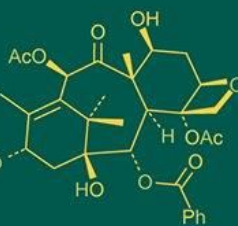
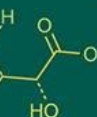
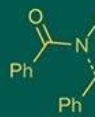


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Genetic variability, heritability and genetic advance for yield and grain nutritional traits in F₂ populations of rice (*Oryza sativa* L.)

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Abstract

Enhancing the yield along with nutritional quality is a major in the rice improvement programmes. The present study aimed to assess the extent of genetic variability, heritability and genetic advance for yield and its component traits, and grain nutritional quality parameters in F₂ populations derived from bio-fortification oriented crosses. Three F₂ populations, namely, ADT 56 x *Kalanamak*, CO54 x *Kalanamak* and CO 54 x *Chinkinkar*, were developed during 2023 and evaluated at Tamil Nadu Rice Research Institute, Aduthurai. All the recommended agronomic practices and observations were recorded on seventeen agro-morphological yield, and quality traits including grain iron, zinc and protein content estimated using ED-XRF. The analysis revealed a wide range of variation for most of the traits with single plant yield, filled grains, total grains per panicle, and grain iron, zinc and protein contents exhibiting particularly high variability across all crosses. Single plant yield ranged from 7.60 to 53.40 g among the populations, while grain iron and zinc contents reached maximum values of 16.90 mg kg⁻¹ and 39.55 mg kg⁻¹ respectively. Moderate to high phenotypic and genotypic coefficients of variation were observed for most yield and nutritional traits, with minimal differences between PCV and GCV, indicating limited environmental influence. High heritability coupled with high genetic advance as percent of mean was recorded for traits such as number of productive tillers, filled grains, unfilled grains and single plant yield suggesting the predominance of additive gene action.

Keywords: Rice, F₂ populations, nutritional traits, variability, heritability, genetic advance

1. Introduction

Rice (*Oryza sativa* L.) stands as the predominant staple food and is the primary source of nourishment for almost 70% of the people. It is the crucial for the dietary and food security source of many Asian countries (Kumar *et al.*, 2020) [6]. India is the world's second largest producer of rice, accounting for 22% of global production. Although rice output and productivity have significantly improved. The green revolution has led to plateaus in yield levels, limiting production efforts to satisfy the demands of a growing population, particularly in developing and underdeveloped countries. According to reports, India's food security may be threatened by the country's projected population growth by 2050 (Fathima *et al.*, 2021) [4].

Consequently, ensuring food security in the future is a very difficult issue, especially for Indian rice producers, since rice is essential to the nation's food and nutritional security. In order to break through yield barriers, rice varieties with high productivity levels and appropriate agronomic traits are needed. Hybridization has been identified as a key plant breeding strategy for achieving necessary diversity and high productivity levels. Additionally, selection in segregating generations must be directed toward producing superior yielding plants, for which yield variability and related qualities are crucial, and the development of efficient selection criteria for yield enhancement is necessary (Butardo *et al.*, 2019) [1].

In such contexts, establishing sustainable breeding programs requires precise understanding of genetic divergence in yield components. Effective varietal improvement hinges on selecting parents with significant genetic differences for hybridization. Improvement for specific traits has been successfully achieved through the strategic use of F₂ segregating populations, facilitating the fixation of desirable combinations.

This study aims to assess variability, heritability, and genetic advance as a percentage of mean for grain yield and its components. Additionally, it explores the frequency distribution patterns based on skewness and kurtosis in the F₂ segregating generation for three selected crosses. Such analyses are pivotal for identifying superior genotypes with potential for higher yield and better performance under varying environmental conditions.

2. Materials and Methods

The current investigation was carried out in the experimental field of Department of Plant Breeding and Genetics, Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu. Based on documented results, parents having contracting grain iron and zinc were chosen and crossed and developed mapping populations during 2023. Three F₂ generations resulting from the cross between ADT 56 x *Kalanamak*, CO 54 x *Kalanamak*, and CO 54 x *Chinkinkar* were grown. Twenty six days old seedlings were transplanted in to the main field with a spacing of 30 cm x 30 cm. A total of 222, 156 and 207 possible F₂ segregants of each cross were identified and labeled for further assessment. The recommended agronomic practices and crop protection measures were followed during the crop growth period. Each F₂ plant was harvested separately. Observations were recorded from randomly selected plants of each of the cross combinations and each of the randomly selected individual plant was tagged before anthesis. Data on all the seventeen characters namely DM-Days to Maturity, PH-Plant Height, NPT-number of productive tillers per plant, FL-Flag leaf length, FW-Flag leaf width, KL-kernel length; KB-kernel breadth; LBR-length-to-breadth ratio, PL-Panicle Length, PW-Panicle Weight, NB-Number of branches per panicle, FG-Filled Grains, UFG-Unfilled Grains, TNP-Total number of Grains per Panicle, TSW-Thousand Seed Weight, SPY-Single Plant Yield, FEB-Fe content in brown rice and ZNB-ZN content in brown rice and PCB-Protein content in brown rice were analyzed at TRRI, quality lab, with ED-XRF. The recorded data was subjected to statistical analysis as analysis of variance, genetic variability and correlation analysis using R studio software.

