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Genetic variability, trait association studies for quality trait in short grain aromatic rice (*Oryza sativa* L.)

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Abstract
During Kharif 2020, twenty-two rice genotypes were assessed for quality-attributing attributes at a Banaras Hindu University (BHU) agriculture research farm. For quality traits like kernel length, kernel breadth, l:b ratio of the kernel, l:b ratio of the cooked kernel, aroma, and elongation ratio, statistical analysis was used to assess genotypic coefficient variation (GCV), phenotypic coefficient variation (PCV), broad-sense heritability, and genetic advance as a percentage of the mean (GAM). For the various characters under investigation, analysis of variance, GCV, and PCV demonstrated significant variation. While kernel length had a substantial positive correlation relationship with the l/b ratio and after cooking kernel length, it had a significant negative relationship with the elongation ratio. Positive and direct effects were found for kernel length, kernel breadth, l/b ratio of the kernel, and elongation ratio among all the characters studied through path analysis, while Negative and direct effects were found for amylose content, kernel length after cooking, kernel breadth after cooking, and l/b ratio of the cooked kernel. Sik Nadiya, Gundari Bhog, Kapoor Bhog, Jeera Phul, Rani Manger, J R 32, Kalanamak Bhu, Chak Hao Angoubi-4, and Govind Bhog 5 genotypes were identified as having strong aroma.

Keywords: PCV, GCV, correlation, path analysis, h^2, genetic advance as percentage of mean, grain quality traits, rice

Introduction
Rice (*Oryza sativa* L.) is an important and one of the staple food crops in the world and a rich source of calories and protein for more than half of the world's population, notably in the eastern hemisphere, i.e. South East Asia. Rice cultivation covers 164.19 million hectares, yielding 509.87 million metric tonnes globally (FAO, 2021) [8]. Rice is grown on 45 million hectares in India, with a production of 121.46 million tonnes and productivity of 2756 kg/ha (DAC&FW 2021) [4]. Rice is grown in 70 districts of Uttar Pradesh, covering roughly 5.67 million hectares (12.95 percent of the country), with a production of 13.65 million tonnes and productivity of 21.2 hectares per hectare (FAOSTAT, 2017). Due to the development of improved inbred and hybrid cultivars, irrigation facilities, modern management techniques, synthetic fertilizers, and pesticides, rice production and productivity have increased dramatically since the insurgency of the green revolution. The qualitative attributes that raise the whole economic worth of rice, on the other hand, continue to be overlooked. As many nations throughout the world have achieved rice self-sufficiency, and as people's living standards have improved (Rathi *et al.* 2010) [19], consumer demand for higher-quality rice has risen, making it necessary to breed consumer-preferred rice with desired grain properties all over the world. Rice grain quality is a multifaceted property that encompasses all of the grain's properties and traits. The quality trait of the rice grain is a complex trait that encompasses all of the traits and properties of rice or rice products that match consumer wants and preferences. The fragrance (aroma), form, cooking quality, color, nutritional contents, and milling all contribute to the quality of grain *viz*. Grain size, shape, translucency, and chalkiness are all factors that influence appearance. Rice has a gel consistency (GC) that makes it good for eating and cooking, the gelatinization temperature (GT) and amylose concentration (AC) are both influenced by the starch's composition and structure. Rice quality is difficult to quantify because quality preferences vary from country to country, geographical region to geographical region, and even within the area of the same country. Both consumers and farmers prefer short-grain aromatic rice, particularly in East Uttar Pradesh. Short grain is preferred because it turns sticky and soft after cooking. The discovery and selection of desirable short grain aromatic parents that differ in genetic value are crucial for improving the genetic value of existing cultivars. The current farming practice is heavily reliant on chemicals and fertilizers.

The intensive cropping effect has resulted in a deterioration of soil fertility caused by a decrease in soil organic matter content, along with the deterioration of human health. As a result, organic conditions should be examined on these selected lines.

Materials and Methods

During Kharif 2020, the current study was conducted at the Banaras Hindu University (BHU) agriculture research farm. In a randomized complete block design with three replications, 22 rice genotypes (Table 1), including short grain aromatic rice, were used. Each genotype was planted in a 4 m^2 area. Clay loam with a pH of 6.00 was the soil type. Recommended management measures were followed uniformly for all the replications. Kernel length, kernel width, kernel l:b ratio, kernel length after cooking, kernel breadth after cooking, cooked kernel l:b ratio, amylose content, and fragrance (aroma) content were the parameters evaluated under quality attributed characters (Juliano, 1971). The genetic variances, broad-sense heritability, correlation, and direct and indirect effects of numerous attributes were all calculated.

