6129-A	48	BASMATI-G
24	BASMATI-6129-B	49	BASMATI-1-H
25	BASMATI-6129-D	50	BASMATI-1-I

Morphological parameters including Days to flowering, Day to maturity, plant height, panicle length, number of spikelet's per panicle, test weight, L/B ratio after cooking, leaf length, leaf width, panicle bearing tiller per plant, yield per plant, biological yield, and Harvest index.

Physiological and biochemical parameters includes leaf chlorophyll content (**Palta, 1990**), total protein by Lawry's method (**Dulley and Grieve, 1975**), aroma test using 1.7% KOH solution (**Sood and Siddiq, 1978**), alkali spreading value by incubating six grains of milled rice in 100 ml of 1.7% KOH at 30°C for 23h (**Little *et al*., 1958**), gel consistency was developed to differentiate high amylase rice with contrasting amylograph pasting viscosities (**Cagampang *et al*., 1973**).

Statistical analysis

Each genotype had five randomly selected plants, and an average value of observations recorded with respect to metric characters was calculated and then used for statistical analysis. Below are the details of statistical analysis.

Mean: Mean value of character which had more than one observation was determined using Mean= $\Sigma X_i/N$. Where; ΣX= Sum of the values at all the observations, N= Number of observations.

Analysis of variance (ANOVA): An analysis of variance for each character was carried out using $Y_{ij} = \mu + t_i + b_j + e_{ij}$. Where; Y_{ij}= Performance of i^{th} genotype and j^{th} replication, μ= General mean effect, t_i= Effect of i^{th} genotype, b_j= Effect of j^{th} replication, e_{ij}= random error associated with i^{th} genotype and j^{th} replication.

Procedure of analysis: Table 2 presents an analysis of variance and expectation mean sum of squares for randomized block design due to different sources of variation.

Table 2: Analysis of variance and expectation of mean sum of squares

Source of variation	Df	MS	EMS	F-ratio
Replication	(r-1)	MSr	$\sigma^2 e + v\sigma^2 r$	MSr/MSe
Genotype	(v-1)	MSg	$\sigma^2 e + r\sigma^2 g$	MSg/MSe
Error	(r-1) (v-1)	MSe	$\sigma^2 e$	

Where; r= Number of replications, v= Number of genotypes, σ^2g= Variance due to genotypes, σ^2r= Variance due to replications, σ^2e= Environmental variance, df = Degree of freedom, MS= Mean sum of squares, EMS= Estimated mean sum of squares. MSr, MSg and MSe stand for mean sum of squares due to replications, genotypes and error, respectively.

Correction factor (CF) was calculated using: CF= $\frac{(GT)^2}{r.v}$;

Where, GT= Grand total, r= Number of replications, v= Number of genotypes.

Range: It was determined as the difference between the highest and lowest mean value for each character as follows- Range = $X_n - X_t$; Where, X_n= Highest mean value of character, X_t= Lowest mean value of character.

Standard error of mean: Standard error of means was calculated by formula S.Em. = $\sqrt{\frac{2EMS}{r}}$

Coefficient of Variation: It is the measure of variability evolved. Coefficient of variation is the ratio of standard deviation of a sample to its mean and expressed in percentage.

$$CV (\%) = \frac{\text{Standard deviation}}{\text{Mean}} \times 100$$

Results and discussion

To compare the field circumstances, a thorough statistical analysis of the data was conducted, and the recorded data is displayed in tables and figures. The following subheadings: morphological, physiological and biochemical parameters—have been used to classify and present the overall findings.