3. Results and Discussion

Mean Performance of F₂ generation: The results of genetic variability and other genetic parameters are shown and represented in Table and Fig. 1 and 2. A perusal of the results on mean performance and range of the yield contributing and nutritional traits were studied in the present investigation (Rao *et al.*, 2014) [15] revealed maximum range for single plant yield followed by grain iron, zinc and protein content while minimum range was observed for flag leaf width. Single plant yield for ADT 56 x *Kalanamak* ranges from 9.20 gm to 53.40 gm with mean of 27.26 gm, and for CO 54 x *Kalanamak* 9.20 gm to 45.70 gm with a mean of 28.23 gm, and for CO 54 x *Chinkinkar* 7.60 gm to 52.60 gm with a mean of 25.26gm. Similarly, filled grains and total number of grains were recorded in the study ranged from 73.50 to 284.10 (ADT 56 x *Kalanamak*), 72.60 to 289.60 (CO54 x *Kalanamak*) and 51.20 to 283.30 (CO 54 x *Chinkinkar*). The maximum grain iron content noted as 16.90 kg/mg with a average mean of 12.32 kg/mg in ADT 56 x *Kalanamak* and incase of maximum grain zinc content observed as 39.55 mg/kg with a mean of 24.54 mg/kg in CO 54 x *Chinkinkar*. The average value for the grain protein content was 12.83 %. Similar results were reported by

Bharath *et al.* 2018 [17].

The phenotypic variation for Days to maturity ranged from 102.75 to 159.38 (ADT 56 x *Kalanamak*, 113.30 to 153.80 (CO54 x *Kalanamak*) and 110.30 to 156.80 (CO 54 x *Chinkinkar*) respectively. The average performance of Plant height noted as a 128.81 m (ADT 56 x *Kalanamak*) followed by 122.19 and 151.22 in CO54 x *Kalanamak* and CO 54 x *Chinkinkar*. The number productive tillers per plant had an average mean of 20.17, 20.88 and 20.48 for ADT 56 X *Kalanamak*, CO54 x *Kalanamak* and CO 54 x *Chinkinkar*. Flag leaf length and Flag leaf width recorded with mean of 39.22, 1.54 for ADT 56 x *Kalanamak*, 37.27 and 1.41 for CO 54 x *Kalanamak* and 47.85 to 1.30 in CO 54 x *Chinkinkar* respectively. Panicle length in the F₂ population ranged from 21.40 to 37.30 in ADT 56 X *Kalanamak*, 25.10 to 35.60cm in CO54 x *Kalanamak* and 17.20 to 37.50cm in CO 54 x *Chinkinkar*. Whereas the panicle weight had an average mean of 2.85 for ADT 56 x *Kalanamak*, 2.98 for CO54 x *Kalanamak* and 2.97 in case of CO 54 x *Chinkinkar*. Similarly, the panicle length showed an average performance with 29.37cm, 29.58cm and 24.83 cm in ADT 56 x *Kalanamak*, CO54 x *Kalanamak* and CO 54 x *Chinkinkar* respectively. The current study discovered adequate genetic variation for all of the variables under investigation in the F₂ populations, and the materials could potentially be utilized for association mapping and as donors in Direct seeded Rice (DSR) conditions (Dikshit *et al.*, 2016) [3].

3.1 Variability studies

Estimating genotypic and phenotypic coefficients of variation is crucial for understanding the impact of environmental factors on various traits. Environmental influence on a character is measured by the difference in coefficients of variation between genotype and phenotype (Akinwale *et al.*, 2011). Genetic parameters were categorized as follows: GCV and PCV into low (0-10%), moderate (10-20%) and high (>20%); Heritability into low (0-30%), moderate (30-60%) and high (>60%); and genetic advance as a percentage of the mea into low (0-10%), moderate (10-20%) and high (>20%).

