

Original Research Article

Genetic variability and character association studies on yield attributing and grain quality traits in rice (*Oryza sativa* L.)

ABSTRACT

Aim: The present investigation was undertaken with 49 genotypes to study variability and genetic parameters in addition to character association and path effects of yield, yield attributing and quality traits.

Design: Simple lattice design with two replications.

Place of study: Forty-nine genotypes were sown at IIRR Farm at ICRISAT, Hyderabad during Kharif season 2023.

Methodology: The data was collected for all the genotypes and evaluated for variability, correlation and path coefficient studies.

Results: High range of variation and high heritability coupled with high genetic advance as percent mean was recorded for days to 50 per cent flowering, plant height, productive tillers plant⁻¹, test weight, LB ratio, water uptake, kernel length after cooking, zinc content and iron content. Correlation revealed that the grain yield was positively correlated with days to 50% flowering, productive tillers plant⁻¹, LB ratio and iron content, meanwhile plant height, test weight, head rice recovery, kernel length, kernel breadth, water uptake, volume expansion ratio, amylose content, kernel length after cooking, elongation ratio and zinc content were found to be negatively correlated. Path analysis identified that iron content exerted the highest direct positive effect on grain yield plant⁻¹ followed by kernel length and productive tillers plant⁻¹, indicating that selection for these characters is likely to bring about an overall improvement in grain yield directly.

Conclusion: The study found adequate genetic variability, with high heritability and additive gene action in certain traits. The prime selection indices include days to 50% flowering, productive tillers plant⁻¹, LB ratio, kernel length, and iron content. These parameters should be given priority in rice breeding programs for high grain yield and quality traits.

Key words: GCV, PCV, Heritability, Genetic advance, Correlation, Path

Introduction

Rice is the principal source of nutrition for about 3 billion people in the world. Seven Asian countries account for more than 80% of the global rice production which is 540.62 million tonnes from 138.56 million hectares. In India it is grown in an area of 43.79 m ha with a production of 116.42 mt and productivity of 2659 kg/ha which contributes 41 per cent of total food grain production (Devi *et al.*,

2021). By 2050, it is predicted that 160 million tons of rice is needed to feed the ever growing Indian population (Muthu *et al.* 2020).

To feed the accelerating population with diminishing natural resources and environmental fluctuations on one-hand and varieties that have grain quality that the consumer demands, on the other became a challenging factor. The economic value and the consumer acceptance of a rice variety depend on rice grain quality. Rice grain quality is a complex trait, it comes from a polygenic group of traits that are affected by environmental factors, crop management and the resulting interactions among these. Grain quality in rice is mainly determined based on physical properties (such as head rice recovery, grain size and shape, and grain color), biochemical composition (such as amylose content, aroma, and others), and nutritional properties (such as micronutrients, and others) (Sultana *et al.*, 2022).

The ultimate goal of a plant breeder is to create versatile and high-yielding cultivars with good grain quality that are adaptable to a wide range of conditions. Presence of variability among the genotypes and the relationship between yield and its attributing traits is crucial for selection, which may be described using correlation and path coefficient analysis. The correlation coefficient evaluates the impact of individual traits on seed yield. Path analysis determines whether independent characters have a direct or indirect effect on the dependent variable.

Materials and methods

Plant material and experimental design and layout

The present investigation consists of 49 genotypes obtained from Indian Institute of Rice Research, Rajendranagar, Hyderabad out of which four were checks namely, Gontrobidhan-3, BPT-5204, Zincorice and Protozinc that are superior in yield, quality and micronutrient content respectively. The layout of the experiment is Simple lattice design with two replications. The lines were sown at IIRR Farm at ICRISAT, Hyderabad during Kharif 2023 on a raised nursery. All suggested measures were followed to get a good crop. The 35 days old seedlings were transplanted in the main field, each line is transplanted in five rows of 4.5m with 20x15cm of spacing. All the recommended package of practices were followed throughout the crop period to ensure a healthy crop. The data for quantitative traits, namely, plant height (cm), productive tillers plant⁻¹, test weight (g) and yield plant⁻¹(g) were recorded from five randomly selected plants; and qualitative traits, namely, head rice recovery (%), kernel length (mm), kernel breadth (mm), lb ratio, water uptake (ml), volume expansion ratio, amylose content (%), kernel length after cooking (mm), elongation ratio, zinc content (ppm) and iron content (ppm) were obtained from random grain sample taken from each plot in each replication. Days to 50% flowering is however, recorded on plot basis.

Statistical methods

The data collected was subjected to statistical analysis using SAS software to obtain phenotypic and genotypic coefficient of variation, correlation coefficients and path coefficients. Phenotypic and genotypic coefficients of variation (PCV and GCV) were as per Burton (1952) and were categorized as low (0-10%), moderate (10-20%) and high (>20%) as indicated by Sivasubramanian and Madhavamenon (1973). Heritability in broad sense was estimated as the ratio of genotypic variance to the phenotypic variance as suggested by Hanson *et al.* (1956) and it was categorized as low (0-30%), moderate (30- 60%) and high (>60%) as indicated by Johnson *et al.* (1955). Genetic advance (GA) and genetic advance as percent of the mean (GAM) were calculated by using the formulae given by Johnson *et al.* (1955). The Genetic advance as percent of the mean was categorized as low (0-10%), moderate (10- 20%) and high (>20%) according to Johnson *et al.* (1955). Correlation coefficients were calculated by using the formulae given by Johnson *et al.* (1955). The direct and indirect effects for genotypes were estimated by using path coefficient analysis suggested by Wright (1921) and Dewey and Lu (1959).

Results and discussion

Forty-nine accessions consists of four checks namely BPT 5204, Gontrobidan-3, Protozinc and Zincoricewere evaluated for yield, yield attributing and quality traits and the means of the entries in two replications was also analyzed for the estimation of components of genetic variance.

