Received: 01 Sep 2023 | Revised: 13 Sep 2023 | Accepted: 28 Sep 2023

Electronic Journal of Plant Breeding

Research Article

Genetic variability and association studies for yield and quality characters in BC_3F_2 generation of rice (*Oryza sativa* L.)

A. Kalaivani[1], R. Pushpam[1*], R. Suresh [1], M. Raveendran[2] and A. Senthil [3]

[1]Department of Rice, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, India
[2]Department of Biotechnology, Centre for Plant Molecular Biology and Biotechnology, Tamil Nadu Agricultural University, Coimbatore, India
[3]Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore, India
***E-Mail**:pushpamtnau@gmail.com

Abstract
The aim of the present study was to assess the degree of genetic variation, heritability, and character relationship among yield, yield attributing and grain quality parameters in BC_3F_2 of CO 52 x APD19002 population. In the current study, number of total tillers per plant, number of productive tillers per plant, flag leaf length, number of filled grains per panicle and single plant yield showed high PCV and GCV. It became evident that there exists a highly significant and positive association between single plant yield and number of productive tillers per plant followed by number of tillers, flag leaf length, plant height, spikelet fertility and test weight. The path coefficient analysis showed that number of productive tillers per plant had high positive direct effect on single plant yield followed by flag leaf length, kernel length, KBAC and LER. The results indicate the number of productive tillers per plant and flag leaf length were identified as the key contributing traits as they are highly heritable and simultaneous consideration of these traits is important for crop improvement. It implies that flag leaf provides more photosynthates to grains along with number of productive tillers per plant which in turn increases the grain yield.

Keywords: Rice, genetic variability, correlation and path association

INTRODUCTION

Rice is the second most widely grown cereal crop in the world and it is known to be staple food source for more than half of the world's population. This makes it a key player to fight against world hunger (Salleh *et al*., 2022). Rice signifies sustenance for human beings, particularly in the Asian subcontinent, which is considered as "Rice Basket" of the world, as it covers 90 percent of the globe's rice area (Alshiekheid *et al*., 2023). The phrase "rice is life" is most appropriate in the case of India because it provides the foundation of livelihood for millions of rural families and is crucial to the nation's food security (Mahajan *et al.,* 2017). Rice yield is a complex trait that is influenced by many factors, including morphological and physiological characteristics. The yield levels of existing rice varieties have plateaued in recent years. This is due to a number of factors, including climate change, soil health issues, and suboptimal crop management practices. In order to sustain rice production, it is important to develop rice varieties with increased yield potential in both adverse and normal conditions (Lipi *et al*., 2020).

The presence of variability for the aimed trait and the skill of the plant breeder during selection determines the success of plant breeding activities (Adhikari *et al*., 2018). Plant breeders must consider different types of genetic variability parameters, *viz.,* the genotypic coefficient of variability (GCV), the phenotypic coefficient of variability (PCV), heritability, and genetic advance, when developing new varieties. Correlation and path coefficients are statistical tools that can be used to understand the relationships between different traits (Bitew *et al*., 2023). Correlation coefficients measure the strength of the relationship between two traits, while path coefficients measure the direct and indirect effects of one trait on another. Both analyses used to identify the important traits and superior genotypes (Islam *et al*., 2020).

Breeders must comprehend the degree of variation, inheritance and association of key agronomic traits. Hence, the aim of the present study was to analyse the degree of genetic variation, heritability and character relationship among yield and yield-attributing parameters in BC_3F_2 of CO 52×APD 19002 population.

MATERIALS AND METHODS

The present research was conducted in Department of Rice during Summer 2023 in order to assess the existence and range of genetic variability in BC_3F_2 plants. Department of Rice situated in TNAU, Coimbatore is located at an altitude of 426.72 m above the mean sea level and at a latitude of 11° N and longitude of 77° E. A total of 534 BC_3F_2 plants from the cross CO 52 x APD19002 which harbours the two most important abiotic stress tolerant QTLs such as salinity (*Saltol*) and drought (*qDTY1.1* and *qDTY2.1*) were involved in this study. Fourteen quantitative traits *viz*., plant height (cm), days to first flowering (days), chlorophyll content index (using Chlorophyll content meter), flag leaf length (cm), total number of tillers per plant, number of productive tillers per plant, panicle length (cm), number of filled grains per panicle, spikelet fertility (%), thousand grain weight (g) and single plant yield (g) were observed on single plant basis. Similarly, eight grain quality parameters such as kernel length before cooking (mm), kernel breadth before cooking (mm), kernel length – breadth ratio (L/B), kernel length after cooking (mm), kernel breadth after cooking (mm), linear elongation ratio (LER), breadth wise expansion ratio (BER) and alkali spreading value (ASV) were also recorded for each plant as per IRRI SES-1993. Genetic parameters were analysed using Statistical Tool for Agricultural Research (STAR - Version: 2.0.1). The environmental variance was determined from parents which are raised in replicated. The formula proposed by Lush (1940) were used to determine the broad sense heritability while genetic advance in mean percent was calculated by the technique Johnson *et al*. (1955). Correlation and path analysis were done by using TNAUSTAT (Manivannan, 2014) and Grapes KAU, respectively.