Morphological parameters

The days to flowering mean value ranged from 112.67-91.67 days and maximum days to flowering was observed in Basmati Norat-439-C and minimum was observed in Basmati C-621-A. A shorter "days to flowering" in rice provides increased yield potential by allowing for a longer grain filling period, better adaptation to challenging environments. Earlier workers have also reported presence of substantial diversity in rice **Kakar et al., 2021** analyzed 74 rice genotypes and recorded days to flowering range from 121.71 days to 85.6 days. Similarly, **Vijay Kumar (2015)** analyzed 57 rice genotypes and found the range for days to flowering 119.37 days and 107.55 days. Days to maturity mean value ranged from 144.67-114.33 days and Basmati 6113-A had the highest and Basmati-5836-C had the lowest days to maturity. Earlier studies by **Ogunbayo et al., 2005** with 40 rice accessions revealed that maximum days to maturity were 147 days and minimum days to maturity were 120 days. Similar results were reported by **Sarif et al., 2020** and **Siddique et al., 2013.** Plant height mean value ranged from 144.97-112.41 cm and Basmati-5875-G had the highest and Basmati-Norat-439-A had the lowest mean performance. Taller plants access more sunlight, enabling greater photosynthesis and potentially higher grain production. **Pachauri et al., 2017** characterized one hundred twenty four rice germplasm accessions and have observed relatively greater range in plant height than the other characters with a wider range (70-184 cm). **Sarawgi et al., 2015** studied that more than 50% accessions were having plant height in the range of 131-150 cm and grouped as tall.

Leaf length mean value ranged from 40.43-23.3 cm in which Basmati-6129-B had the highest and Basmati-5877-A had the lowest mean performance. Leaf width mean value ranged from 1.89- 0.96 cm where Basmati-5874-A had highest and Basmati-375-F had the lowest mean performance. **Devi et al., 2016** studied variance for grain yield and quality traits in rice and found the range for leaf length between 48.9 cm to 23.0 cm which was very much similar to our study whereas the rage of leaf width was found to be 2.3 cm to 1.6 cm and discussed that heritability along with genetic advance was observed for the traits, viz., leaf area and indicated that the character was mostly governed by additive gene effects (**Panse and Sukhatme, 1957**).

Panicle length mean value ranged from 33.58-23.05 cm, Basmati-372 A-G had maximum and Basmati-Sufaid-187-B had the minimum mean performance. A longer panicle length in rice provides a greater number of grains to be produced on a single panicle, which directly translates to increased rice yield, making it a key trait targeted in rice breeding programs to maximize crop productivity. **Abarshahr et al., 2011** reported maximum 33.73 cm while only 22.3 cm panicle lengths. **Tandekar et al., 2014** observed panicle length of various rice genotypes ranged from 32.00 cm to 17.50 cm. Panicle bearing tiller per plant mean value ranged from 15.67-8.33, Basmati 6313-B had the highest and Basmati-5853 had the lowest mean performance. The more panicles a plant has, the more grains it will produce, and the higher its yield will be. **Pandey et al., 2009** estimated mean range of variation in 40 rice genotypes and found the range 18.10 to 7.35. **Yogendra Singh** and **US Singh in year 2008** gave the similar type of result ranging from 15.10 to 9.70. Spikelets per panicle mean value ranged from 228.33-118.33, Basmati Mehtrah-A had the highest while Basmati-Sufaid-187-B had the lowest mean performance. **Pandey et al., 2009** estimated mean range of variation in 40 rice genotypes and found the range 247.40 to 136.25. **Krishna Tandekar** and **Nidhi Koshta (2014)** studied 97 rice germplasm accession and recorded for number of total spikelets ranging from 296.55 to 68.90 which was very much similar to our findings. Grain Yield per plant mean value ranged from 25.98-18.35 gm, Basmati 6113-A had the highest and Basmati 5836-C had the lowest mean performance. **Sarif et a., 2020** conducted an experiment and suggested what **Oladosu et al., 2017** stated that the grain yield per hill does not exist in isolation but rather as a result of interrelation and association with other traits that form a complex relationship that ultimately affects the yield and got the range of 34.37gm to 20.2 gm.