Days to 50 percent flowering recorded a general mean of 66 days (Table 1) (Fig 1) ranging from 55 days (JAK-126) to 97 days (WGL14). The Genotypic coefficient of variation and phenotypic coefficient of variation (Table 2) (Fig 2) for this character are moderate (12.37%, 12.57% respectively). Heritability estimate for the character is 96.9% coupled with high genetic advance as percent of mean (25%) indicating the preponderance of high additive variance. Hence, this trait can be improved by simple selection. Similar results were reported by Bhargavi *et al.* (2021) and Nath and Kole (2021) for GCV, PCV, Heritability and Genetic advance as percent of mean.

Plant height recorded a general mean of 100.8 cm ranging from 71.7 cm (JAK-152) to 154.8 cm (JAK-320). It exhibited moderate variability with GCV (19.8%), PCV (19.8%) and high heritability 99% with high genetic advance as percent of mean 40.7% indicating that the selection is effective. Similar findings were reported by Singh *et al.* (2020) and Sudeepthi *et al.* (2020) for GCV, PCV, heritability and genetic advance as percent mean.

Number of productive tillers plant⁻¹ ranged from 5 (JAK-34, JAK-94 and JAK-208) to 20 (JAK-153) with a general mean of 10. High GCV and PCV was recorded for this character (28.8%, 30.1% respectively) with high heritability estimate (91.7%) and high genetic advance as percent of mean 56.9% indicating a good scope for selection. These were in accordance with Rao *et al.* (2020) and Bhusan *et al.* (2019) for GCV, PCV, heritability and genetic advance as percent mean.

In the present investigation the test weight ranged from 14.16 g (JAK-117) to 31.96 g (JAK-210) with a general mean of 23.12 g. Moderate GCV and PCV (17.28609%, 17.46501% respectively) with high heritability estimate (91.7%) and high genetic advance as percent of mean 35.24% indicating that the selection will be effective. These are similar with Singh *et al.* (2020) and Sudeepthi *et al.* (2020) for GCV, PCV, heritability and genetic advance as percent of mean.

The mean values for yield plant⁻¹ ranged from 6.95g (JAK-208) to 31.8g (WGL14) with an average of 12.59 g. High GCV and PCV was recorded for this trait (39.8%, 40.6% respectively) with the heritability estimate of the character is 95.6% with genetic advance 10 and genetic advance as percent of mean 80% indicating predominance of additive variance. Hence, further improvement by simple selection can be performed for this trait. Similar results were reported by Nath and Kole (2021) and Singh *et al.* (2020) for all the parameters.

Head rice recovery observed from 39.9% (JAK-60) to 70.3% (JAK-284-2) with a mean value of 60.39%. Low GCV (8.7%) and moderate PCV (10.9%) showing variability was influenced by environmental factors. The heritability estimate of the character is 63% coupled with moderate genetic advance as percent of mean (14.4%) and low genetic advance (8.7), showing the presence of non-additive gene action governing the trait. The findings are in accordance with Edukondalu *et al.* (2017) for GCV and Singh *et al.* (2020) for heritability and genetic advance as percent of mean.

The present investigation observed kernel length ranging from 4.47 mm (JAK-77) to 7.91 mm (JAK-26) with a general mean of 5.87 mm. Low GCV (9.7%) and moderate PCV (11.1%) was recorded indicating the effect of external factors on variability. High heritability 75.4%, low genetic advance 1.02 and moderate genetic advance as percent of mean 17.34, showing the presence of non-additive gene action governing the trait. These results are in conformity with Bandi *et al.* (2018) for GCV, Lingaiah *et al.* (2018) for PCV and Singh *et al.* (2020) for heritability and genetic advance as percent mean.

Kernel breadth recorded a general mean of 2.23 mm ranging from 1.77 mm (JAK-117) to 2.69 mm (JAK-472). GCV and PCV shown moderate values (10.6%, 11.3% respectively). High heritability (87%) coupled with genetic advance 0.45 and genetic advance as percent of mean 20.4% indicating that the direct selection is not effective. Similar results were reported by Kumar *et al.* (2020) for GCV and PCV and Devi *et al.* (2022) for heritability and genetic advance as percent of mean.

The LB ratio is ranging from 1.66(JAK-77)to 4.21(JAK-26) with a general mean value of 2.66. The genotypes with high LB ratio were more slender and were more preferred by consumers. Moderate GCV and PCV was recorded (16.5%, 18.5% respectively). High heritability (80%) coupled with high genetic advance as percent of mean (30.6%) and genetic advance 0.81 indicated that presence of additive variance. Hence, simple selection can be practiced for further crop improvement programmes.

The general mean of water uptake is 221.3 ml ranged from 145 ml (JAK-10) to 292.5 ml (JAK-32). The GCV and PCV were moderate (14.5%, 17.2% respectively) with high heritability estimate (71.3%), high genetic advance as percent of mean 25.3% and genetic advance 55.9 indicating that direct selection if effective for the character. The results are in accordance with Devi *et al.* (2020) for GCV and PCV, Devi *et al.* (2022) for heritability and genetic advance as percent of mean.

Volume expansion ratio ranged between 4.35 (BPT-5204 and JAK-320) to 5.63 with a general mean of 4.91. Low GCV and PCV was recorded (0%, 8.5% respectively) with heritability, genetic advance and genetic advance as percent of mean of the character are low (0%, 0, 0%). These findings are reported earlier by Lakshmi *et al.* (2017) for PCV.

Amylose content recorded a general mean of 23.92% ranging from 7.18% (JAK-320) to 28.25% (JAK-286). Moderate GCV and PCV (14.2%, 14.9% respectively) was recorded. High heritability estimate (90.5%) coupled with high genetic advance as percent of mean (27.8%) and genetic advance 6.6 indicating that the selection is effective for the character. The results are in accordance with Singh *et al.* (2020) and Bandi *et al.* (2018) for all the parameters.