RESULTS AND DISCUSSION

In terms of crop improvement, the estimation of genetic diversity variability and association studies are its mean performances became more important inevitable factors for any crop improvement programme. Eleven biometrical and eight grain quality features traits found in the BC_3F_2 segregating population underwent genetic analysis, correlation studies and path analysis.

In this study, the GCV was slightly lower than the PCV for most of the traits (**Table 1)**. This indicates the relatively small effect of environmental factors on the variation of these traits. However, the narrow difference between PCV and GCV suggests that the genotypes of the plants had a significant influence on the expression of these traits. High PCV and GCV were observed for the traits *viz.,* total number of tillers, number of productive tillers per plant, flag leaf length, number of filled grains per panicle and single plant yield. Traits with high PCV and GCV are likely to be under additive gene action, which means that the effects of genes on the traits are additive. The additive nature of these traits provides an opportunity for selection. These results are consistent with the findings of Manojkumar *et al*. (2022), Basu *et al*. (2022), Thúy *et al*. (2022), Prathiksha *et al*. (2022) Almas Fathima *et al*. (2021) and Somtochukwu *et al*. (2021). Moderate PCV was found in traits like plant height and panicle length which were in accordance with Manojkumar *et al*. (2022). Moderate GCV was observed in spikelet fertility and alkali spreading value (ASV). Such traits can be improved through selection in later generations. Low PCV and GCV were observed for test weight, kernel length before cooking (KLBC), kernel breadth before cooking (KBBC), kernel length – breadth ratio, kernel length after cooking (mm), kernel breadth after cooking (mm), linear elongation ratio and breadth wise expansion ratio. Low GCV and PCV were due to the narrow genetic base. These characteristics can be improved by broadening the genetic pool using hybridization or induced mutagenesis, combined with pedigree selection in subsequent generations. These results are in agreement with by Srihari *et al*. (2023) and Prathiksha *et al*. (2022). The consideration of both PCV and GCV holds significance in the selection process because specific genes manifest themselves when favourable environmental conditions prevail (Singh *et al*., 1974).

Traits such as number of productive tillers, flag leaf length, ASV and single plant yield displayed high heritability coupled with high genetic advance as percent of mean (GAM). These characters are governed by additive gene action with less environmental influence and selection will be rewarding. Similar findings were reported by Srihari *et al*. (2023) and Kulsum *et al*. (2022) for flag leaf length; Manojkumar *et al*. (2022) and Prathiksha *et al*. (2022) for number of productive tillers and single plant yield; Sao and Gauraha, (2020) and Basu *et al*. (2022) for ASV. High heritability and moderate genetic advance as per cent of mean was observed for kernel length after cooking (KLAC). High heritability and moderate GAM are the outcome of both additive and non-additive gene action for the trait. High heritability accompanied with low GAM was observed in kernel

Table 1. Estimates of genetic parameters for yield, yield attributing and grain quality traits

Characters	Mean	Range	VP	VG	PCV (%)	GCV (%)	Heritability (%)	GA	GAM	Skewness	Kurtosis
PH (cm)	105.00	24.40	12.85	4.44	12.24	4.23	34.53	9.14	8.70	-1.54**	5.55**
DFF	96.11	30.00	21.56	5.60	22.43	5.83	25.97	11.54	12.00	1.61**	3.80**
CCI	19.94	9.60	6.86	1.35	34.39	6.77	19.70	2.78	13.95	0.001	-1.12**
NT	19.43	37.00	35.86	16.50	184.55	84.93	46.02	34.00	174.95	0.72**	1.04**
NPT	14.69	31.00	25.21	16.29	171.62	110.88	64.61	33.55	228.42	0.68**	0.44**
FLL (cm)	31.26	24.00	20.19	14.80	64.59	47.34	73.29	30.49	97.51	0.72**	0.15**
PL (cm)	25.99	13.14	3.34	1.87	12.87	7.19	55.90	3.85	14.82	-0.32**	-0.12**
FGPP	214.20	168.00	1237.55	703.27	577.75	328.32	56.83	1448.75	676.34	-0.03	-0.99**
SF (%)	75.43	39.53	59.87	9.74	79.38	12.91	16.27	20.06	26.60	-0.38**	-0.48**
TW (g)	13.89	3.64	0.57	0.31	4.07	2.25	55.16	0.64	4.63	0.069**	-0.860**
KLBC (mm)	5.49	1.60	0.08	0.06	1.50	1.10	73.71	0.12	2.27	-1.45**	1.80**
KBBC (mm)	1.72	0.80	0.02	0.01	1.16	0.47	40.54	0.02	0.97	0.09**	1.09**
L/B	3.21	2.29	0.09	0.02	2.90	0.48	16.63	0.03	0.99	-0.18**	1.88**
KLAC (mm)	7.37	3.20	0.60	0.57	8.16	7.80	95.64	1.18	16.07	0.08**	-0.71**
KBAC (mm)	2.92	1.51	0.09	0.01	3.15	0.21	6.59	0.01	0.43	0.03**	-0.61**
LER	1.34	0.50	0.01	0.01	0.68	0.64	93.78	0.02	1.32	0.26**	-0.56**
BER	1.70	0.92	0.03	0.02	1.72	1.13	65.72	0.04	2.33	0.27**	-0.45**
ASV	2.89	3.00	0.69	0.45	23.93	15.61	65.24	0.93	32.16	-0.30**	-0.56**
SPY (g)	33.60	55.27	82.49	72.00	245.47	214.26	87.29	148.32	441.38	0.90**	1.31**

