Original Research Article

Correlation, Heritability and Genetic Advance Studies for Yield and Quality Traits in Rice (Oryza sativa L.)

**ABSTRACT**

**This study was conducted with 43 genotypes to study the variability and correlation for fourteen traits at Regional Agricultural Research Station, PJTAU, Polasa, Jagtial, Telangana during the *Kharif*, 2024. Significant genetic variability was recorded for all the traits studied. Grain yield, number of grains per panicle and 1000 grain weight showed the highest genotypic and phenotypic coefficients of variation. High heritability along with high genetic advance as percent of mean was observed for 1000 grain weight, head rice recovery and grain yield per plant suggesting these traits are suitable for effective selection for further improvement. Correlation analysis showed positive and significant associations of plant height, panicle length, number of grains per panicle, kernel breadth, hulling percentage and milling percentage with grain yield. Path coefficient analysis at the genotypic level indicated that panicle length, number of grains per panicle, kernel breadth and milling percentage had positive direct effects on grain yield. These findings offer useful information for developing effective breeding strategies by highlighting the direct and indirect roles of key traits in improving yield.**

***Keywords:*** *Variability, heritability, genetic advance, correlation and path analysis.*

1. **INTRODUCTION**

Rice (*Oryza sativa* L.) is one of the most important staple food crops in the world, feeding more than half of the global population. As a cereal grain cultivated in diverse agro-climatic conditions, rice plays a vital role in global food security and nutrition. The global area under rice is 167.60 million hectares with production of 517.3 million tonnes. In India, rice is cultivated in 478.28 lakh hectares with production of 1378.24 lakh tonnes and productivity of 2882 kg ha-1. In Telangana, rice is cultivated in 46.85 lakh hectares with production of 168.74 lakh tonnes productivity of 3602 kg ha-1 (5). With increasing population pressure and changing climatic conditions, the sustainable production and genetic improvement of rice varieties have become a major focus in agricultural research. To meet the growing demand and ensure food security in India, the current rice yield must increase to 121 million tonnes by 2050, requiring an annual rise in production by nearly two million tonnes.

Genetic improvement of rice largely depends on the knowledge of genetic parameters such as heritability and genetic advance, which play a crucial role in selection and breeding strategies. Heritability, in the broad sense, measures the proportion of total phenotypic variation that is attributed to genetic variance and indicates the potential response of a trait to selection. High heritability values suggest that the observed trait is less influenced by the environment and more by genetic factors, thus enabling effective selection. Genetic advance shows how much a trait can improve through selection and helps understand the progress possible when both heritability and genetic variation are taken into account. To assess variability among traits, approach was employed. Broad-sense heritability (h²) was calculated according to Burton and Devane (1953), while estimates of expected genetic advance were determined using formulas from Johnson et al. (1995).

Correlation is the measure of the mutual relationship between two variables. The correlation coefficient is a statistical measure that evaluates the degree and direction of relationship among variables, such as grain yield and plant height, days to flowering, or number of tillers. Character association derived by correlation coefficient is considered to be one of the important biometrical tools for formulating a selection index as it discloses the strength of relationship among the group of traits (24). A positive correlation indicates that improvement in one trait is likely to enhance the other, while a negative correlation suggests an inverse relationship. Phenotypic and genotypic correlation studies are vital tools in rice breeding programs to understand the relationships between yield and its component traits. Phenotypic correlation refers to the observable association between traits as influenced by both genetic and environmental factors, while genotypic correlation reflects the true genetic relationship, free from environmental influence.

The concept of path analysis or cause and effect analysis was developed by Wright (1921) and later applied to plant selection by Dewey and Lu (1959). However, correlation alone does not reveal the direct and indirect effects of each trait on yield. Path coefficient analysis addresses this limitation by partitioning the correlation coefficients into direct and indirect effects, thereby offering a deeper understanding of the causal relationships among traits. For example, a trait may show a strong correlation with yield due to its indirect effect through another trait. Identifying traits with high direct effects on grain yield enables breeders to prioritize them in selection strategies. Together, the present study offer a comprehensive approach to trait evaluation and assist in the development of high yielding rice varieties through selection in desirable direction.