The average value of kernel length after cooking 9.38 mm ranging from 7.01 mm (JAK-60) to 12.4 mm (JAK-494). Moderate GCV and PCV was recorded (13.3%, 15.5% respectively). The heritability estimate of the character was 73.9% with genetic advance as percent of mean 23.7% and genetic advance 2.2 showing that the selection is effective. The results are reported by Devi *et al.* (2019) for heritability.

Elongation ratio ranging from 1.21 (JAK-320) to 2.08 (JAK-271) with a general mean of 1.62. It noticed moderate GCV and PCV (10.8%, 12.6% respectively). The heritability estimate is high (72.8%) with genetic advance 0.3 and genetic advance as percent mean 19% was recorded indicating the presence of non-additive gene action. Hence, selection for the trait cannot be effective.

Zinc content varied from 13.2 ppm (JAK-221) to 23.45 ppm (JAK-286) with a mean of 18.38 ppm. High GCV and PCV was recorded (99.3%, 99.5% respectively) for the trait. High heritability (99.7%) with high genetic advance as percent of mean (60.2%) and genetic advance 7.5 indicating the presence of additive variance. Hence, selection is effective for further crop improvement. The results are in conformity of Singh *et al.* (2020) for GCV and PCV and Ullah *et al.* (2023) for heritability and genetic advance as percent of mean.

In the present study, iron content recorded from 1.5 ppm (JAK-117) to 22.485 ppm (BPT-5204) with a mean of 3.71 ppm. Moderate GCV and PCV was recorded for the character (15.5%, 15.6% respectively). High heritability (98.3%) coupled with high genetic advance as percent mean 31.7 and genetic advance 5.8 indicating that the selective is effective. These findings are reported by Sudeepti *et al.* (2020) for GCV and Ullah *et al.* (2023) for heritability and genetic advance as percent of mean.

Table 1 Mean performance of the 49 genotypes with respect to yield, yield component and quality related traits

| S.No. | Genotype | DFF | PH | PP | TW | YP | HRR | KL | KB | LB | WU | VER | AC | KLAC | ER | Zn | Fe |
|-------|----------|-----|--------|----|-------|-------|-------|------|------|------|--------|------|-------|-------|------|-------|------|
| 1 | JAK-10 | 59 | 77.18 | 12 | 22.34 | 12.60 | 55.70 | 5.71 | 2.13 | 2.67 | 145.00 | 4.55 | 23.34 | 9.50 | 1.65 | 17.00 | 1.95 |
| 2 | JAK-20 | 70 | 124.31 | 11 | 28.41 | 15.49 | 58.45 | 5.55 | 2.02 | 2.74 | 202.50 | 4.50 | 23.78 | 8.00 | 1.43 | 16.65 | 3.60 |
| 3 | JAK-25 | 63 | 106.98 | 10 | 24.50 | 11.44 | 65.70 | 6.06 | 2.28 | 2.64 | 202.50 | 4.40 | 25.83 | 9.45 | 1.55 | 19.25 | 2.05 |
| 4 | JAK-26 | 58 | 98.31 | 8 | 26.53 | 12.66 | 61.60 | 7.91 | 1.87 | 4.21 | 261.00 | 5.00 | 22.72 | 12.65 | 1.59 | 20.40 | 2.90 |
| 5 | JAK-32 | 69 | 83.96 | 7 | 27.45 | 9.46 | 50.20 | 7.62 | 1.96 | 3.88 | 292.50 | 4.70 | 25.00 | 13.50 | 1.77 | 15.65 | 3.85 |
| 6 | JAK-34 | 62 | 91.20 | 5 | 22.87 | 7.69 | 59.95 | 5.50 | 2.29 | 2.39 | 235.00 | 5.30 | 24.54 | 8.75 | 1.58 | 17.10 | 3.05 |
| 7 | JAK-58 | 64 | 126.18 | 7 | 29.81 | 10.72 | 55.35 | 5.64 | 2.59 | 2.17 | 217.50 | 5.15 | 24.81 | 9.85 | 1.74 | 19.70 | 3.60 |
| 8 | JAK-60 | 66 | 111.68 | 8 | 21.63 | 12.87 | 39.92 | 5.21 | 2.53 | 2.06 | 228.00 | 4.85 | 25.25 | 7.01 | 1.42 | 20.70 | 4.80 |
| 9 | JAK-77 | 59 | 99.28 | 8 | 21.9 | 8.88 | 69.45 | 4.47 | 2.68 | 1.66 | 207.50 | 5.15 | 26.09 | 9.15 | 2.04 | 20.00 | 2.20 |
| 10 | JAK-94 | 57 | 114.43 | 5 | 19.37 | 7.79 | 67.12 | 6.30 | 2.38 | 2.64 | 147.50 | 4.80 | 25.19 | 10.05 | 1.71 | 20.50 | 4.85 |
| 11 | JAK-99 | 59 | 95.26 | 10 | 26.72 | 11.94 | 65.61 | 6.12 | 2.34 | 2.60 | 268.00 | 5.10 | 27.94 | 9.90 | 1.65 | 19.20 | 1.95 |
| 12 | JAK-117 | 56 | 104.00 | 13 | 14.16 | 11.93 | 63.15 | 5.47 | 1.77 | 3.09 | 275.00 | 5.05 | 26.55 | 9.95 | 1.81 | 18.70 | 1.50 |
| 13 | JAK-126 | 55 | 128.71 | 10 | 25.00 | 15.69 | 59.20 | 5.87 | 2.11 | 2.77 | 207.50 | 5.00 | 22.92 | 9.45 | 1.61 | 17.65 | 2.20 |
| 14 | JAK-152 | 74 | 71.75 | 11 | 22.99 | 13.36 | 55.00 | 5.95 | 2.10 | 2.66 | 177.50 | 4.95 | 27.81 | 9.05 | 1.51 | 17.35 | 3.10 |
| 15 | JAK-153 | 68 | 85.60 | 20 | 22.45 | 7.75 | 57.85 | 5.37 | 2.70 | 1.99 | 178.00 | 5.00 | 27.40 | 7.57 | 1.45 | 20.70 | 4.00 |
| 16 | JAK-172 | 65 | 83.50 | 9 | 25.95 | 9.97 | 62.60 | 6.61 | 2.11 | 3.12 | 216.50 | 4.85 | 23.00 | 8.93 | 1.44 | 21.55 | 3.70 |
| 17 | JAK-208 | 63 | 96.33 | 5 | 28.21 | 6.95 | 61.30 | 5.67 | 2.49 | 2.27 | 196.50 | 5.15 | 26.98 | 9.80 | 1.79 | 17.55 | 3.50 |
| 18 | JAK-210 | 66 | 101.33 | 6 | 31.96 | 12.38 | 69.50 | 6.34 | 2.42 | 2.61 | 205.00 | 4.65 | 22.40 | 10.15 | 1.63 | 15.40 | 3.00 |
| 19 | JAK-216 | 69 | 120.85 | 14 | 21.43 | 17.18 | 61.75 | 5.94 | 2.42 | 2.45 | 170.00 | 4.50 | 26.32 | 8.25 | 1.38 | 14.15 | 2.80 |
| 20 | JAK-221 | 70 | 119.63 | 10 | 26.91 | 10.19 | 50.00 | 5.92 | 2.49 | 2.37 | 259.00 | 4.70 | 24.71 | 9.75 | 1.60 | 13.20 | 2.35 |