**. Significant at the 0.01 level

PH - Plant Height, DFF - Days to first flowering, CCI – Chlorophyll content index, NT - Number of total tillers per plant, NPT - Number of Productive Tillers per plant, FLL - Flag leaf length, PL - Panicle Length, FGPP - Filled Grain Per Panicle, SF - Spikelet Fertility, TW - Test weight, KLBC - Kernel Length Before Cooking, KBBC - Kernel Breadth Before Cooking, L/B ratio - Length Breadth Ratio, KLAC - Kernel Length After Cooking , KBAC - Kernel Breadth After Cooking, LER - Linear Elongation Ratio, BER - Breadth wise Expansion Ratio, ASV - Alkali Spreading Value, SPY - Single Plant Yield, VP - Phenotypic variation, VG - Genotypic variation, PCV - Phenotypic coefficient of variation, GCV - Genotypic coefficient of variation, GA - Genetic Advance, GAM - Genetic Advance as percentage of mean

length before cooking, linear elongation ratio and breadth wise expansion ratio. This indicates non additive gene action and selection for such traits may not be effective. Moderate heritability and high GAM were observed in number of tillers. Traits like plant height, panicle length, test weight and KBBC showed moderate heritability and low GAM. Low heritability and high GAM were observed for spikelet fertility. It reveals that Spikelet fertility was governed by few additive genes and selection will be rewarding. Low heritability and low GAM were observed in days to first flowering, chlorophyll content index, L/B ratio and kernel breadth after cooking (KBAC). Similar findings were reported by Prathiksha et.al (2022) for L/B ratio and KBAC, Seneega *et al*. (2019) for KLBC and Sala and Geetha (2015) for LER and BER.

Frequency distribution of yield, yield attributing and quality traits were depicted (**Fig. 1.)**Significant positive skewness was observed for days to first flowering, total number of tillers, number of productive tillers, flag leaf length, test weight, KBBC, KLAC, KBAC, LER, BER and single plant yield. A significant positive skewness and leptokurtic nature of distribution was noticed for days to first flowering, total number of tillers, KBBC and single plant yield which provides an opportunity for selecting superior segregants. Similar findings were reported by Nirubana *et al.* (2019) for days to first flowering, total number of tillers and single plant yield. Significant negatively skewed leptokurtic distribution was detected in plant height, KLBC and L/B. ASV showed significant negative skewness and platykurtic distribution. It infers that the chance of dominance and dominance based duplicate epistasis. Which infers that more than one gene governs such trait. These results are consistent with the findings of Nirubana *et al.* (2019) and Nikhitha *et al.* (2020).

Correlation studies offer breeders a valuable insight into the relationships among different traits, which in turn assist in the identification and selection of superior genotypes. Consequently, gaining a deeper comprehension of how these attributes relate to individual plant yield would enhance the precision and accuracy of