Biological yield mean value ranged from 95.66-70.78 gm, Basmati-5875-C had the highest while Basmati 372A-F had the lowest mean performance. **Pandey et al., 2009** estimated mean, range in 40 rice genotypes and found the range between 125.20 gm maximum to 45.50 gm minimum and mean was 83.33 gm for the biological yield which were very similar to our findings. These more or less similar findings were done by the earlier researchers like **Ovung et al., 2012** founded the range between 128.48 gm maximum to 72.55 gm minimum and mean was 97.35 gm. Harvest index mean value ranged from 35.45-20.68%, Basmati-6129-A had the highest while Basmati 5877-A had the lowest mean performance. **Krishna Tandekar and Nidhi Koshta (2014)** estimated mean range of variation in 97 rice genotypes and found the range from 66.2% to 31.50% and mean value was 50.77% for the Harvest Index which were very similar to our findings. These more or less similar findings were done by the earlier researchers like **Pandey et al. 2009** founded the range between 48.92% maximum to 13.79% gm minimum and mean was 26.38%. Test weight using 1000-Seed weight mean value ranged from 25.38-18.24 gm, while Basmati 375-E had the highest and Basmati 1-H had the lowest mean performance. A higher test weight indicates higher quality grain. Grains with higher test weights are denser, have larger kernels, and are more uniform. Grains with higher test weights have a higher yield potential because they are healthier and well-developed. **Pandey et al., 2009** estimated mean, range of 40 rice genotypes and found the range between 25.93 gm to 12.60 gm. The results are in agreement with **Guru et al., 2017** got range 23.07 gm to 11.87 gm which was very much similar to our finding. L/B ratio after cooking mean value ranged from 4.41-2.43, Basmati-376-C had the highest and Basmati-5875-E had the lowest mean performance. **Hossain et al. 2009** reported L/B and elongation ratio of cooked rice ranging from 2.39 to 5.07, respectively.

Physiological and Biochemical Parameter

Total chlorophyll ranged from 45.13 (Basmati-5875-E) to 32.23 (Basmati Norat-439-A) among all genotypes. **Kakar et al., 2021** analyzed 74 rice breeding lines for chlorophyll content and found the range between 49.19 to 28.35 which was very similar to our findings. Similar result was obtained by other researchers in rice (**Gaballah et al., 2022, Alshiekheid et al., 2023**). Total Protein of grain ranged from 13.31-8.26g/100g where highest was in Basmati-376-C and lowest was recorded for Basmati 6129-G

(8.26g/100g) among all genotypes. **Aiyswaraya et al., 2017** taken 150 germplasm accessions and observed the protein content ranged from 7.54 g/100g to 14.70 g/100g. A scrutiny of above findings on the estimation of protein content by different workers reveals that the low protein category ranged from 2.8 to 7.38% and the other extreme ranged from 9.07 to 15.9% in genotypes belonging to O. sativa. Amylose content was found for Basmati 6113-B (32.6%) whereas lowest was recorded for Basmati Sufaid -187-B (15.97%) among all genotypes. According to **Dipti, Hossain, Bari, and Kabir (2002)**, good quality rice will have a head rice yield of at least 70%, therefore, it can be claimed that these three rice varieties have an intermediate quality in terms of head rice yield percentage. **Sarif et al., 2020** analysed 32 rice accessions and got the mean value of total amylose content 19.85%.

The highest alkali spreading value was found with the highest value 5 for Basmati-372A-G, Basmati-5888-E and Basmati-6129-D and the lowest alkali spreading value performance was recorded for Basmati-377-A, Basmati-5853, Basmati C-621-B, Basmati C-622-I, Basmati Mehtrah-A. **Chemuta et al., 2016** selected twelve rice genotypes and scored total Alkali spreading value according to rice affected and found Alkali spreading value high (5) for ITA 310, Kilombero, Kahogo, IR 54, Wahiwahi and lowest for Red Afaa, IR 2793. There is an inversely proportional relationship between alkali digestion value and the gelatinization temperature, the genotypes with low alkali digestion have a high gelatinization temperature. **Manir et al., 2024**. The highest gel consistency was found with the highest mean value for Basmati-372A-E (92.3) whereas lowest mean performance was recorded for Basmati-1-I (31.8). Hard gel consistency observed in this study was due to formation of rigid rice gels, which occur as a result association of starch polymers in the aqueous phase. **Chemuta et al., 2016** analyzed variance of the gel consistency values of the 12 rice genotypes and found maximum value for IR 2793 (99.50) and lowest for ITA 310 (31.50) whereas mean value for total gel consistency was 68.87.