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|----|-----------|----|--------|----|-------|-------|-------|------|------|------|--------|------|-------|-------|------|-------|-------|
| 21 | JAK-271 | 78 | 73.98 | 13 | 25.13 | 7.51 | 64.95 | 5.13 | 1.89 | 2.70 | 228.00 | 5.30 | 25.37 | 10.10 | 2.08 | 14.75 | 2.65 |
| 22 | JAK-273 | 65 | 112.83 | 10 | 23.81 | 10.05 | 53.70 | 5.64 | 2.33 | 2.41 | 187.50 | 4.95 | 24.87 | 8.35 | 1.47 | 17.80 | 1.55 |
| 23 | JAK-274 | 64 | 120.83 | 13 | 21.16 | 7.95 | 53.65 | 6.47 | 2.00 | 3.30 | 242.50 | 4.75 | 24.66 | 12.30 | 1.87 | 21.45 | 1.60 |
| 24 | JAK-286 | 57 | 81.68 | 10 | 24.66 | 12.34 | 57.40 | 6.58 | 2.02 | 3.25 | 288.50 | 4.90 | 28.25 | 8.95 | 1.35 | 23.45 | 1.95 |
| 25 | JAK-320 | 69 | 154.83 | 6 | 29.05 | 10.65 | 63.30 | 6.08 | 2.60 | 2.33 | 252.50 | 4.40 | 7.18 | 7.30 | 1.21 | 21.35 | 2.20 |
| 26 | JAK-410 | 58 | 82.33 | 11 | 19.50 | 18.99 | 63.10 | 6.29 | 1.90 | 3.24 | 227.50 | 5.15 | 25.63 | 9.40 | 1.49 | 12.30 | 2.55 |
| 27 | JAK-411 | 60 | 77.73 | 15 | 30.27 | 17.65 | 64.45 | 5.90 | 2.08 | 2.83 | 222.50 | 4.65 | 26.31 | 9.70 | 1.65 | 14.55 | 2.50 |
| 28 | JAK-416 | 57 | 87.15 | 12 | 19.48 | 16.59 | 62.90 | 5.96 | 1.99 | 2.98 | 222.50 | 5.10 | 27.14 | 9.65 | 1.61 | 17.60 | 2.10 |
| 29 | JAK-424 | 69 | 140.90 | 10 | 20.65 | 9.62 | 63.50 | 6.04 | 2.19 | 2.75 | 260.00 | 5.45 | 23.06 | 10.60 | 1.75 | 22.30 | 3.05 |
| 30 | JAK-467 | 70 | 73.18 | 7 | 15.34 | 8.47 | 65.00 | 5.57 | 2.01 | 2.76 | 218.00 | 4.93 | 24.99 | 8.45 | 1.67 | 22.45 | 3.45 |
| 31 | JAK-468 | 67 | 72.66 | 10 | 18.79 | 10.59 | 52.70 | 5.73 | 2.21 | 2.59 | 237.50 | 4.45 | 21.32 | 10.75 | 1.89 | 22.45 | 3.60 |
| 32 | JAK-469 | 59 | 123.28 | 10 | 25.56 | 14.19 | 57.30 | 5.44 | 2.62 | 2.07 | 288.50 | 4.64 | 24.14 | 7.79 | 1.59 | 18.55 | 3.70 |
| 33 | JAK-472 | 63 | 130.83 | 8 | 24.22 | 10.93 | 61.50 | 5.40 | 2.69 | 2.00 | 257.50 | 4.90 | 24.58 | 8.85 | 1.64 | 16.65 | 4.95 |
| 34 | JAK-474 | 72 | 110.35 | 12 | 17.54 | 11.79 | 59.70 | 5.24 | 2.34 | 2.25 | 215.00 | 5.40 | 25.38 | 8.35 | 1.58 | 17.30 | 3.40 |
| 35 | JAK-494 | 77 | 105.76 | 7 | 19.98 | 7.56 | 56.60 | 6.41 | 2.10 | 3.04 | 229.50 | 4.70 | 25.32 | 12.80 | 2.21 | 17.40 | 4.35 |
| 36 | JAK-542 | 77 | 104.98 | 7 | 24.03 | 8.52 | 64.10 | 6.68 | 2.09 | 3.18 | 247.50 | 4.85 | 25.03 | 9.60 | 1.43 | 16.00 | 4.10 |
| 37 | JAK-595 | 69 | 90.03 | 10 | 21.11 | 7.65 | 54.55 | 5.70 | 2.21 | 2.58 | 192.50 | 4.75 | 22.89 | 9.05 | 1.58 | 17.05 | 4.95 |
| 38 | JAK-622 | 67 | 84.81 | 9 | 23.62 | 12.73 | 65.30 | 5.61 | 2.49 | 2.25 | 195.00 | 4.90 | 24.34 | 8.10 | 1.44 | 21.50 | 2.95 |
| 39 | JAK-659 | 64 | 125.00 | 10 | 23.17 | 9.83 | 64.55 | 5.42 | 2.49 | 2.17 | 245.00 | 5.10 | 14.19 | 9.30 | 1.71 | 19.85 | 2.10 |
| 40 | JAK-284-2 | 63 | 93.31 | 9 | 25.66 | 10.58 | 70.30 | 6.52 | 2.16 | 3.01 | 190.00 | 4.65 | 22.04 | 10.30 | 1.57 | 15.50 | 1.95 |
| 41 | JAK-377-3 | 66 | 72.08 | 15 | 22.98 | 12.80 | 67.70 | 6.50 | 2.17 | 2.98 | 187.50 | 4.65 | 20.12 | 10.00 | 1.53 | 16.30 | 2.60 |
| 42 | JAK-420-2 | 65 | 78.56 | 9 | 23.90 | 11.18 | 54.75 | 5.61 | 2.39 | 2.34 | 278.00 | 5.05 | 17.99 | 9.10 | 1.71 | 20.50 | 2.40 |
| 43 | JAK-625 | 71 | 122.50 | 15 | 22.57 | 12.94 | 64.65 | 5.49 | 2.31 | 2.36 | 238.00 | 5.20 | 24.48 | 8.95 | 1.75 | 19.65 | 2.80 |
| 44 | JAK-595-1 | 73 | 112.00 | 6 | 24.01 | 7.66 | 63.95 | 5.57 | 2.22 | 2.50 | 192.50 | 5.00 | 24.16 | 9.20 | 1.64 | 18.50 | 2.65 |
| 45 | WGL14 | 97 | 107.70 | 10 | 16.35 | 31.80 | 64.25 | 5.26 | 1.82 | 2.88 | 205.00 | 5.63 | 24.59 | 7.75 | 1.46 | 13.50 | 19.10 |