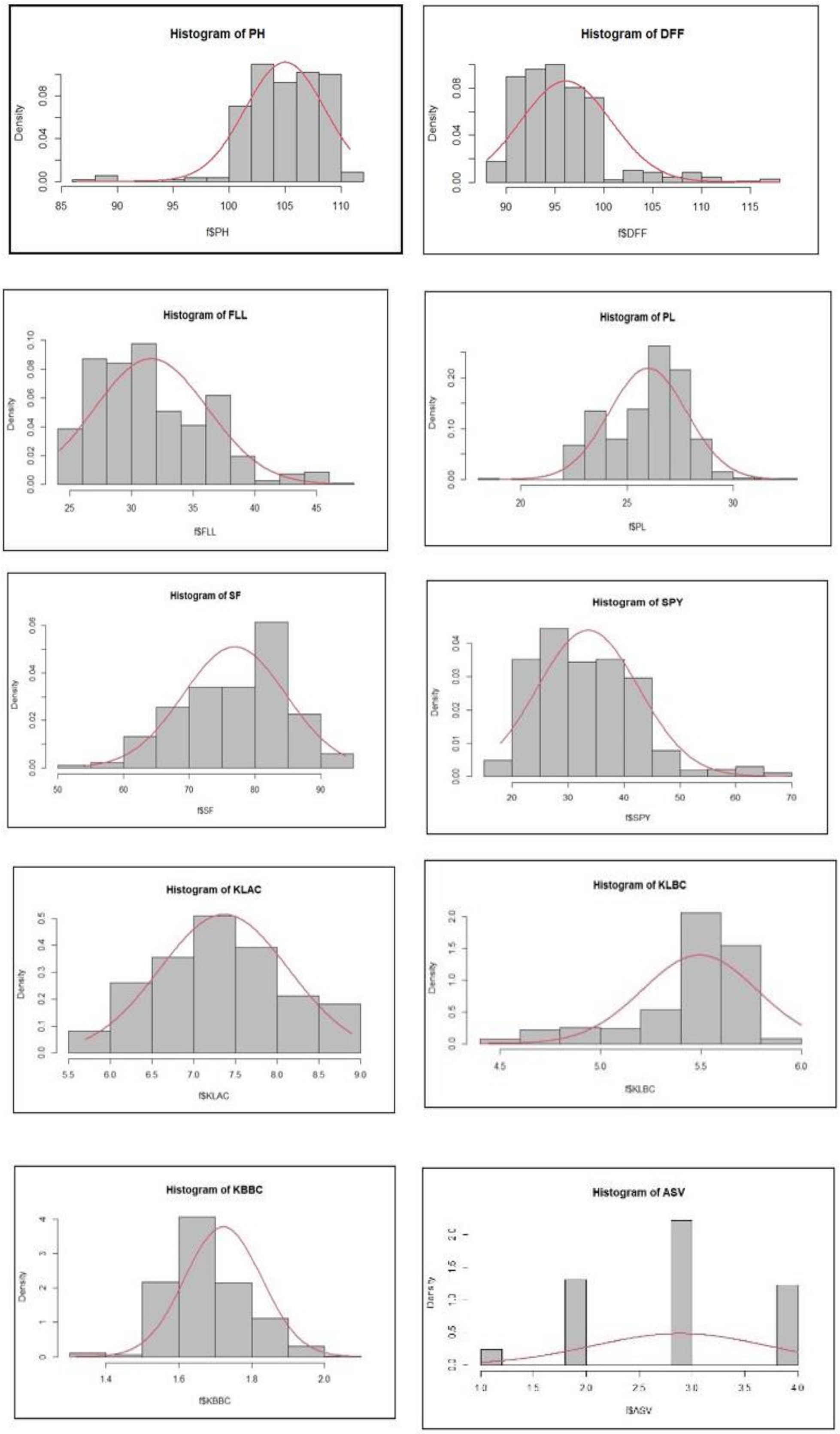

Fig. 1. Frequency distribution of yield, yield attributing and quality traits in BC_3F_2

https://doi.org/10.37992/2023.1403.134

Table 2. Correlation coefficient analysis for yield, yield attributing and grain quality traits

Traits	PH	DFF	CCI	NT	NPT	FLL	PL	FGPP	SF	TW	KLBC	KBBC	L/B	KLAC	KBAC	LER	BER	ASV	SPY
PH	1.000	-0.023	0.033	0.426***	0.438***	0.386***	0.018	-0.007	0.037	0.084	-0.068	-0.036	-0.009	0.014	-0.079	0.066	-0.055	0.016	0.41***
DFF	-0.023	1.000	0.021	-0.020	-0.042	-0.079	0.118**	0.092*	0.029	-0.008	-0.010	0.000	-0.004	-0.050	0.047	-0.066	0.043	0.055	-0.048
CCI	0.033	0.021	1.000	0.063	0.069	0.050	0.051	0.057	0.080	-0.046	-0.069	0.001	-0.034	-0.071	0.020	-0.053	0.018	0.020	0.064
NT	0.426***	-0.020	0.063	1.000	0.918***	0.811***	0.008	0.002	0.255***	0.326***	-0.054	-0.015	-0.015	-0.026	-0.079	0.000	-0.070	0.021	0.889***
NPT	0.438***	-0.042	0.069	0.918***	1.000	0.886***	0.023	0.011	0.263***	0.338***	-0.053	-0.030	-0.005	-0.025	-0.070	0.002	-0.052	-0.001	0.964***
FLL	0.386***	-0.079	0.050	0.811***	0.886***	1.000	0.062	0.014	0.253***	0.313***	-0.052	-0.014	-0.014	-0.015	-0.052	0.018	-0.045	0.025	0.897***
PL	0.018	0.118**	0.051	0.008	0.023	0.062	1.000	0.833***	0.125**	0.000	-0.019	0.011	-0.009	0.033	0.002	0.063	-0.001	0.034	0.047
FGPP	-0.007	0.092*	0.057	0.002	0.011	0.014	0.833***	1.000	0.18***	0.032	-0.028	-0.017	0.005	-0.007	-0.005	0.010	0.009	-0.014	0.009