Table 3. Mean performance of morphological traits recorded which were taken before harvesting of different rice genotypes at the reproductive growth stage

S.No	Genotypes	DF	DM	PH	PBT/P	PL	NS/P	LL	LW
1	BASMATI-372A-E	96.33	137.67	140.65	12.67	26.52	140.67	26.83	1.28
2	BASMATI-372A-F	96.33	134.67	144.36	13.33	29.99	138.00	25.97	1.13
3	BASMATI-372A-G	102.67	137.67	142.99	13.33	33.58	139.33	25.63	1.25
4	BASMATI-375-E	103.67	138.67	139.42	9.67	26.67	220.67	37.63	1.19
5	BASMATI-375-F	105.00	138.00	140.29	11.00	23.68	208.33	37.27	0.96
6	BASMATI-376-C	100.33	134.33	140.43	10.33	26.74	130.33	31.91	1.20
7	BASMATI-377-A	101.00	138.00	141.47	10.67	28.72	135.33	23.53	1.33
8	BASMATI-5836-C	97.33	114.33	140.16	13.67	26.51	130.33	36.13	1.19
9	BASMATI-5836-E	95.33	119.00	137.63	12.67	28.46	155.33	37.20	1.18
10	BASMATI-5836-F	93.67	120.67	134.92	9.00	28.71	137.33	33.93	1.20
11	BASMATI-5853	110.33	131.00	130.09	8.33	24.48	138.33	31.97	1.26
12	BASMATI-5874-A	97.67	124.67	120.78	13.33	26.60	144.33	34.17	1.89
13	BASMATI-5874-B	97.33	122.67	142.02	13.67	27.56	154.67	32.03	1.61
14	BASMATI-5875-C	100.67	125.67	137.60	9.33	27.57	197.33	32.20	1.28
15	BASMATI-5875-D	103.33	125.33	137.20	11.33	29.52	176.33	28.80	1.32
16	BASMAT-5875-E	102.67	124.67	130.48	11.00	28.84	182.67	23.40	1.31
17	BASMATI-5875-G	99.33	125.67	144.97	12.67	27.70	179.67	23.73	1.35
18	BASMATI-5877-A	104.33	129.67	137.40	8.33	26.75	134.00	23.30	1.27
19	BASMATI-5877-B	112.00	132.67	133.17	12.33	29.69	135.67	25.67	1.24
20	BASMATI-5888-E	104.67	141.33	135.82	13.67	27.52	192.67	31.07	1.27
21	BASMATI-6113-A	106.33	144.67	135.75	14.33	27.31	217.67	26.87	1.29
22	BASMATI-6113-B	105.33	142.67	131.12	10.67	29.15	220.67	38.10	1.31
23	BASMATI-6129-A	97.67	125.33	126.25	11.67	27.78	135.33	39.73	1.51
24	BASMATI-6129-B	97.33	121.33	123.68	12.33	24.87	134.00	40.43	1.29
25	BASMATI-6129-D	95.33	124.67	129.03	14.67	25.93	136.67	37.90	1.52