Panse and Sukhatme (1985) employed ANOVA, Burton (1952) [1] used PCV and GCV, Johnson *et al.* (1955) [9] used simple correlation, while Dewey and Lu used path analysis (1959) [5]. The genetic characteristics (GCV, PCV, broad-sense heritability, and genetic advance as percent of mean). WINDOWSTAT was used to analyze the data that was generated.

Table 1: List of genotypes used in this study

1.	Tulsi Manger	12.	Gangai Phul
2.	Java Phul	13.	Kalanamak Namak
3.	Sik Nandiya	14.	Govind Bhog
4.	Gundari Bhog	15.	J R 32
5.	Kala Jeera	16.	Rajendra Kasturi
6.	Aadam Chini	17.	Kalanamak Bhu
7.	Badshah Bhog	18.	Chak Hao Poireiton 1
8.	Thakur Bhog	19.	Chak Hao Amubi-2
9.	Kapoor Bhog	20.	Chak Hao Sempak-3
10.	Rani Manger	21.	Chak Hao Angoubi-4
11.	Jeera Phul	22.	Govind Bhog-5

Result and Discussion

Any plant breeding effort must be based on the presence of genetic variability. The results of the analysis of variance (Table 2) revealed significant variation for each of the quality criterion features. Roy *et al.* discovered a similar type of variation (2009) [16].

Among the quality contributing characteristics, the genotypic coefficient of variation ranged from 0.93 to 23.76 percent. Aroma content had high GCV and PCV (Table 3), while the remainder of the characters had low GCV and PCV values. The magnitude of GCV and PCV values was characterized as low (less than 10%), moderate (10-20%), and high (more than 20%) (Sivasubramanian and Madhavamenon, 1973) [20]. Kernel L/B ratio, kernel breadth, kernel length after cooking, kernel breadth after cooking, and elongation ratio all had very low GCV and PCV values. Dhurai *et al.* (2014) [7]. published a similar report. Kernel length, L/B ratio of the cooked kernel, and amylose content all showed moderate GCV and PCV. Plant height, kernel length after cooking, L/B ratio, kernel length, elongation ratio, and panicle length all displayed moderate to low PCV and GCV values, according to Chandra *et al.* (2009) [3]. GCV and PCV levels were found to be high between aromas.

Kernel length (0.99), Kernel breadth (0.99), Kernel length after cooking (0.99), Kernel breadth after cooking (0.99), Amylose content (0.99), L:B ratio of Cooked kernel (0.99), Aroma (0.96), Elongation ratio (0.99), and L/B ratio (0.10) all had strong heritability in this study (Table 3). High heritability isn't enough to produce significant progress through selection in one generation unless it's accompanied by significant genetic progress. Aroma, amylose content, l/b ratio of the cooked kernel, kernel length, and kernel breadth after cooking were all assessed as having high heritability along with high GAM. Roy *et al.* (2021) [15] reported comparable results for amylose content, kernel breadth after cooking, kernel breadth, l/b ratio of the cooked kernel, and l/b ratio of the kernel. Dhanwani *et al.* (2013) [6] obtained comparable results for kernel l:b ratio and cooked kernel breadth after cooking. The elongation ratio, kernel length after cooking, and kernel breadth all showed high heritability and moderate genetic progress. According to Chakraborty *et al.* (2009) [2], In the cooking quality aspects of a gel consistency, cooked rice kernel width, and cooked rice kernel breadth-wise elongation ratio, there was high heritability and moderate genetic progress. For the l/b ratio, there was a low heritability coupled with low GAM. Strong aromas were discovered in Badshah Bhog, Sik Nandiya, Kundari Bhog, Kapoor Bhog, Rani Manger, Jeera Phul, J R 32, Kalanamak Bhu, and Govind Bhog-5 in the current investigation. The aroma (Table 6) will be scored by the panel of 5 judges as, 1 = strong, 2 = medium and 3 = absent as per the protocol of Sood and Siddiq (1978) [21]. Sahu *et al.* (2015) [17], found that the Badshah Bhog has a strong scent.