Table 1 displays the PCV and GCV values for characteristics in three crosses. The study on variability demonstrated for all the three crosses that the phenotypic and genotypic coefficients of variation were moderate for PH, FW, KB, L/B, FEB, ZNB and PCB. The high phenotypic and genotypic coefficients were recorded for NPT, FL, PW, FG, UFG, TGP and SPY. The phenotypic coefficient variation (PCV) and genotypic coefficient of variation (GCV) was highest for the UFG with 56.86 followed by SPY with 34.02 and lowest for KL 7.18 (CO 54 x *Chinkinkar*). Furthermore, the minimal difference between GCV and PCV for all traits indicated that environmental factors had a negligible effect on the expression of these characteristics.

Both high heritability and high genetic advance were exhibited high by almost all traits except KL, which had moderate genetic advance mean and CO 54 x *Kalanamak* and CO 54 x *Chinkinkar* showed moderate genetic advance mean values for DM. The cross combination CO 54 x *Chinkinkar* had highest GAM value with 67.44 for single plant yield followed by NPT in ADT 56 x *Kalanamak* with 65.89.

Traits showing high PCV, GCV, heritability and genetic advance per mean suggests that these traits are influenced significantly by additive gene action. Selective breeding

efforts targeting these traits could yield beneficial improvements. Similar finding were reported by Bharath *et al.* 2018 ^[17], Khandappagol, *et al.* 2019 ^[5], Manojkumar *et al.* 2023 ^[9], Piyari *et al.* 2023 ^[13]. Comparable results were observed by Prasanth *et al.* 2024 ^[18] who noted high heritability paired with substantial genetic advance for traits

such as the number of productive tillers and filled grains per panicle. Heritability estimates of a trait reflects the reliability of predicting its phenotypic value. High heritability increases the effectiveness of selecting specific traits, thereby making their improvement particularly beneficial.

Table 1. List of parents used in the study

Parents	Parentage	Characters	Source
ADT 56	WGL1437/MDU5	Short duration, good cooking & eating qualities. Moderately resistant to leaf blast, grain discoloration, stem borer and leaf folder	TRRI, Aduthurai
CO 54	CB04110/CB 05501	White Medium slender rice. Moderately resistant to Blast, Sheath rot, Brown Spot and BPH	Coimbatore, TNAU
Kalanamak	Landrace	Short duration, Finest quality, resistant to blast. Cooked rice is fluffy, soft, non-sticky, sweet, and easily digestible with relatively longer shelf-life. It had 15.6 mg kg ⁻¹ of iron. It is famous for taste, palatability, and aroma	TRRI, Aduthurai
Chinkinkar	Landrace	Short duration, grain colour-red long bold, low gel consistency. Zn (26.4 mg kg ⁻¹), Fe (16.10 mg kg ⁻¹) and protein (10)	TRRI, Aduthurai

Table 2: Estimation of variability studies in three different crosses in F₂ populations

Parameters	Crosses	DM	PH	NPT	FL	FW	KL	KB	L/B
Mean	ADT56×Kalanamak	133.80	128.81	20.48	39.22	1.54	6.57	2.26	2.98
	CO54×Kalanamak	130.49	122.19	20.88	37.27	1.41	6.32	2.17	2.96
	CO54×Chinkinkar	130.33	151.22	20.17	47.85	1.30	6.19	2.12	2.99
Maximum	ADT56×Kalanamak	159.38	165.58	38.82	67.23	2.50	8.50	2.90	4.83
	CO54×Kalanamak	153.80	172.60	38.20	56.20	2.20	7.60	2.60	3.90
	CO54×Chinkinkar	156.80	198.60	38.40	75.20	1.80	7.60	2.60	4.33
Minimum	ADT56×Kalanamak	102.75	90.78	6.83	25.42	0.70	5.40	1.20	2.07
	CO54×Kalanamak	113.30	94.50	9.50	22.20	1.00	5.50	1.50	2.23
	CO54×Chinkinkar	110.30	103.20	5.20	28.30	1.10	5.10	1.40	2.17
PCV	ADT56×Kalanamak	10.28	11.85	32.04	21.22	19.52	8.05	13.29	15.40
	CO54×Kalanamak	9.61	12.44	26.96	23.31	22.26	7.34	12.02	12.14
	CO54×Chinkinkar	8.66	13.51	32.07	21.76	12.37	7.18	14.13	15.38
GCV	ADT56×Kalanamak	10.18	11.73	32.01	20.84	19.51	7.86	13.26	15.36
	CO54×Kalanamak	9.50	12.32	26.92	22.97	22.26	7.12	11.96	12.10
	CO54×Chinkinkar	8.52	13.36	32.00	21.50	12.36	7.03	14.05	15.36
H ₂	ADT56×Kalanamak	98.05	97.96	99.82	96.38	99.97	95.39	99.42	99.45
	CO54×Kalanamak	97.79	98.05	99.73	97.06	99.96	93.97	99.09	99.30
	CO54×Chinkinkar	96.78	97.82	99.60	97.58	99.82	95.78	98.97	99.71
GAM	ADT56×Kalanamak	20.76	23.91	65.89	42.14	40.19	15.82	27.23	31.55
	CO54×Kalanamak	19.36	25.12	55.38	46.61	45.85	14.21	24.53	24.84
	CO54×Chinkinkar	17.27	27.21	65.80	43.75	25.43	14.17	28.80	31.60