1. **MATERIALS AND METHODS**

The present investigation was carried out during *Kharif* 2024 at the Regional Agricultural Research Station (RARS), Polasa, Jagtial, Telangana. The experimental material comprised six CMS lines (JMS 13A, JMS 17A, JMS 24A, CMS 59A, RMS 1A and RMS 9A) and five restorer lines (R15, R36, R45, R67 and R91). A total of 30 hybrids were developed using a Line × Tester mating design. In addition, two standard hybrid checks (Shabnam and US 312) were included, making a total of 43 entries (6 lines, 5 testers, 30 hybrids and 2 checks). 30 days old seedlings of all 43 entries were transplanted into the main field using a Randomized Block Design (RBD) with two replications. Each entry was planted in two rows of 4 meters length with a spacing of 20 × 15 cm. Five random plants from each entry and each replication were used to record the data on plant height (cm), panicle length (cm), number of productive tillers per plant and grain yield per plant (g). Days to 50% flowering was recorded on whole plot basis. Five random panicles from each entry was used to record the number of grains per panicle and spikelet fertility (%) and random seed sample was used to record 1000 grain weight and quality traits *viz.,* hulling percentage, milling percentage, head rice recovery (%), kernel length (mm), kernel breadth (mm) and kernel length-to-breadth (L/B) ratio. The estimates of PCV and GCV were classified as low (<10%), medium (10 to 20%) and high (>20%) (Sivasubramanian and Madhavamenon, 1973). Broad sense heritability (h2) was calculated as the ratio of the genotypic variance to the phenotypic variance using the formula according to Allard (1960) and they were categorized using the criteria of Robinson et al. (1949): 0-30% = low; 31-60% = moderate; >60% = high. Genetic advance was calculated as per Burton (1952). Expected gain was calculated as genetic advance following the procedure suggested by Johnson et al (1955) and classified as high (>20%), moderate (10-20%) and low (<10%). Analysis was done as per Singh and Chaudhary (1985) for correlation coefficient and Dewey and Lu (1959) for path analysis. The association between different traits at both genotypic and pheonotypic levels were examined following Al Jibouri *et al.* (1958). The analysis of variance (ANOVA) was conducted using the methodology outlined by Panse and Sukhatme (1967).

**3. RESULTS AND DISCUSSION**

Analysis of variance (Table 1) revealed significant variation for all the traits indicating presence of ample amount of variation for all the traits studied in the present experimental material.

 The phenotypic coefficient of variation (PCV) was low for the days to 50% flowering, plant height, panicle length, spikelet fertility, kernel breadth, kernel L/B ratio, hulling percent and milling percent indicating the presence of less variability for these traits in present experimental material. Whereas, number of productive tillers per plant (6), kernel length and head rice recovery recorded moderate levels of PCV values. High PCV was observed for the traits such as number of grains per panicle, 1000 grain weight and grain yield per plant (7), (8). High PCV was noted for yield and important yield attributing traits, revealed the presence of high variability for these traits and hence simple selection could be practised to improve these yield traits which in turn increase the yield. All the traits except number of productive tillers per plant exhibited narrow differences between PCV and GCV values indicated the minimal influence of environment on expression of these traits, thus selection in desirable direction could helps in improvement of these characters. These results were in accordance with the finding of Sameera et al. (33), Kumar et al (2) and Anusha et al. (35).

 Heritability gives the amount of transmission of traits from parent to its offsprings. In present investigation, the traits *viz.,* days to 50% flowering, kernel length, plant height, 1000 grain weight (14), head rice recovery, milling percent, grain yield per plant, kernel length, panicle length, number of grains per panicle (9), kernel breadth, hulling percent and kernel L/B ratio registered moderate to high levels of heritability (Table 2). Since these traits exhibited high transmission rate, using present material, simple selection can be practiced to develop early maturing genotypes with high yield potential. Lodging of rice varieties at the time of harvest is one of major issues in present day’s rice cultivation, as it increases the production cost as reduces the grain quality. As plant height also showed high heritability, selection for the dwarf stature in segregating generations could yield non lodging genotypes as dwarf stature is one of the important traits that resists lodging.1000 grain weight is one of the important yield attributing traits that recorded high heritability values, hence selection towards coarse or fine grain cultures results in development of different grain segment varieties according to preference of consumer needs. Number of productive tillers per plant exhibited moderate values of heritability indicating the its low rate of transmission to its progeny and less scope for its improvement. The results obtained were coincides with the findings of Tripathi et al (10),