26	BASMATI-6129-G	99.00	122.67	135.88	13.33	27.47	133.67	38.10	1.21
27	BASMATI-6141-A	104.67	133.33	114.40	13.33	29.02	133.67	38.27	1.13
28	BASMATI-6141-B	105.33	137.33	115.86	13.67	30.85	132.67	38.10	1.17
29	BASMATI-6311-C	112.33	134.33	139.87	13.33	28.47	170.67	39.30	1.25
30	BASMATI-6313-B	99.67	132.33	141.34	15.67	28.94	171.33	33.97	1.25
31	BASMATI C-621-A	91.67	135.67	135.74	13.33	25.11	214.67	24.97	1.28
32	BASMATI C-621-B	97.00	131.33	128.70	11.67	27.21	214.33	25.60	1.23
33	BASMATI C-621-C	93.33	132.33	130.90	10.33	24.85	220.67	26.50	1.26
34	BASMATI C-622-I	94.00	122.67	136.97	11.33	26.98	226.00	29.93	1.29
35	BASMATI MEHTRAH-A	97.00	129.33	119.12	9.67	27.92	228.33	29.53	1.34
36	BASMATI NORAT-439-A	106.33	143.33	112.41	11.33	29.37	187.33	39.13	1.36
37	BASMATI NORAT-439-B	104.33	143.33	117.95	13.33	27.52	190.67	37.80	1.35
38	BASMATI NORAT-439-C	112.67	137.67	117.43	12.00	28.90	184.67	32.60	1.37
39	BASMATI-SUFAID-187-A	99.67	134.33	125.73	13.67	24.74	127.33	33.53	1.76
40	BASMATI-SUFAID-187-B	96.00	133.00	131.18	13.00	23.05	118.33	33.30	1.31
41	BASMATI-SUFAID-187-E	97.33	132.67	132.58	12.33	24.27	129.33	32.27	1.28
42	BASMATI SURAKH-A	102.67	129.33	132.69	14.33	25.03	138.33	30.83	1.25
43	BASMATI SURAKH-B	110.67	134.33	133.17	12.33	27.14	140.67	31.03	1.29
44	BASMATI TALL-C	103.33	136.33	140.46	9.67	29.47	226.67	32.67	1.34
45	BASMATI TALL-D	103.33	136.00	136.90	11.00	30.16	203.33	33.37	1.21
46	PAK BASMATI-A	99.00	126.67	136.71	13.33	26.77	220.67	35.33	1.19
47	SATHI BASMATI-B	93.67	124.00	139.74	14.00	27.59	216.33	35.77	1.25
48	BASMATI-G	101.67	142.33	138.46	11.67	27.88	211.33	31.83	1.31
49	BASMATI-1-H	103.67	135.67	136.49	10.33	28.74	206.67	33.03	1.27
50	BASMATI-1-I	105.33	137.33	137.40	10.67	29.43	148.33	40.10	1.67
	Mean	**101.17**	**131.89**	**133.32**	**12.04**	**27.57**	**170.29**	**32.45**	**1.31**