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|----|----------------|----|-------|----|-------|-------|-------|------|------|------|--------|------|-------|------|------|-------|-------|
| 46 | Gontrobidhan-3 | 64 | 94.26 | 10 | 16.82 | 23.50 | 50.90 | 5.18 | 2.15 | 2.40 | 197.50 | 4.95 | 23.46 | 8.10 | 1.56 | 16.65 | 2.95 |
| 47 | Zincorice | 66 | 84.71 | 10 | 22.06 | 18.59 | 56.25 | 5.67 | 2.10 | 2.69 | 220.00 | 5.35 | 22.25 | 7.40 | 1.30 | 23.70 | 3.10 |
| 48 | Protozinc | 69 | 89.78 | 11 | 25.48 | 25.09 | 64.35 | 6.29 | 2.17 | 2.89 | 197.50 | 5.00 | 20.88 | 9.75 | 1.54 | 23.45 | 3.00 |
| 49 | BPT-5204 | 96 | 91.95 | 9 | 15.25 | 21.99 | 64.45 | 5.05 | 1.87 | 2.69 | 188.00 | 4.35 | 24.83 | 9.00 | 1.71 | 15.70 | 22.48 |

DFF=Days to 50% flowering, PH=Plant height, TW=Test weight. HRR=Head rice recovery, KL=kernel length, KB=Kernel breadth, LB=LB ratio, WU=water uptake, VER=Volume expansion ratio, KLAC=Kernel length after cooking, ER=elongation ratio, Zn=Zinc content, Fe=Iron content, YP=Yield plant⁻¹

UNDER PEER REVIEW

Table 2 Estimation of variability, heritability and genetic advance for yield and yield contributing and quality traits

| Characters | Coefficient of variance | | Heritability(%) | Genetic advance | Genetic advance as percent mean (%) |
|------------|-------------------------|--------|-----------------|-----------------|-------------------------------------|
| | GCV(%) | PCV(%) | | | |
| DFF | 12.37 | 12.57 | 96.90 | 16.79 | 25.09 |
| PH(cm) | 19.83 | 19.88 | 99.40 | 41.07 | 40.73 |
| PP | 28.85 | 30.12 | 91.70 | 5.71 | 56.93 |
| TW(g) | 17.28 | 17.46 | 97.90 | 8.14 | 35.24 |
| YP(g) | 39.80 | 40.69 | 95.66 | 10.09 | 80.19 |
| HRR(%) | 8.78 | 10.99 | 63.80 | 8.73 | 14.46 |
| KL(mm) | 9.71 | 11.18 | 75.40 | 1.02 | 17.37 |
| KB(mm) | 10.62 | 11.37 | 87.00 | 0.45 | 20.42 |
| LB | 16.58 | 18.51 | 80.00 | 0.81 | 30.61 |
| WU(ml) | 14.53 | 17.21 | 71.30 | 55.99 | 25.30 |
| VER | 0 | 8.55 | 0 | 0 | 0 |
| AC(%) | 14.23 | 14.95 | 90.50 | 6.67 | 27.89 |
| KLAC | 13.39 | 15.57 | 73.90 | 2.22 | 23.72 |
| ER | 10.82 | 12.68 | 72.80 | 0.30 | 19.03 |
| FE(ppm) | 99.34 | 99.59 | 99.70 | 7.58 | 60.27 |
| ZN(ppm) | 15.53 | 15.66 | 98.30 | 5.83 | 31.74 |