 Generally, high heritability indicates that selection based on phenotype will be more effective. However, its usefulness in breeding increases when it is also supported by high genetic advance, as stated by Johnson *et al.* (1955). Genetic advance gives an idea of the actual improvement expected through selection, which cannot be determined by heritability alone. Hence, the combined study of heritability and genetic advance provides a strong basis for effective selection.

 In the present study (Table 2), genetic advance ranged from low (2.71) for hulling percent to high (50.89) for grain yield per plant. High heritability and high genetic advance were observed for grain yield per plant, 1000 grain weight and head rice recovery. Similar observations were reported (11), (12), (51-53). These are important yield and quality traits and are mostly controlled by additive genes. Therefore, selecting genotypes with better performance for these traits can lead to higher yield with good physical grain quality parameters. In contrast, traits like days to 50% flowering, plant height (13), spikelet fertility and milling percent showed high heritability but low to moderate genetic advance. This suggests the involvement of both additive and non additive gene actions. Hence, improving these traits may require additional breeding methods such as heterosis breeding or recurrent selection. Number of productive tillers per plant, an important yield trait, showed moderate heritability and low genetic advance, indicating its complete control by non additive genes. Therefore, this trait can be improved mainly through heterosis breeding. Grain yield itself, being a complex trait influenced by many factors, showed high heritability and genetic advance, suggesting control by additive genes. Similar observations were reported Singh *et al*. (32), Mounika *et al*. (30), Satyaraj *et al*. (31).

Correlation analysis (Table 3) revealed that grain yield per plant was positively associated with several yield and quality related traits such as plant height, panicle length, number of grains per panicle, kernel breadth, hulling percentage and milling percentage, suggesting that these traits play a vital role in enhancing yield potential. Days to 50% flowering exhibited a positive relationship with head rice recovery and a negative association with kernel length-to-breadth ratio, while its correlation with grain yield was negative but non significant. Plant height showed strong positive associations with panicle length, number of grains per panicle, thousand grain weight, kernel length and kernel breadth. Similarly, panicle length was positively correlated with thousand grain weight, kernel length, kernel breadth and grain yield, while it exhibited a negative association with spikelet fertility and head rice recovery. Number of productive tillers per plant was positively associated with 1000 grain weight, kernel length, kernel breadth and milling percentage. Number of grains per panicle had favourable correlations with spikelet fertility, hulling percentage and head rice recovery, while showing negative relationships with 1000 grain weight, kernel length and kernel L/B ratio. 1000 grain weight exhibited positive associations with kernel length and breadth but had negative correlations with spikelet fertility, hulling percentage and head rice recovery. Spikelet fertility was positively related to number of grains per panicle and hulling percentage. Kernel length showed positive associations with kernel breadth and kernel length-to-breadth ratio but had a negative relationship with head rice recovery. Kernel breadth was positively associated with grain yield and negatively with head rice recovery. The kernel length-to-breadth ratio showed a negative relationship with head rice recovery and grain yield. Hulling percentage had favourable correlations with milling percentage and grain yield. Milling percentage, in turn, showed strong positive associations with head rice recovery and yield. Although head rice recovery had positive associations with number of grains per panicle, it showed negative relationships with 1000 grain weight and grain yield. These findings were also corroborated by Krantikumar et al (16), Nayak et al (17), Shanthi Priya et al (48), Sridevi et al (18), Meena et al (19), Nath et al (1), Surjaye et al (15), Saketh et al. (49), Kumer et al. (2), Roy et al. (1), Islam et al. (50).