Table 2: Analysis of variance (ANOVA) for quality traits in short grain aromatic rice

Source of variation	D. f.	Mean sum of square (MSS)								
		Kernel length	Kernel breadth	L/B ratio	Kernel length after cooking	Kernel breadth after cooking	Amylose content	L: B ratio of Cooked kernel	Aroma	Elongation ratio
Replication	2	0.105	0.0001	0.010	1.176	0.225	4.749	0.003	0.246	0.108
Genotype	21	0.558**	0.043**	0.104**	0.864**	0.215**	43.101**	0.095**	0.534**	0.044**
Error	42	0.039	0.001	0.013	0.141	0.056	0.486	0.016	0.152	0.012

*,** Significant at 5%, and 1% level of probability, respectively.

Table 3: Mean, range, GCV, PCV, heritability, and genetic advance for short grain aromatic rice

Traits	Mean	Range		GCV	PCV	Heritability (broad sense)	Genetic advance as % of the mean (GMA)
		Minimum	Maximum				
Kernel length	4.21	3.47	5.26	11.18	11.18	0.99	23.01
Kernel breadth	1.89	1.71	2.21	7.04	7.06	0.99	14.45

L/B ratio	2.25	1.98	2.71	0.93	2.85	0.10	0.634
Kernel length after cooking	7.07	6.30	8.66	7.85	7.88	0.99	16.12
Kernel breadth after cooking	3.36	3.01	4.07	9.90	9.92	0.99	20.33
Amylose content	20.02	8.30	22.98	19.51	19.52	0.99	40.17
L:B ratio Cooked kernel	2.12	1.78	2.55	12.13	12.19	0.99	24.87
Aroma	1.69	1.10	2.63	23.76	24.20	0.96	48.06
Elongation ratio	1.69	1.54	1.87	8.54	8.58	0.99	17.52

Table 4: Estimation of genotypic correlation coefficient among nine quality attributing characters in short grain aromatic rice

Traits	Amylose content	Kernel length	Kernel breadth	Kernel length/ breadth ratio	Kernel length after cooking	Kernel breadth after cooking	L/ B of cooked kernel	Elongation ratio
Amylose content	1.0000	0.0371	0.2710	-0.1532	-0.0062	-0.3440	0.4128	0.0282
Kernel length		1.0000	0.4625	0.7465**	0.8582**	0.4079	0.4240	-0.6681**
Kernel breadth			1.0000	-0.2690	0.3042	0.1589	0.1025	-0.4201
Kernel length/breadth				1.0000	0.6354**	0.2557	0.3650	-0.4954*
Kernel length after cooking					1.0000	0.2950	0.6909**	-0.1824
Kernel breadth after cooking						1.0000	-0.4843	-0.3381
L/B of cooked kernel							1.0000	0.1759
Elongation ratio								1.0000
Aroma content	0.0879	-0.1597	0.0964	-0.1725	-0.3983	-0.4603	-0.1122	-0.3744

** significant at a 1% probability level.

Kernel length had a substantial positive correlation with the L/B ratio of the kernel and kernel length after cooking, but a significant negative correlation with the elongation ratio. Krishna *et al.*, (2013) showed that the kernel length had a significant positive correlation with the L/B ratio and kernel length after cooking, whereas kernel width had a significant negative correlation with the L/B ratio (Table 4). Singh *et al.* (2017) [18] found a significant and positive correlation between kernel length and the l/b ratio of the kernel and kernel length after cooking, and Kumar *et al.* (2019) also found a significant and positive correlation between kernel length and the l/b ratio of the kernel and kernel length after cooking. Nayak *et al.*, (2001) and Nayak and Reddy, (2005) [11] both found a favorable correlation between kernel length and kernel L/B ratio. Kernel length after cooking had a substantial positive correlation with the cooked kernel's L/B ratio. Roy *et al.* (2021) [15] reported a similar outcome. After cooking, the L/B ratio of kernels showed a strong positive correlation with kernel length, while the elongation ratio showed a negative and significant correlation. Krishna *et al.* (2013) found the L/B ratio was shown to have a significant positive correlation with kernel length after heating and elongation ratio. The attribute fragrance (aroma) content, on the other hand, showed no significant correlation. Kernel length had a strong negative correlation with the elongation ratio.

According to correlation analysis, kernel length after cooking appeared to be the key contributing factor, which could be useful in genotype selection.

Kernel length, kernel width, kernel l/b ratio, and elongation ratio all had a positive and direct effect on aroma content (Table 5). Kernel breadth was found to have a favorable and direct effect (Roy *et al.*, 2021) [15], Priyanka *et al.* (2020), and Kumar *et al.* (2016) [13] found that the kernel length has a favorable and direct effect, while Kumar *et al.* (2012) reported Amylose content, kernel length after cooking, kernel breadth after cooking, and the l/b ratio of cooked kernel all had a negative and direct effect. Roy *et al.* (2021) [15] found that amylose content, kernel width after cooking, kernel length, and the l/b ratio of the cooked kernel had negative and direct effects. Naik *et al.* (2021) [10] discovered that amylose content and LER have both negative and direct effects.