DFF=Days to 50% flowering, PH=Plant height, TW=Test weight. HRR=Head rice recovery, KL=kernel length, KB=Kernel breadth, LB=LB ratio, WU=water uptake, VER=Volume expansion ratio, KLAC=Kernel length after cooking, ER=elongation ratio, Zn=Zinc content, Fe=Iron content, YP=Yield plant⁻¹

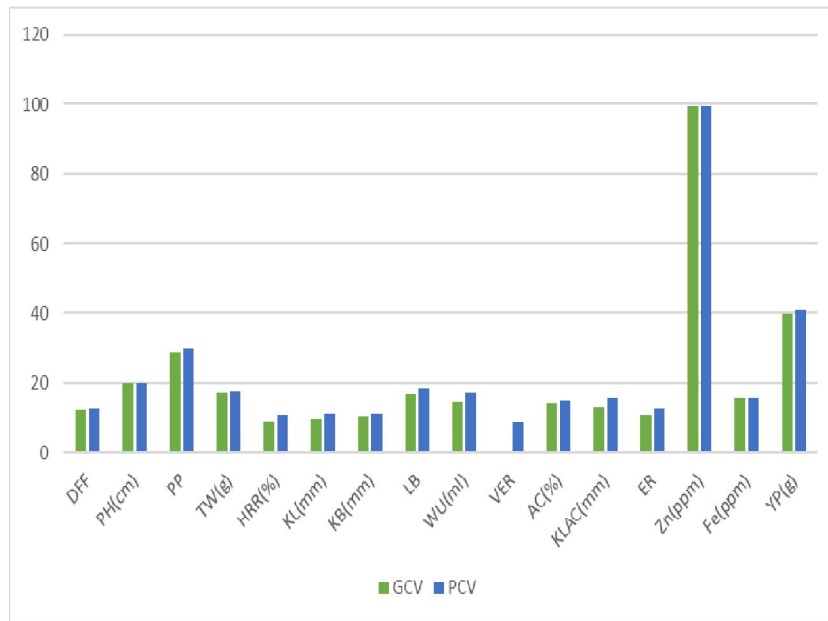


Fig 1 Coefficient of variations for yield, yield attributing and quality traits

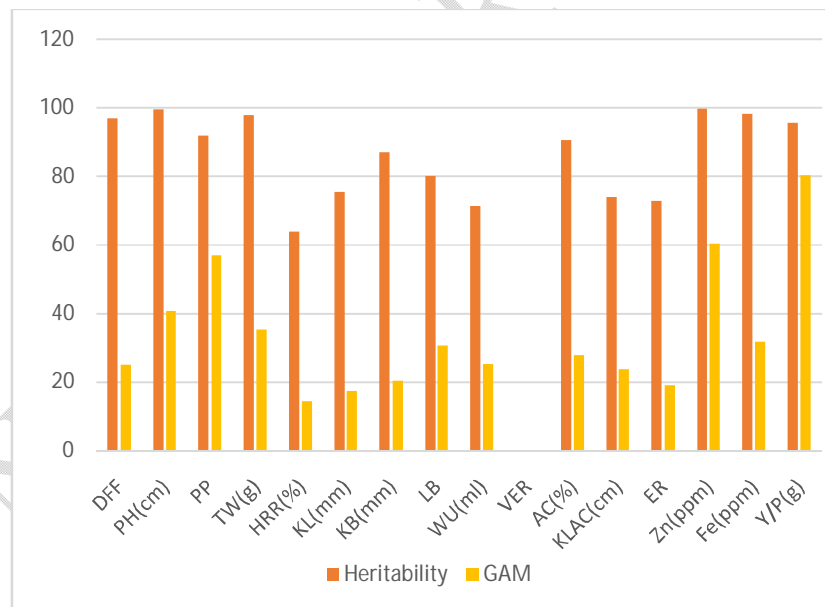


Fig 2 Heritability and genetic advance as percent mean for yield, yield attributing and quality traits

Character association is driven by the correlation coefficient, aids in the evaluation of the relative influence of various yield attributing and quality traits on grain yield. In the present investigation, correlation analysis among yield and its attributing traits (Table 3) revealed the grain yield was positively correlated with days to 50% flowering (0.0555), productive tillers plant⁻¹(0.2827), LB ratio (0.1188) and iron content (0.2683) indicating that these traits could be considered as a criteria of selection for higher grain yield, since they were mutually and directly associated with grain yield. The observed positive correlation of grain yield with these traits was supported by Jasmine *et al.*(2022), Kiran *et al.* (2023) in rice. However, plant height (-0.1471), test weight (-0.1207), head rice recovery (-0.0386), kernel length (-0.0387), kernel breadth (-0.2787), water uptake (-0.1334), volume expansion ratio (-0.1538), amylose content (-0.0276), kernel length after cooking (-0.2349), elongation ratio (-0.3381) and zinc content (-0.092) were found to be negatively correlated with a yield that would hinder the expression of the plant yield as reported by Vennela *et al.* (2021) and Lakshmi *et al.* (2020). Hence, selecting the accessions with late maturity producing more no of productive tillers plant⁻¹, reduced plant height, and less kernel breadth would be rewarding.

Pearson correlation plot (Fig 3) depicting the strong correlation between kernel length and LB ratio while, no correlation between days to 50% flowering and Productive tillers plant⁻¹, Productive tillers plant⁻¹ and LB ratio; and kernel length and zinc content. The yield plant⁻¹ had a moderate correlation with productive tillers plant⁻¹.