While correlation studies helps in identifying associations among traits, they do not reveal the precise contribution of each trait to grain yield. To overcome this limitation, path coefficient analysis was employed to partition the observed correlations into direct and indirect effects, providing a clearer understanding of the traits influencing yield. The analysis (Table 4) at the genotypic level revealed that panicle length (18), (19), (21), kernel breadth, number of grains per panicle (22), (47) and milling percentage and had positive direct effects on grain yield, indicating their important role in improving yield potential. Number of productive tillers per plant and spikelet fertility showed a direct positive genotypic effect on grain yield per plant (54), though its correlation with yield was positive but not significant. On the other hand, days to 50% flowering, plant height, 1000 grain weight, kernel length, hulling percentage and head rice recovery exhibited negative direct effects on grain yield. Kernel length and 1000 grain weight showed strong negative direct effects, indicating their limited utility for direct selection (43). Although the number of grains per panicle had a very small direct effect, its overall impact on yield was positive due to favourable indirect contributions through spikelet fertility and grain quality traits. These findings suggest that traits such as panicle length, number of grains per panicle, kernel breadth and milling percentage should be prioritized in breeding programs to enhance grain yield in rice. Yadav et al (42), Prem kumar et al (4), Pavan et al (20), Sameera et al (45), Gour et al (46), Maneesha et al. (3), Sadhu et al (23) quoted similar results from their findings.

**Table 1. Analysis of variance for grain yield, yield contributing and quality traits in rice**

|  |  |  |
| --- | --- | --- |
| **S. No** | **Character** | **Mean sum of squares** |
| **Replications (d.f = 1)** | **Genotypes (d.f = 42)** | **Error (d.f = 42)** |
|  | Days to 50 % flowering | 2.62 | 80.55\*\*\* | 1.30 |
|  | Plant height (cm) | 2.79 | 230.33\*\*\* | 5.95 |
|  | Panicle length (cm) | 2.26 | 7.32\*\*\* | 0.83 |
|  | Number of productive tillers per plant | 1.61 | 1.45\* | 0.73 |
|  | Number of filled grains per panicle | 130.65 | 5342.51\*\*\* | 715.93 |
|  | 1000 grain weight (g) | 1.47 | 28.39\*\*\* | 0.75 |
|  | Grain yield per plant (g) | 3.90 | 50.74\*\*\* | 2.92 |
|  | Spikelet fertility (%) | 1.26 | 99.75\*\*\* | 6.22 |
|  | Kernel length (mm) | 0.00 | 0.76\*\*\* | 0.01 |
|  | Kernel breadth (mm) | 0.00 | 0.04\*\*\* | 0.00 |
|  | Kernel L/ B ratio | 0.01 | 0.21\*\*\* | 0.04 |
|  | Hulling (%) | 1.54 | 3.84\*\*\* | 0.64 |
|  | Milling (%) | 1.28 | 10.40\*\*\* | 0.53 |
|  | Head rice recovery (%) | 10.18 | 169.29\*\*\* | 5.01 |

**\*: Significant at 5 per cent level; \*\*: Significant at 1 per cent level**

 **Table 2. Estimates of variability, heritability and genetic advance for yield and quality parameters in rice**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Characters** | **Mean** | **Range** | **PCV (%)** | **GCV (%)** | **Heritability in broad sense (h2) (%)** | **Genetic Advance as****% of mean** |
| **Min** | **Max** |
| 1 | Days to 50 % flowering | 89.06 | 77.00 | 101.00 | 7.18 | 7.07 | 0.968 | 14.326 |
| 2 | Plant height | 109.69 | 93.20 | 138.20 | 9.91 | 9.66 | 0.950 | 19.383 |
| 3 | Panicle length | 27.25 | 24.00 | 32.40 | 7.41 | 6.61 | 0.794 | 12.132 |
| 4 | Number of productive tillers per plant | 9.04 | 7.60 | 11.00 | 11.58 | 6.63 | 0.327 | 7.807 |
| 5 | Number of grains per panicle | 225.51 | 99.00 | 348.00 | 24.41 | 21.33 | 0.764 | 38.394 |
| 6 | 1000 grains weight | 18.46 | 11.05 | 27.08 | 20.68 | 20.14 | 0.948 | 40.394 |
| 7 | Grain yield per plant | 18.68 | 10.70 | 32.40 | 27.73 | 26.17 | 0.891 | 50.898 |
| 8 | Spikelet fertility | 86.36 | 66.28 | 95.09 | 8.43 | 7.92 | 0.882 | 15.323 |
| 9 | Kernel length (mm) | 5.70 | 4.39 | 6.75 | 10.97 | 10.77 | 0.964 | 21.779 |
| 10 | Kernel breadth (mm) | 1.59 | 1.23 | 1.87 | 9.68 | 8.25 | 0.727 | 14.497 |
| 11 | Kernel L/ B ratio | 3.60 | 3.02 | 4.58 | 9.90 | 8.05 | 0.661 | 13.481 |
| 12 | Hulling per cent | 81.10 | 76.41 | 83.98 | 1.85 | 1.56 | 0.714 | 2.716 |
| 13 | Milling per cent | 66.49 | 58.18 | 70.40 | 3.52 | 3.34 | 0.903 | 6.544 |
| 14 | Head rice recovery | 46.90 | 28.85 | 63.41 | 19.90 | 19.32 | 0.943 | 38.646 |