Path analysis divides the correlation coefficient into direct and indirect effects, allowing for the identification of effective qualities for further development. Path analysis demonstrated that the kernel L/B ratio, kernel width, kernel length, and elongation ratio were reliable for the selected program in this study.

The residual effect observed was on the upper side, at (0.8369), indicating that the traits included in the study only explain 16.31% of the phenotypic variation, implying that more traits should be included in the study.

Table 5: Genotypic path coefficient analysis showing the direct and indirect effects of quality attributing characters in short grain aromatic rice

Traits	Amylose content	Kernel length	Kernel breadth	Kernel length/ breadth ratio	Kernel length after cooking	Kernel breadth after cooking	L/ B of cooked kernel	Elongation ratio
Amylose content	-0.5526	-0.0205	-0.1497	0.0846	0.0034	0.1901	-0.2281	-0.0156
Kernel length	0.1147	3.0905	1.4293	2.3072	2.6521	1.2607	1.3103	-2.0648
Kernel breadth	0.7531	1.2853	2.7791	-0.7475	0.8453	0.4416	0.2848	-1.1675
Kernel length/breadth	-0.5656	2.7566	-0.9932	3.6925	2.3460	0.9442	1.3476	-1.8291
Kernel length after cooking	0.0211	-2.9141	-1.0328	-2.1575	-3.3958	-1.0018	-2.3461	0.6193
Kernel breadth after cooking	0.4397	-0.5213	-0.2031	-0.3268	-0.3770	-1.2781	0.6190	0.4321
L/B of cooked kernel	-0.5415	-0.5562	-0.1344	-0.4788	-0.9063	0.6354	-1.3118	-0.2307
Elongation ratio	0.0884	-2.0945	-1.3170	-1.5530	-0.5717	-1.0600	0.5514	3.1350
Aroma content	0.0879	-0.1597	0.0964	-0.1725	-0.3983	-0.4603	-0.1122	-0.3744
Partial R^2	-0.0486	-0.4937	0.2678	-0.6369	1.3527	0.5883	0.1472	-1.1737

R SQUARE = 0.2996 RESIDUAL EFFECT = 0.8369

Table 6: Assessment of aroma in 22 short grain aromatic genotypes of rice

S. No.	Genotype	Scent	Judge 1	Judge 2	Judge 3	Judge 4	Judge 5	Mean
1	Tulsi Manger	P	2	2	2	2	1	1.8
2	Java Phul	P	3	3	3	2	3	2.8
3	Sik Nandiya	P	1	1	1	1	2	1.2
4	Gundari Bhog	P	1	1	1	1	2	1.2
5	Kala Jeera	P	3	3	3	2	3	2.8
6	Aadam Chini	P	2	2	1	2	2	1.8
7	Badshah Bhog	P	1	1	2	2	1	1.4
8	Thakur Bhog	P	2	2	2	1	2	1.8
9	Kapoor Bhog	P	1	1	1	1	2	1.2
10	Rani Manger	P	1	1	1	2	2	1.4
11	Jeera Phul	P	1	1	1	2	1	1.2
12	Gangai Phul	P	2	2	1	2	2	1.8
13	Kalanamak Namak	P	2	2	2	1	2	1.8
14	Govind Bhog	P	2	2	1	2	2	1.8
15	J R 32	P	1	1	1	2	1	1.2
16	Rajendra Kasturi	P	2	2	1	2	2	1.8
17	Kalanamak Bhu	P	1	1	1	1	2	1.2
18	Chak Hao Poireiton 1	P	2	2	2	1	1	1.6
19	Chak Hao Amubi-2	P	2	1	2	2	2	1.8
20	Chak Hao Sempak-3	P	2	2	2	1	3	2
21	Chak Hao Angoubi-4	P	1	1	1	2	2	1.4
22	Govind Bhog-5	P	1	1	1	1	2	1.2

Conclusion

The inclusive result indicates that there is an adequate genetic variability found in the studied materials. The character L/B ratio of kernel with low heritability with low genetic advance indicating the character is influenced by environmental effect and hence, selection might not be useful than heterosis breeding will be useful in improving this trait.

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