SF	0.037	0.029	0.080	0.255***	0.263***	0.253***	0.125**	0.18***	1.000	0.164***	0.020	-0.054	0.050	0.046	-0.088*	0.053	-0.054	-0.009	0.277***
TW	0.084	-0.008	-0.046	0.326***	0.338***	0.313***	0.000	0.032	0.164***	1.000	-0.005	-0.063	0.033	-0.008	-0.002	-0.008	0.038	-0.028	0.328***
KLBC	-0.068	-0.010	-0.069	-0.054	-0.053	-0.052	-0.019	-0.028	0.020	-0.005	1.000	-0.437***	0.805***	0.783***	-0.075	0.429***	0.175***	-0.052	-0.040
KBBC	-0.036	0.000	0.001	-0.015	-0.030	-0.014	0.011	-0.017	-0.054	-0.063	-0.437***	1.000	-0.877***	-0.409***	0.348***	-0.284***	-0.24***	0.050	-0.015
L/B	-0.009	-0.004	-0.034	-0.015	-0.005	-0.014	-0.009	0.005	0.050	0.033	0.805***	-0.877***	1.000	0.684***	-0.276***	0.422***	0.236***	-0.063	-0.008
KLAC	0.014	-0.050	-0.071	-0.026	-0.025	-0.015	0.033	-0.007	0.046	-0.008	0.783***	-0.409***	0.684***	1.000	-0.107*	0.897***	0.127**	-0.056	-0.006
KBAC	-0.079	0.047	0.020	-0.079	-0.070	-0.052	0.002	-0.005	-0.088*	-0.002	-0.075	0.348***	-0.276***	-0.107*	1.000	-0.096*	0.825***	0.065	-0.054
LER	0.066	-0.066	-0.053	0.000	0.002	0.018	0.063	0.010	0.053	-0.008	0.429***	-0.284***	0.422***	0.897***	-0.096*	1.000	0.067	-0.043	0.023
BER	-0.055	0.043	0.018	-0.070	-0.052	-0.045	-0.001	0.009	-0.054	0.038	0.175***	-0.24***	0.236***	0.127**	0.825***	0.067	1.000	0.038	-0.047
ASV	0.016	0.055	0.020	0.021	-0.001	0.025	0.034	-0.014	-0.009	-0.028	-0.052	0.050	-0.063	-0.056	0.065	-0.043	0.038	1.000	0.003
SPY	0.41***	-0.048	0.064	0.889***	0.964***	0.897***	0.047	0.009	0.277***	0.328***	-0.040	-0.015	-0.008	-0.006	-0.054	0.023	-0.047	0.003	1.000