**Table 3. Phenotypic (P) and Genotypic (G) correlation coefficients for grain yield, yield contributing and quality traits in rice.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SOURCE** |  | **DFF** | **PH** | **PL** | **NPT** | **NGP** | **1000 GW** | **SF** | **KL** | **KB** | **L/B** | **HP** | **MP** | **HRR** | **GYP** |
| **DFF** | **G** | **1.0000** | 0.0569 | -0.0399 | -0.0194 | 0.1011 | 0.0127 | 0.0466 | -0.1636 | 0.0432 | -0.2417\* | -0.1854 | -0.1014 | 0.2508\* |  -0.1389 |
|  | **P** | **1.0000** | 0.0436 | -0.0406 | -0.0125 | 0.0906 | 0.0178 | 0.0350 | -0.1622 | 0.0319 | -0.1952 | -0.1428 | -0.1020 | 0.2365\* | -0.1315 |
| **PH** | **G** |  | **1.0000** | 0.8009\*\* | 0.0431 | 0.2548\* | 0.3851\*\* | -0.1966 | 0.2612\* | 0.3301\*\* | 0.0065 |  0.0200 | 0.0401 | -0.2044 | 0.6149\*\* |
|  | **P** |  | **1.0000** | 0.6693\*\*\* | 0.0216 | 0.0194 | 0.3747\*\*\* | -0.1774 | 0.2502\* | 0.2940\*\* | -0.0178 | -0.0028 | 0.0402 | -0.1891 | 0.5841\*\* |
| **PL** | **G** |  |  | **1.0000** | 0.0623 | 0.1406 | 0.5132\*\* | -0.4174\*\* | 0.4202\*\* | 0.4180\*\* | 0.1215 |  0.0378 | 0.0228 | -0.2906\*\* | 0.6875\*\* |
|  | **P** |  |  | **1.0000** | 0.0847 | 0.1817 | 0.4375\*\*\* | -0.3293\*\* | 0.3803\*\*\* | 0.3241\*\* | 0.1063 | 0.0035 | -0.0071 | -0.2539\* | 0.5764\*\* |
| **NPT** | **G** |  |  |  | **1.0000** | -0.2027 | 0.2730\* | -0.1082 | 0.3185\*\* | 0.3662\*\* | 0.0434 | 0.1428 |  0.2404\* | 0.1693 | 0.0254 |
|  | **P** |  |  |  | **1.0000** | -0.1428 | 0.1364 | -0.0661 | 0.1944 | 0.2432\* | -0.0289 | 0.1207 |  0.2212 | 0.0777 | 0.0768 |
| **NGP** | **G** |  |  |  |  | **1.0000** | -0.4440\*\* | 0.3181\*\* | -0.5525\*\* | -0.1508 | -0.6070\*\* | 0.2622\* | 0.0199 | 0.4051\*\* | 0.3840\*\* |