Parameters	Crosses	PL	PW	FG	UFG	TGP	SPY	FEB	ZNB	PCB
Mean	ADT56×Kalanamak	29.37	2.85	177.28	65.03	242.31	27.26	12.32	25.03	8.80
	CO54×Kalanamak	29.58	2.98	186.14	56.71	242.85	28.23	12.41	25.57	9.43
	CO54×Chinkinkar	24.83	2.97	170.95	69.40	240.35	25.26	11.76	24.54	9.06
Maximum	ADT56×Kalanamak	37.30	5.30	284.10	193.30	469.60	53.40	16.90	36.75	11.54
	CO54×Kalanamak	35.60	4.40	289.60	116.20	380.30	45.70	15.84	32.56	12.83
	CO54×Chinkinkar	37.50	5.08	283.30	174.50	439.00	52.60	16.70	39.35	11.73
Minimum	ADT56×Kalanamak	21.40	1.44	73.50	7.80	101.80	9.20	8.60	17.47	7.21
	CO54×Kalanamak	25.10	1.53	72.60	18.60	108.80	9.20	9.12	18.69	7.21
	CO54×Chinkinkar	17.20	1.45	51.20	8.20	100.40	7.60	8.10	17.53	5.80
PCV	ADT56×Kalanamak	11.32	26.62	26.98	47.43	23.37	26.79	12.36	12.88	10.15
	CO54×Kalanamak	7.74	21.86	22.87	45.51	20.88	24.45	13.16	12.56	15.19
	CO54×Chinkinkar	18.00	24.00	33.71	56.86	31.30	35.36	16.42	17.81	11.76
GCV	ADT56×Kalanamak	10.99	26.57	26.47	47.37	23.26	21.53	12.29	12.85	10.03
	CO54×Kalanamak	7.28	21.80	22.33	45.37	20.70	17.99	13.10	12.53	15.13
	CO54×Chinkinkar	17.71	23.94	33.33	56.82	31.21	34.02	16.39	17.78	11.67
H ₂	ADT56×Kalanamak	94.19	99.63	96.20	99.73	99.06	64.58	98.89	99.56	97.65
	CO54×Kalanamak	88.53	99.53	95.35	99.39	98.36	74.13	99.08	99.55	99.13
	CO54×Chinkinkar	96.79	99.48	97.76	99.86	99.43	92.60	99.56	99.68	98.46
GAM	ADT56×Kalanamak	21.97	54.64	53.47	57.45	47.68	35.63	25.17	26.41	20.43
	CO54×Kalanamak	21.11	44.81	44.92	63.17	42.30	57.26	26.85	25.76	31.03
	CO54×Chinkinkar	35.89	49.19	67.08	56.98	64.10	67.44	33.68	36.58	23.86

DFP-Days to Fifty percent Flowering, PH-Plant Height, NPT-number of productive tillers per plant, FL-Flag leaf length, FW-Flag leaf width, PL-Panicle Length, PW-Panicle Weight, NB-Number of branches per panicle, FG-Filled Grains, UFG-Unfilled Grains, TGP-Total number of Grains per Panicle, HSW-Hundred Seed

Weight, SPY-Single Plant Yield, KL-Kernel Length, KB-Kernel Breadth, LB-Length to Breadth ratio, HP-Hulling percentage; MP-milling percentage; HRR-head rice recovery; KL-kernel length; KB-kernel breadth; LBR-length-to-breadth ratio; FEB-Fe content in brown rice and FEP-Fe content in polished rice.

4. Conclusion

The present study revealed substantial genetic variability among the three F₂ rice populations for yield and nutritional components. Wide ranges for single plant yield, filled grains and grain iron, zinc and protein contents indicated good scope for effective selection. Moderate to high PCV and GCV with narrow differences between them suggested minimal environmental influences on trait expression. High heritability coupled with high genetic advance for most of the traits, particularly productive tillers, filled grains and single plant yield, indicated the predominance of additive gene action. These traits can be effectively improved through direct selection in early generations. The F₂ populations represent valuable genetic resources for yield improvement and grain bio-fortification in rice especially under direct seeded rice conditions.

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All authors offered equal suggestions and contributions on original drafts preparations.

6. Conflict of Interests

The authors declare that they have no conflict of interest

7. Author's Contributions

All authors listed have made a substantial, direct and intellectual contribution to the work and approved it for publication

8. Ethical Approval: None

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