*** Correlation is significant at 0.001 level (two tailed)
** Correlation is significant at 0.01 level (two tailed)
* Correlation is significant at 0.05 level (two tailed)

PH - Plant Height, DFF - Days to first flowering, CCI – Chlorophyll content index, NT - Number of total tillers per plant, NPT - Number of Productive Tillers per plant, FLL - Flag leaf length, PL - Panicle Length, FGPP - Filled Grain Per Panicle, SF - Spikelet Fertility, TW - Test weight, KLBC - Kernel Length Before Cooking, KBBC - Kernel Breadth Before Cooking, L/B ratio - Length Breadth Ratio, KLAC - Kernel Length After Cooking , KBAC - Kernel Breadth After Cooking, LER - Linear Elongation Ratio, BER - Breadth wise Expansion Ratio, ASV - Alkali Spreading Value, SPY - Single Plant Yield.

Table 3. Path coefficient analysis of grain yield, yield attributing and quality traits

CHARACTERS	PH	DFF	CCI	NT	NPT	FLL	PL	FGPP	SF	TW	KLBC	KBBC	L.B	KLAC	KBAC	LER	BER	ASV	SPY
PH	**-0.0111**	0.0001	0.0000	0.0138	0.3398	0.0684	0.0012	0.0004	0.0009	0.0003	-0.0207	0.0091	0.0000	-0.0082	-0.0364	0.0287	0.0241	-0.0001	0.4104
DFF	0.0003	**-0.0052**	0.0000	-0.0007	-0.0326	-0.0140	0.0075	-0.0053	0.0008	-0.0003	-0.0030	0.0001	0.0000	0.0307	0.0216	-0.0283	-0.0191	-0.0002	-0.0480
CCI	-0.0004	-0.0001	**-0.0013**	0.0020	0.0534	0.0088	0.0032	-0.0033	0.0020	-0.0002	-0.0211	-0.0003	0.0002	0.0431	0.0092	-0.0228	-0.0082	-0.0001	0.0643
NT	-0.0047	0.0001	-0.0001	**0.0325**	0.7119	0.1436	0.0005	-0.0001	0.0065	0.0009	-0.0166	0.0037	0.0001	0.0161	-0.0365	0.0001	0.0309	-0.0001	0.8890
NPT	-0.0048	0.0002	-0.0001	0.0298	**0.7752**	0.1569	0.0015	-0.0007	0.0067	0.0009	-0.0161	0.0075	0.0000	0.0153	-0.03230	0.0009	0.0231	0.0000	0.9640
FLL	-0.0043	0.0004	-0.0001	0.0263	0.6868	**0.1771**	0.0039	-0.0008	0.0064	0.0009	-0.0158	0.0035	0.0001	0.0091	-0.0240	0.0077	0.0196	-0.0001	0.8968
PL	-0.0002	-0.0006	-0.0001	0.0003	0.0180	0.0109	**0.0635**	-0.0478	0.0032	-0.0002	-0.0059	-0.0028	0.0000	-0.0199	0.0011	0.0272	0.0007	-0.0001	0.0473
FGPP	0.0001	-0.0005	-0.0001	0.0001	0.0088	0.0025	0.0529	**-0.0574**	0.0046	-0.0003	-0.0085	0.0043	0.0000	0.0042	-0.0021	0.0042	-0.0041	0.0001	0.0087
SF	-0.0004	-0.0002	-0.0001	0.0083	0.2037	0.0449	0.0079	-0.0103	**0.0254**	0.0000	0.0062	0.0137	-0.0002	-0.0280	-0.0405	0.0230	0.0240	0.0000	0.2774
TW	-0.0005	0.0003	0.0000	0.0040	0.0973	0.0225	-0.0022	0.0027	-0.0001	**0.0072**	0.0088	0.0061	-0.0001	-0.0032	0.0257	-0.0045	-0.0321	-0.0002	0.1317
KLBC	0.0007	0.0001	0.00010	-0.0018	-0.0410	-0.0092	-0.0012	0.0016	0.0005	0.0002	**0.3049**	0.1108	-0.0037	-0.4760	-0.0345	0.1852	-0.0773	0.0002	-0.0403
KBBC	0.0004	0.0000	0.0000	-0.0005	-0.0229	-0.00240	0.0007	0.0010	-0.0014	-0.0002	-0.1333	**-0.2534**	0.0040	0.2489	0.1611	-0.1226	0.1057	-0.0002	-0.0150
L.B	0.0001	0.0000	0.0000	-0.0005	-0.0037	-0.0024	-0.0006	-0.0003	0.0013	0.0002	0.2454	0.2222	**-0.0046**	-0.4159	-0.1276	0.1821	-0.1040	0.0003	-0.0081
KLAC	-0.0001	0.0003	0.0001	-0.0009	-0.0195	-0.0026	0.0021	0.0004	0.0012	0.0000	0.2387	0.1037	-0.0031	**-0.6080**	-0.0496	0.3874	-0.0561	0.0002	-0.0059
KBAC	0.0009	-0.0002	0.0000	-0.0026	-0.0540	-0.0092	0.0001	0.0003	-0.0022	0.0004	-0.0227	-0.08820	0.0013	0.0652	**0.4627**	-0.0415	-0.3639	-0.0003	-0.0541
LER	-0.0007	0.0003	0.00010	0.0000	0.0016	0.0031	0.0040	-0.0006	0.0014	-0.0001	0.1308	0.0719	-0.0019	-0.5453	-0.0445	**0.4319**	-0.0295	0.0002	0.0227
BER	0.0006	-0.0002	0.0000	-0.0023	-0.0406	-0.0079	-0.0001	-0.0005	-0.0014	0.0005	0.0535	0.0607	-0.0011	-0.0774	0.3818	0.0289	**-0.4410**	-0.0002	-0.0466
ASV	-0.0002	-0.0003	0.0000	0.0007	-0.0011	0.0045	0.0022	0.0008	-0.0002	0.0004	-0.0159	-0.0126	0.0003	0.0338	0.0302	-0.0187	-0.0167	**-0.0041**	0.0031

RESIDUE= 0.2418

PH - Plant Height, DFF - Days to first flowering, CCI – Chlorophyll content index, NT - Number of total tillers per plant, NPT - Number of Productive Tillers per plant, FLL - Flag leaf length, PL - Panicle Length, FGPP - Filled Grain Per Panicle, SF - Spikelet Fertility, TW - Test weight, KLBC - Kernel Length Before Cooking, KBBC - Kernel Breadth Before Cooking, L/B ratio - Length Breadth Ratio, KLAC - Kernel Length After Cooking , KBAC - Kernel Breadth After Cooking, LER - Linear Elongation Ratio, BER - Breadth wise Expansion Ratio, ASV - Alkali Spreading Value, SPY - Single Plant Yield.

selection, with these traits serving as effective indicators for the process. Phenotypic correlations among the traits were presented (**Table 2)**. It became evident that there exists a notably highly significant and positive association between single plant yield and the number of productive tillers per plant followed by total number of tillers, flag leaf length, plant height, spikelet fertility per cent and test weight. These results were in accordance with Thúy *et al*. (2022) and Prathiksha *et al*. (2022) for number of productive tillers and plant height; Somtochukwu *et al*. (2021) and Kalaiselvan *et al*. (2019) for test weight; Swapnil *et al*. (2020) and Almas Fathima *et al*. (2021) for number of tillers and Muthuvijayaragavan and Jebaraj (2022) for spikelet fertility. To improve the single plant yield it requires simultaneous improvement of associated traits *viz.,* number of productive tillers, total number of tillers, flag leaf length, plant height, spikelet fertility and test weight. The same results were highlighted by Islam *et al*. 2020. Plant height have highly significant positive correlation with number of tillers, number of productive tillers per plant and flag leaf length. Comparative findings reported by Patel *et al*. (2023) and Priyanka *et al*. (2019) for productive tillers, single plant yield and Seneega *et al*. (2019) for kernel breadth, L/B ratio. Number of productive tillers per plant have highly significant positive correlation with plant height, number of tillers, flag leaf length, spikelet fertility, test weight and single plant yield. Panicle length have highly significant positive correlation with days to first flowering, filled grain per panicle and spikelet fertility. From these results it clearly showed that flag leaf length provides high photosynthetic energy which in turn increases the number of filled grains per panicle and spikelet fertility. These traits are increasing the grain yield indirectly and therefore simultaneous consideration of these traits is important for crop improvement.