|  | **P** |  |  |  |  | **1.0000** | -0.3909\*\*\* | 0.3005\*\* | -0.4758\*\*\* | -0.1770 | -0.3598\*\*\* | 0.2299\* | 0.0107 | 0.3228\*\* | 0.3509\*\* |
| **1000 GW** | **G** |  |  |  |  |  | **1.0000** | -0.2790\*\* | 0.6921\*\* | 0.703\*\* | 0.2040 | -0.2238\* | -0.0423 | -0.4043\*\* | 0.1450 |
|  | **P** |  |  |  |  |  | **1.0000** | -0.2432\* | 0.6672\*\*\* | 0.5908\*\*\* | 0.1571 | -0.1802 | -0.0287 | -0.3691\*\*\* | 0.1323 |
| **SF** | **G** |  |  |  |  |  |  | **1.0000** | -0.5387\*\* | -0.1845 | -0.5456\*\* | 0.2747\* | 0.0520 | 0.2052 | 0.1163 |
|  | **P** |  |  |  |  |  |  | **1.0000** | -0.4849\*\*\* | -0.1546 | -0.3918\*\*\* | 0.1868 | 0.0275 | 0.1740 | 0.1114 |
| **KL** | **G** |  |  |  |  |  |  |  | **1.0000** | 0.6997\*\* | 0.6168\*\* | -0.1515 | 0.1989 | -0.5788\*\* |  0.0640 |
|  | **P** |  |  |  |  |  |  |  | **1.0000** | 0.5962\*\*\* | 0.5249\*\*\* | -0.1330 | 0.1929 | -0.5452\*\*\* | 0.0664 |
| **KB** | **G** |  |  |  |  |  |  |  |  | **1.0000** | -0.1289 | -0.1379 |  0.0816 | -0.3372\*\* | 0.2266\* |
|  | **P** |  |  |  |  |  |  |  |  | **1.0000** | -0.3646\*\*\* | -0.1476 | 0.0683\*\* | -0.2677\* | 0.1690 |
| **L/B** | **G** |  |  |  |  |  |  |  |  |  | **1.0000** | -0.0562 | 0.2062 | -0.4092\*\* | -0.1689 |
|  | **P** |  |  |  |  |  |  |  |  |  | **1.0000** | -0.0066 | 0.1597 | -0.3310\*\* | -0.1075 |
| **HP** | **G** |  |  |  |  |  |  |  |  |  |  | **1.0000** |  0.5840\*\* | 0.1738 | 0.2367\* |
|  | **P** |  |  |  |  |  |  |  |  |  |  | **1.0000** | 0.5161\*\*\* | 0.1418 | 0.2463\* |
| **MP** | **G** |  |  |  |  |  |  |  |  |  |  |  | **1.0000** | 0.879\*\* | 0.2208\* |
|  | **P** |  |  |  |  |  |  |  |  |  |  |  | **1.0000** | 0.0963 | 0.1965 |
| **HRR** | **G** |  |  |  |  |  |  |  |  |  |  |  |  | **1.0000** | -0.1608 |
|  | **P** |  |  |  |  |  |  |  |  |  |  |  |  | **1.0000** | -0.1400 |