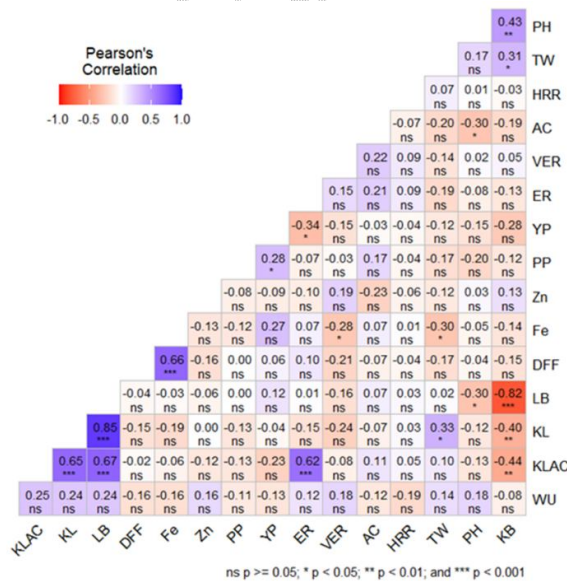


Fig 3 Pearson's correlation plot for yield, yield component and quality traits

Table 3 Correlation coefficient for yield, yield component and quality traits

| | DFF | PH | PP | TW | HRR | KL | KB | LB | WU | VER | AC | KLAC | ER | Zn | Fe | YP |
|------|-----|--------|----------|---------|---------|----------|-----------|-------------|--------|--------|--------|-----------|-----------|---------|-----------|---------|
| DFF | 1 | 0.0413 | 0.002811 | -0.1685 | 0.04264 | -0.15233 | -0.1478 | -0.038413 | 0.1566 | -0.213 | -0.071 | -0.0249 | 0.1037 | 0.15997 | 0.6631*** | 0.0555 |
| PH | | 1 | -0.20155 | 0.1731 | 0.00785 | -0.11881 | 0.4329** | -0.303934* | 0.1752 | 0.0156 | 0.298* | -0.1266 | -0.0793 | 0.03437 | -0.0535 | -0.1471 |
| PP | | | 1 | -0.1717 | 0.04068 | -0.12929 | -0.1248 | -0.000579 | 0.1082 | 0.0275 | 0.1671 | -0.1283 | -0.0718 | 0.08248 | -0.1247 | 0.2827* |
| TW | | | | 1 | 0.07374 | 0.33119* | 0.3075* | 0.018129 | 0.141 | 0.1402 | -0.199 | 0.0952 | -0.1916 | 0.11719 | -0.2987* | -0.1207 |
| HRR | | | | | 1 | 0.02865 | -0.0304 | 0.027965 | -0.186 | 0.0934 | -0.072 | 0.0471 | 0.0886 | 0.06094 | 0.0147 | -0.0386 |
| KL | | | | | | 1 | -0.4035** | 0.846772*** | 0.2355 | 0.2407 | -0.074 | 0.6502*** | -0.1495 | 0.00392 | -0.1867 | -0.0387 |
| KB | | | | | | | 1 | 0.815004*** | 0.0767 | 0.0468 | -0.191 | -0.4358** | -0.1271 | 0.13303 | -0.1397 | -0.2787 |
| LB | | | | | | | | 1 | 0.2359 | 0.1607 | 0.0717 | 0.6745*** | 0.0102 | -0.0573 | -0.03 | 0.1188 |
| WU | | | | | | | | | 1 | 0.1765 | -0.123 | 0.252 | 0.1188 | 0.15789 | -0.161 | -0.1334 |
| VER | | | | | | | | | | 1 | 0.2169 | -0.0794 | 0.151 | 0.19207 | -0.2842* | -0.1538 |
| AC | | | | | | | | | | | 1 | 0.1095 | 0.207 | -0.228 | 0.0722 | -0.0276 |
| KLAC | | | | | | | | | | | | 1 | 0.6185*** | 0.12321 | -0.061 | -0.2349 |
| ER | | | | | | | | | | | | | 1 | -0.0967 | 0.0652 | 0.3381* |
| Zn | | | | | | | | | | | | | | 1 | -0.1297 | -0.092 |
| Fe | | | | | | | | | | | | | | | 1 | 0.2683 |
| YP | | | | | | | | | | | | | | | | 1 |

* ,** ,*** Significant at 5 % , 1 % and 0.1% levels, respectively DFF=Days to 50% flowering, PH=Plant height, TW=Test weight. HRR=Head rice recovery, KL=kernel length, KB=Kernel breadth, LB=LB ratio, WU=water uptake, VER=Volume expansion ratio, KLAC=Kernel length after cooking, ER=elongation ratio, Zn=Zinc content, Fe=Iron content, YP=Yield plant⁻¹

Path coefficient analysis allows the separation of the correlation coefficients into direct as well as indirect effects (Table 4). Iron content (0.7051) exerted the highest direct positive effect on grain yield per plant followed by kernel length (0.3345) and productive tillers plant⁻¹ (0.2615), indicating that selection for these characters is likely to bring about an overall improvement in grain yield directly. These findings were also reported by Singh *et al.* (2020) and Sudeepthi *et al.* (2020). The direct effects of other twelve characters were too low to be considered of any consequence. Although LB ratio (-0.7349) had a negative direct effect, its indirect effect through kernel breadth (0.5889), kernel length (0.2763) was positive. In the present investigation, high positive indirect effects on grain yield per plant were of LB ratio via, kernel breadth (0.5889). Thus, indirect selection for this trait would be beneficial in enhancing the yield potential of rice varieties.