Among the cooking quality traits KLBC have highly significant positive correlation with L/B ratio, KLAC, LER and BER whereas it showed highly significant negative correlation with KB. KB has highly significant positive correlation with KBAC and highly significant negative correlation with L/B ratio, KLAC, LER and BER. KLAC have highly significant positive correlation with L/B ratio, LER and BER and highly significant negative correlation with KBBC and KBAC. KBAC have highly significant positive correlation with and BER whereas it showed highly significant negative correlation with spikelet fertility, L/B ratio, KLAC and LER. LER and BER had highly significant positive correlation with L/B ratio. In the present investigation the related findings were carried out by Patel *et al*. (2023) and Seneega *et al*. (2019).

Path coefficient analysis is used to study the direct and indirect effects of individual yield components on yield. This information can help breeders to focus on the traits that have the greatest impact on yield, so they can spend less time and resources on less important traits. The path coefficient analysis showed that number of productive tillers per plant had the highest positive direct effect on grain yield (**Table 3)**. Similar findings were reported by Singh *et al*., (2020), Prathiksha *et al*. (2022), Muthuvijayaragavan and Murugan (2020) and Priyanka *et al*. (2019). The traits *viz*., flag leaf length, kernel length, KBAC and LER showed moderate level of direct positive effects on grain yield. High level of negative direct effect was observed in KLAC on grain yield which is in accordance with Prathiksha *et al*. (2022).The high positive indirect effect was recorded by number of tillers, flag leaf length and spikelet fertility percentage on the single plant yield *via* number of productive tillers per plant. High negative indirect effect was recorded by kernel length *via* KLAC. The residual effect (0.2418) in path analysis revealed that the independent factors explained over 76 percent of the variability in grain yield, signifying most of the essential yield components were taken into consideration.

From this study, based on the results of all the analyses, the number of productive tillers per plant and flag leaf length are recognized as the key traits as they are highly heritable and simultaneous consideration of these traits is important for crop improvement. It implies that flag leaf provides more photosynthates to grains along with number of productive tillers per plant which in turn increases the grain yield.

REFERENCES

Adhikari, B. N., Joshi, B. P., Shrestha, J.and Bhatta, N. R. 2018. Genetic variability, heritability, genetic advance and correlation among yield and yield components of rice (*Oryza sativa* L.). *Journal of Agriculture and Natural Resources*, **1**(1): 149-160. [Cross Ref]

Alshiekheid, M. A., Dwiningsih, Y. and Alkahtani, J. 2023. Analysis of Morphological, Physiological, and Biochemical Traits of Salt Stress Tolerance in Asian Rice Cultivars at Different Stages. Preprints, 1-19. [Cross Ref]

Basu, S. R., Baskheti, D. C., Deo, I., Nautiyal, M. K., Singh, S. and Sharma, N. 2022. Studies on genetic variability parameters for yield, quality and nutritional traits in basmati and aromatic rice (*Oryza sativa* L.). *In Biological Forum–An International Journal,***14(**4a): 379-384.

Bitew, JM., Abebe, D., Wondiferaw, D. and Desie, A. 2023 Variability and Correlation Study on Lowland Green Super Rice in Western Ethiopia. Adv CropSci Tech., **11**: 560.

Fathima, M. A., Geetha, S., Amudha, K. and Uma, D. 2021. Genetic variability, frequency distribution and association analysis in ADT (R) 48 x Kavuni derived F2 population of rice (*Oryza sativa* L.). *Electronic*

Journal of Plant Breeding, **12**(3): 659-666. [Cross Ref]

Islam, S. S., Anothai, J., Nualsri, C. and Soonsuwon, W. 2020. Correlation and path analysis of phenological traits of Thai upland rice genotypes. *Songklanakarin J. Plant Sci*, **7:** 133-142

Johnson, Herbert W., Robinson H. F. and Comstock, R. E. 1955. Estimates of genetic and environmental variability in soybeans. *Agronomy journal,* **47**(7): 314-318. [Cross Ref]

Kalaiselvan, S., Subramanian, A., Thirumurugan, T. and Rajanbabu, V. 2019. Genetic variability and association studies in F_2 population of rice under sodicity. *Electronic Journal of Plant Breeding*, **10**(2): 601-613. [Cross Ref]

Kulsum, U., Sarker, U.and Rasul, M. G. 2022. Genetic variability, heritability and interrelationship in salt-tolerant lines of T. Aman rice. *Genetika*, **54**(2): 761-776. [Cross Ref]

Lipi, L. F., Hasan, M. J., Akter, A., Quddus, M. R., Biswas, P. L., Ansari, A. and Akter, S. 2020. Genetic variation, heritability and genetic advance in some promising rice hybrids. SAARC *Journal of Agriculture*, **18**(2): 39-49. [Cross Ref]

Lush, J. L. 1940. Intrusive collection of regression of offspring on dams asa method of estimating heritability of characters. *Proc. Am. Soc. Anim. Prod*., **33**: 293-301.

Mahajan, G., Kumar, V. and Chauhan, B. S. 2017. Rice production in India. Rice production worldwide, 53-91. [Cross Ref]

Manivannan, N. 2014. TNAUSTAT-Statistical package.