	Min	91.67	114.33	112.41	8.33	23.05	118.33	23.30	0.96
	Max	112.67	144.67	144.97	15.67	33.58	228.33	40.43	1.89
	SE(d)	2.63	1.93	1.33	0.93	0.57	2.06	0.50	0.02
	C.D.	5.23	3.83	2.65	1.85	1.12	4.09	0.99	0.03
	C.V.	3.19	1.79	1.22	9.45	2.51	1.48	1.89	1.49

DF = days to flowering, DM = days to maturity, PH = plant height, PBT/P = panicle bearing tiller per plant, NS/P = no. of spikelet per panicle, LL= leaf length, LW = leaf width, DF = days to flowering, DM = days to maturity, PH = plant height

Table 4. Mean performance of morphological traits recorded which were taken after harvesting of different rice genotypes.

S. No.	Germplasm	l/b ratio after cooking	Test weight	Biological yield	Harvest index	Grain yield
1	BASMATI-372A-E	3.46	21.41	72.28	29.03	20.98
2	BASMATI-372A-F	3.08	21.99	70.78	32.33	22.88
3	BASMATI-372A-G	3.68	22.74	75.34	26.12	19.67
4	BASMATI-375-E	3.63	25.38	86.89	23.85	20.73
5	BASMATI-375-F	3.49	24.68	86.19	25.84	22.27
6	BASMATI-376-C	4.41	21.60	83.55	24.78	20.71
7	BASMATI-377-A	3.65	19.07	80.05	25.09	20.09
8	BASMATI-5836-C	3.53	20.33	86.65	21.18	18.35
9	BASMATI-5836-E	3.61	22.41	85.24	24.66	21.02
10	BASMATI-5836-F	3.45	21.92	74.33	26.33	19.57
11	BASMATI-5853	3.26	19.97	79.33	26.74	21.21
12	BASMATI-5874-A	2.96	18.70	73.17	33.75	24.69
13	BASMATI-5874-B	2.79	21.06	77.85	30.07	23.40
14	BASMATI-5875-C	3.20	21.09	95.66	26.87	25.27
15	BASMATI-5875-D	2.57	22.42	91.35	26.02	23.77
16	BASMAT-5875-E	2.43	23.29	73.69	32.22	23.74
17	BASMATI-5875-G	2.57	21.62	76.10	30.77	23.41
18	BASMATI-5877-A	2.83	20.51	90.25	20.68	18.66
19	BASMATI-5877-B	2.45	20.10	85.44	24.81	21.20
20	BASMATI-5888-E	2.48	22.29	73.70	29.46	21.71
21	BASMATI-6113-A	2.82	22.91	73.54	34.45	25.98
22	BASMATI-6113-B	3.48	24.21	72.10	34.26	24.70
23	BASMATI-6129-A	3.67	21.59	79.03	35.45	23.52
24	BASMATI-6129-B	2.77	21.77	79.40	29.03	23.05
25	BASMATI-6129-D	3.76	20.36	73.57	32.26	23.73
26	BASMATI-6129-G	2.77	21.32	76.44	30.26	23.13
27	BASMATI-6141-A	2.68	23.34	72.61	29.98	21.77
28	BASMATI-6141-B	3.28	22.89	71.59	28.52	20.42
29	BASMATI-6311-C	3.49	21.50	78.32	25.81	20.22
30	BASMATI-6313-B	3.60	19.22	76.14	26.42	20.12
31	BASMATI C-621-A	3.47	22.13	82.30	26.04	21.43
32	BASMATI C-621-B	3.42	19.50	83.84	25.25	21.17
33	BASMATI C-621-C	3.10	20.93	84.07	25.94	21.81
34	BASMATI C-622-I	3.32	22.92	73.43	26.63	19.56
35	BASMATI MEHTRAH-A	3.08	19.58	73.32	30.88	22.65
36	BASMATI NORAT-439-A	3.22	20.33	76.25	30.27	23.08
37	BASMATI NORAT-439-B	3.21	21.55	72.72	29.34	21.34
38	BASMATI NORAT-439-C	3.49	20.76	73.76	28.80	21.24
39	BASMATI-SUFAID-187-A	3.46	20.71	79.29	25.65	20.34
40	BASMATI-SUFAID-187-B	4.20	20.48	73.67	25.00	18.42
41	BASMATI-SUFAID-187-E	4.05	20.47	77.34	28.26	21.85
42	BASMATI SURAKH-A	4.19	22.03	74.55	27.52	20.51
43	BASMATI SURAKH-B	3.43	20.83	73.09	30.55	22.33
44	BASMATI TALL-C	3.74	20.89	74.35	28.21	20.97
45	BASMATI TALL-D	3.27	21.55	74.17	28.47	21.11
46	PAK BASMATI-A	2.96	21.29	77.64	27.88	21.65
47	SATHI BASMATI-B	3.40	20.59	73.57	29.18	21.47
48	BASMATI-G	2.93	22.89	77.18	27.60	21.30
49	BASMATI-1-H	3.30	18.24	72.33	27.45	19.86
50	BASMATI-1-I	2.75	19.51	72.98	26.80	19.55
	Mean	**3.27**	**21.38**	**77.78**	**27.94**	**21.62**
	Min	2.43	18.24	70.78	20.68	18.35
	max	4.41	25.38	95.66	35.45	25.98
	SE(d)	0.19	0.50	0.71	0.59	0.41
	C.D.	0.37	0.99	1.40	1.17	0.81
	C.V.	6.92	2.85	1.11	2.59	2.31

Table 5. Mean performance of physiological and biochemical traits recorded.