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Table 4 Direct and indirect effects of independent variables on dependent variable

| | DFF | PH(cm) | PP | TW(gm) | HRR(%) | KL(cm) | KB(cm) | L/B | WU(ml) | VER | AC(%) | KLAC(cm) | ER | Zn(ppm) | Fe(ppm) |
|----------|----------------|---------------|---------------|---------------|--------------|---------------|----------------|----------------|----------------|--------------|----------------|--------------|----------------|----------------|---------------|
| DFF | -0.3497 | -0.002 | 0.0015 | 0.0927 | -0.0025 | 0.0679 | 0.0819 | 0.0013 | 0.051 | -0.0028 | 0.0133 | 0.039 | -0.0061 | 0.0917 | -0.2641 |
| PH(cm) | 0.0002 | 0.0396 | -0.007 | 0.0063 | -0.0005 | -0.0037 | 0.0151 | -0.0105 | 0.0067 | 0.0002 | -0.0122 | -0.0045 | -0.0032 | 0.0012 | -0.0004 |
| PP | -0.0011 | -0.0465 | 0.2615 | -0.0459 | 0.0024 | -0.0397 | -0.0248 | -0.0087 | -0.0305 | 0.0071 | 0.0441 | -0.0358 | -0.0176 | -0.0234 | -0.0222 |
| TW(gm) | -0.0184 | 0.011 | -0.0122 | 0.0694 | 0.0036 | 0.0229 | 0.0234 | -0.0001 | 0.01 | -0.0106 | -0.0133 | 0.0079 | -0.0104 | -0.0035 | -0.0261 |
| HRR(%) | -0.0001 | 0.0002 | -0.0002 | -0.001 | -0.02 | -0.0006 | 0.0012 | -0.0009 | 0.0035 | -0.0015 | 0.0008 | -0.0007 | -0.0015 | 0.0015 | -0.0013 |
| KL(cm) | -0.065 | -0.0315 | -0.0508 | 0.1102 | 0.0096 | 0.3345 | -0.1096 | 0.2763 | 0.0863 | -0.0708 | -0.0153 | 0.2139 | -0.0417 | 0.0099 | -0.0747 |
| KB(cm) | 0.1752 | -0.2853 | 0.0709 | -0.2524 | 0.0448 | 0.245 | -0.7478 | 0.5889 | 0.0521 | 0.0026 | 0.1363 | 0.2652 | 0.0489 | -0.1392 | 0.1838 |
| L/B | 0.0027 | 0.1943 | 0.0243 | 0.0007 | -0.0342 | -0.6069 | 0.5788 | -0.7349 | -0.1831 | 0.0922 | -0.0631 | -0.4688 | 0.0112 | 0.0554 | -0.0101 |
| WU(ml) | 0.0027 | -0.0031 | 0.0022 | -0.0027 | 0.0033 | -0.0048 | 0.0013 | -0.0046 | -0.0186 | -0.0017 | 0.0017 | -0.0044 | -0.0019 | -0.0029 | 0.0029 |
| VER | 0.0008 | 0.0005 | 0.0026 | -0.0147 | 0.0071 | -0.0203 | -0.0003 | -0.012 | 0.0088 | 0.096 | 0.0166 | -0.0178 | 0.0011 | 0.0069 | 0.0003 |
| AC(%) | 0.0047 | 0.0381 | -0.0208 | 0.0237 | 0.005 | 0.0057 | 0.0225 | -0.0106 | 0.0115 | -0.0213 | -0.1236 | -0.0109 | -0.0229 | 0.0276 | -0.0091 |
| KLAC(mm) | -0.0003 | -0.0003 | -0.0004 | 0.0003 | 0.0001 | 0.0019 | -0.0011 | 0.0019 | 0.0007 | -0.0006 | 0.0003 | 0.003 | 0.0019 | -0.0002 | -0.0004 |
| ER | -0.0048 | 0.0223 | 0.0188 | 0.0418 | -0.021 | 0.0348 | 0.0183 | 0.0042 | -0.0281 | -0.0032 | -0.0517 | -0.1732 | -0.2792 | 0.017 | 0.005 |
| Zn(ppm) | 0.0212 | -0.0024 | 0.0072 | 0.0041 | 0.0061 | -0.0024 | -0.015 | 0.0061 | -0.0125 | -0.0058 | 0.018 | 0.0057 | 0.0049 | -0.0807 | 0.0202 |
| Fe(ppm) | 0.5324 | -0.0073 | -0.0597 | -0.2658 | 0.0455 | -0.1575 | -0.1733 | 0.0097 | -0.1096 | 0.0021 | 0.052 | -0.1013 | -0.0125 | -0.1761 | 0.7051 |

Diagonal bold values indicate direct effects, Residual Effect =0.677, DFF=Days to 50% flowering, PH=Plant height, TW=Test weight. HRR=Head rice recovery, KL=kernel length, KB=Kernel breadth, LB=LB ratio, WU=water uptake, VER=Volume expansion ratio, KLAC=Kernel length after cooking, ER=elongation ratio, Zn=Zinc content, Fe=Iron content

Conclusion

The present study revealed a high range of variation and high heritability coupled with high genetic advance was recorded for days to 50 per cent flowering, plant height, productive tillers plant⁻¹, test weight, LB ratio, water uptake, kernel length after cooking, zinc content and iron content. The overall study reveals the presence of a broad genetic base, less environmental influence and additive gene action for the traits studied. Hence, simple and early generation selection of promising lines from present gene pool would be effective for future gene introgression programs. correlation revealed that the grain yield was positively correlated with days to 50% flowering, productive tillers plant⁻¹, LB ratio and iron content indicating that these traits could be considered as a criteria of selection for higher grain yield. Direct positive associations between yield per plant and iron content, kernel length and productive tillers plant⁻¹, selection for which would be effective to enhance the yield potential. Also, L/B ratio via kernel breadth exhibited high positive indirect effects. Therefore, these characters would be most suitable for indirect selection of yield in rice improvement programs.

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