Manojkumar, D., Srinivas, T., Rao, L. S., Suneetha, Y., Sundaram, R. M. and Kumari, V. P. 2022. Study of genetic variability and trait associations in F_2 Population of YH3 x AKDRMS 21-54 intra-specific cross of rice. *The Pharma Innovation Journal,* **11**(9): 1735-1742.

Muthuvijayaragavan, R. and Murugan, E. 2020. Association analysis of F_2 generation in rice (*Oryza sativa* L.) under salinity condition. *Electronic Journal of Plant Breeding*, **11** (1): 283-289. [Cross Ref]

Muthuvijayaragavan, R. and Jebaraj, S. 2022. Correlation and path coefficient analysis in F_2 families of rice (*Oryza sativa* L.) under direct seeded condition. *Journal of Genetics*, *Genomics and Plant Breeding,* **6**(2): 44-53

Nirubana, V., Vanniarajan, C., Aananthi, N., Banumathy, S., Thiyageshwari, S. and Ramalingam, J. 2019. Variability and frequency distribution studies in F_2 segregating population of rice with phosphorous starvation tolerance Gene (OsPSTOL 1) introgressed. *Int J Curr Microbiol App Sci,* **8**(9): 2620-2628. [Cross Ref]

Nikhitha, T. C., Pushpham, R., Raveendran, M. and Manonmani, S. 2020. Genetic variability and frequency distribution studies in F_2 population involving traditional variety mappillai samba. *Electronic Journal of Plant Breeding*, **11**(03): 933-938. [Cross Ref]

Patel, S. N., Sakriya, S. G., Vaja, S. and Patel, V. P. 2023. Correlation analysis in F_2 segregating generation of rice (*Oryza sativa* L. var. *indica*). *The Pharma Innovation Journal*, **12**(6): 4927-4929.

Prathiksha, R., Pushpam, R., Amudha, K. and Raveendran, M. 2022. Estimation of genetic parameters and character association for yield and quality traits in BC1F2 population of rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding,* **13**(2): 498-505. [Cross Ref]

Priyanka, A. R., Gnanamalar, R. P., Banumathy, S., Senthil, N. and Hemalatha, G. 2019. Genetic variability and frequency distribution studies in F_2 segregating generation of rice. *Electronic Journal of Plant Breeding*, **10**(3): 988-994. [Cross Ref]

Singh, S. K., Habde, S., Singh, D. K., Khaire, A., Mounika, K. and Majhi, P. K. 2020. Studies on character association and path analysis studies for yield, grain quality and nutritional traits in F_2 population of rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding*, **11**(3): 969-975. [Cross Ref]

Srihari, G., Babu, P. R., Babu, J. D., Jayalalitha, K. and Sreelakshmi, C. 2023. Characterisation, genetic parameters of variation and correlation studies in Molakolukulu Rice cultivars of Andhra Pradesh, India. *Electronic Journal of Plant Breeding*, **14**(2): 540-550. [Cross Ref]

Singh, A. K., Singh, K.P. and Singh,V. P. 1974. Genetic analysis of induced mutation of okra (*Abelmoschus esculentus* L. Moench). *Veg. Sci,* **25**(2): 174 –177.

Salleh, S. B., Rafii, M. Y., Ismail, M. R., Ramli, A., Chukwu, S. C., Yusuff, O. and Hasan, N. A. 2022. Genotype-by-environment interaction effects on blast disease severity and genetic diversity of advanced blast-resistant rice lines based on quantitative traits. Frontiers in Agronomy, 4, 990397. [Cross Ref]

Somtochukwu, O. C. and Efisue, A. A. Heritability and Genetic Components Studies of F_2 Population of Rice (*O. Sativa* L.). *Ecology and Evolutionary Biology,* **6**(4): 113-119. [Cross Ref]

Swapnil, K. P., Chakraborty, M., Singh, D. N., Kumari, P. and Ekka, J. P. 2020. Genetic variability, correlation and path coefficient studies in F_2 generation of rice (*Orzya sativa* L.). *International Journal of Chemical Studies*, **8**(4): 3116-3120. [Cross Ref]

Seneega, T. A., Gnanamalar, R. P., Parameswari, C., Vellaikumar, S. and Priyanka, A. R. 2019. Genetic variability and association studies in F_2 generation of rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding*, **10**(2): 512-517. [Cross Ref]

Sao, A.and Gauraha, D. 2020. Genetic variability studies for yield and quality parameters in aromatic breeding lines of rice (*Oryza sativa* L.). *Journal of Pharmacognosy and Phytochemistry*, **9**(6): 1637-1640.

Sala, M. and Geetha, S. 2015. Variability studies for quality traits in rice with high iron and zinc content in segregating population. *Journal of Cereals and Oilseeds*, **6**(7): 39-42. [Cross Ref]

Thúy, L. T., Vu, T. N., Pham, V. T., Nguyen, A. D. and Nguyen, T. K. 2022. Variability, correlation and path analysis for several quantitative traits derived multi-parent advanced generation inter-cross (Magic) F_2 population of rice (*Oryza sativa* L.). *International Journal of Scientific Research and Management* (IJSRM), **10**(11): 356-363. [Cross Ref]