S. No.	Germplasm	Chlorophyll content	Protein content (%)	Amylose Content (%)

1	BASMATI-372A-E	34.37	11.95	22.86
2	BASMATI-372A-F	35.67	11.85	21.4
3	BASMATI-372A-G	35.80	12.63	21.56
4	BASMATI-375-E	37.80	9.76	20.49
5	BASMATI-375-F	43.00	12.10	21.26
6	BASMATI-376-C	33.70	13.31	19.23
7	BASMATI-377-A	43.87	9.79	24.17
8	BASMATI-5836-C	38.60	10.20	16.98
9	BASMATI-5836-E	33.73	10.31	21.52
10	BASMATI-5836-F	35.97	8.84	18.82
11	BASMATI-5853	32.37	10.08	21.92
12	BASMATI-5874-A	35.77	9.38	22.39
13	BASMATI-5874-B	44.53	10.01	18.11
14	BASMATI-5875-C	44.87	9.43	20.81
15	BASMATI-5875-D	42.90	8.39	19.94
16	BASMAT-5875-E	45.13	9.84	21.15
17	BASMATI-5875-G	42.97	8.95	17.08
18	BASMATI-5877-A	34.50	10.19	25.97
19	BASMATI-5877-B	36.90	10.47	26.23
20	BASMATI-5888-E	43.40	12.19	21.85
21	BASMATI-6113-A	38.37	10.00	30.37
22	BASMATI-6113-B	43.27	9.78	32.6
23	BASMATI-6129-A	40.67	8.83	29.2
24	BASMATI-6129-B	38.50	8.63	17.52
25	BASMATI-6129-D	35.37	8.44	22.72
26	BASMATI-6129-G	36.90	8.26	17.76
27	BASMATI-6141-A	35.80	9.00	24.62
28	BASMATI-6141-B	37.83	8.51	25.2
29	BASMATI-6311-C	36.03	8.43	24.75
30	BASMATI-6313-B	37.90	9.66	23.3
31	BASMATI C-621-A	39.00	9.79	18.81
32	BASMATI C-621-B	43.50	9.83	18.72
33	BASMATI C-621-C	40.73	8.56	23.15
34	BASMATI C-622-I	34.53	9.40	31.56
35	BASMATI MEHTRAH-A	38.20	10.10	16.02
36	BASMATI NORAT-439-A	32.23	8.59	22.71
37	BASMATI NORAT-439-B	36.50	8.47	24.4
38	BASMATI NORAT-439-C	36.00	8.65	23.71
39	BASMATI-SUFAID-187-A	42.13	9.91	27.85
40	BASMATI-SUFAID-187-B	43.37	9.80	15.97
41	BASMATI-SUFAID-187-E	42.03	9.77	22
42	BASMATI SURAKH-A	39.50	9.77	29.76
43	BASMATI SURAKH-B	38.47	10.78	25.76
44	BASMATI TALL-C	38.17	8.38	24.4
45	BASMATI TALL-D	40.37	8.29	21.57
46	PAK BASMATI-A	39.73	11.19	22.84
47	SATHI BASMATI-B	34.37	13.25	25.82
48	BASMATI-G	44.10	12.43	20.68
49	BASMATI-1-H	32.70	10.61	17.08
50	BASMATI-1-I	35.93	10.70	22.11
	Mean	**38.56**	**9.95**	**22.6**
	Min	32.23	8.26	15.97
	max	45.13	13.31	32.6
	SE(d)	0.73	0.37	0.32
	C.D.	1.44	0.74	0.86
	C.V.	2.30	4.59	3.43

Table: 4.6 Mean performance of physiological and biochemical traits

S.NO	**Name of variety**	**Gel Consistency**		**Alkali spreading value**	
		Score (mm)	**Disintegation**	**Score**	**Degradation**
1	BASMATI-372A-E	92.3	Soft	3	Affected
2	BASMATI-372A-F	87.6	Soft	4	Affected
3	BASMATI-372A-G	91.4	Soft	5	Dispersed
4	BASMATI-375-E	58.3	Medium	3	Affected
5	BASMATI-375-F	40.2	Medium	4	Affected
6	BASMATI-376-C	53.6	Medium	3	Affected
7	BASMATI-377-A	66.2	Medium	2	Not Affected
8	BASMATI-5836-C	40.3	Medium	3	Affected
9	BASMATI-5836-E	45.8	Medium	3	Affected

10	BASMATI-5836-F	38.9	Hard	4	Affected
11	BASMATI-5853	43.5	Medium	2	Not Affected
12	BASMATI-5874-A	90.3	Soft	3	Affected
13	BASMATI-5874-B	87.8	Soft	3	Affected
14	BASMATI-5875-C	49.7	Medium	3	Affected
15	BASMATI-5875-D	58.2	Medium	3	Affected
16	BASMAT-5875-E	71.4	Soft	3	Affected
17	BASMATI-5875-G	52.5	Medium	4	Affected
18	BASMATI-5877-A	79.5	Soft	4	Affected
19	BASMATI-5877-B	77.2	Soft	4	Affected
20	BASMATI-5888-E	55.8	Medium	5	Dispersed
21	BASMATI-6113-A	62.5	Medium	4	Affected
22	BASMATI-6113-B	58.3	Medium	4	Affected
23	BASMATI-6129-A	40.5	Hard	4	Affected
24	BASMATI-6129-B	62.8	Medium	3	Affected
25	BASMATI-6129-D	75.7	Soft	5	Dispersed
26	BASMATI-6129-G	72.9	Soft	4	Affected
27	BASMATI-6141-A	49.5	Medium	4	Affected
28	BASMATI-6141-B	41.3	Medium	4	Affected
29	BASMATI-6311-C	38.3	Hard	4	Affected
30	BASMATI-6313-B	45.2	Medium	3	Affected
31	BASMATI C-621-A	51.5	Medium	3	Affected
32	BASMATI C-621-B	58.6	Medium	2	Not Affected
33	BASMATI C-621-C	62.3	Medium	3	Affected
34	BASMATI C-622-I	47.4	Medium	2	Not Affected
35	BASMATI MEHTRAH-A	75.2	Soft	2	Not Affected
36	BASMATI NORAT-439-A	84.5	Soft	2	Not Affected
37	BASMATI NORAT-439-B	85.4	Soft	2	Not Affected
38	BASMATI NORAT-439-C	89.2	Soft	4	Affected
39	BASMATI-SUFAID-187-A	56.3	Medium	3	Affected
40	BASMATI-SUFAID-187-B	71.9	Soft	4	Affected
41	BASMATI-SUFAID-187-E	66.7	Medium	3	Affected
42	BASMATI SURAKH-A	76.5	Soft	3	Affected
43	BASMATI SURAKH-B	71.6	Soft	2	Not Affected
44	BASMATI TALL-C	79.2	Soft	3	Affected
45	BASMATI TALL-D	75.5	Soft	4	Affected
46	PAK BASMATI-A	58.3	Medium	2	Not Affected
47	SATHI BASMATI-B	39.7	Hard	3	Affected
48	BASMATI-G	35.3	Hard	3	Affected
49	BASMATI-1-H	32.8	Hard	2	Not Affected
50	BASMATI-1-I	31.8	Hard	4	Affected

CONCLUSION

Diversity is prerequisite for any crop improvement program as it helps in the development of superior recombinants. Diversity offers a range of selections to breeders that may produce superior rice varieties and contribute to targeted crop improvement. The present study aimed to assess the diversity of aromatic rice genotypes and the obtained knowledge which could be utilized further in breeding programme for crop improvement. It will be important in the future of plant breeding as it helps develop crops that can adapt to climate change, agronomical traits, higher yield, speed flower over different aspects and meet food demand with sustainable agriculture .

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