**\*: Significant at 5 per cent level; \*\*: Significant at 1 per cent level**

DFF: Days to 50 % flowering, PH: Plant height, PL: Panicle length, NPT: Number of productive tillers per plant, NGP: Number of filled grains per panicle, 1000 GW: 1000 grain weight, KL: Kernel length, KB: Kernel breadth, L/B: Length/Breadth Ratio, HP: Hulling percentage, MP: Milling percentage, HRR: Head rice recovery, GYP: Grain yield per plant.

**Table 4. Phenotypic (P) and Genotypic (G) path coefficients for grain yield, yield contributing and quality traits in rice**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SOURCE** |  | **DFF** | **PH** | **PL** | **NPT** | **NGP** | **1000 GW** | **SF** | **KL** | **KB** | **L/B** | **HP** | **MP** | **HRR** | **GYP** |
| **DFF** | **G** | **-0.1333** | -0.0076 | 0.0053 | 0.0026 | -0.0125 | -0.0017 | -0.0062 | 0.0218 | -0.0058 | 0.0322 | 0.0247 | 0.0135 | -0.0334 | -0.1389 |
|  | **P** | **0.0947** | -0.0041 | 0.0038 | 0.0012 | -0.0086 | -0.0017 | -0.0033 | 0.0154 | -0.0030 | 0.0185 | 0.0135 | 0.0097 | -0.0224 | -0.1315 |
| **PH** | **G** | -0.0028 | **-0.0485** | -0.0388 | -0.0021 | -0.0124 | -0.0187 | 0.0095 | -0.0127 | -0.0160 | -0.0003 | -0.0010 | -0.0019 | 0.0099 | 0.6149\*\* |
|  | **P** | 0.0141 | **0.3237** | 0.2167 | 0.0070 | 0.0635 | 0.1213 | -0.0574 | 0.0810 | 0.0952 | -0.0058 | -0.0009 | 0.0130 | -0.0612 | 0.5841\*\* |
| **PL** | **G** | -0.0423 | 0.8503 | **1.0616** | 0.0661 | 0.1493 | 0.5449 | -0.4431 | 0.4460 | 0.4438 | 0.1290 | 0.0401 | 0.0242 | -0.3085 | 0.6875\*\* |
|  | **P** | -0.0181 | 0.2980 | **0.4453** | 0.0377 | 0.0809 | 0.1948 | -0.1466 | 0.1693 | 0.1443 | 0.0473 | 0.0016 | -0.0032 | -0.1131 | 0.5764\*\* |
| **NPT** | **G** | 0.0020 | 0.0045 | 0.0065 | **0.1044** | -0.0212 | 0.0285 | -0.0113 | 0.0333 | 0.0382 | 0.0045 | 0.0149 | 0.0251 | 0.0177 | 0.0254 |
|  | **P** | 0.0006 | 0.0010 | 0.0039 | **0.0461** | -0.0066 | 0.0063 | -0.0030 | 0.0090 | 0.0112 | -0.0013 | 0.0056 | 0.0102 | 0.0032 | 0.0768 |
| **NGP** | **G** | 0.0004 | 0.0011 | 0.0006 | -0.0009 | **0.0043** | -0.0019 | 0.0014 | -0.0024 | -0.0006 | -0.0026 | 0.0011 | 0.001 | 0.0017 | 0.3840\*\* |
|  | **P** | 0.0090 | 0.0195 | 0.0181 | -0.0142 | **0.0996** | -0.0389 | 0.0299 | -0.0474 | -0.0176 | -0.0359 | 0.0229 | 0.0011 | 0.0322 | 0.3509\*\* |
| **1000 GW** | **G** | -0.0041 | -0.1233 | -0.1643 | -0.0874 | 0.1421 | **-0.3201** | 0.0893 | -0.2215 | -0.2250 | -0.0653 | 0.0717 | 0.0135 | 0.1294 | 0.1450 |
|  | **P** | -0.0011 | -0.0224 | -0.0261 | -0.0081 | 0.0233 | **-0.0597** | 0.0145 | -0.0398 | -0.0353 | -0.0094 | 0.0108 | 0.0017 | 0.0220 | 0.1323 |
| **SF** | **G** | 0.0211 | -0.0891 | -0.1893 | -0.0490 | 0.1442 | -0.1265 | **0.4534** | -0.2442 | -0.0837 | -0.2474 | 0.1246 | 0.0236 | 0.0930 | 0.1163 |
|  | **P** | 0.0081 | -0.0412 | -0.0764 | -0.0153 | 0.0697 | -0.0565 | **0.2321** | -0.1125 | -0.0359 | -0.0909 | 0.0434 | 0.0064 | 0.0404 | 0.1114 |
| **KL** | **G** | 0.1390 | -0.2219 | -0.3570 | -0.2706 | 0.4694 | -0.5880 | 0.4577 | **-0.8496** | -0.5945 | -0.5240 | 0.1287 | -0.1690 | 0.4918 | 0.0640 |
|  | **P** | -0.1160 | 0.1790 | 0.2720 | 0.1391 | -0.3403 | 0.4772 | -0.3468 | **0.7153** | 0.4265 | 0.3755 | -0.0951 | 0.1380 | -0.3900 | 0.0664 |
| **KB** | **G** | 0.0272 | 0.2079 | 0.2632 | 0.2306 | -0.0950 | 0.4427 | -0.1162 | 0.4406 | **0.6297** | -0.0812 | -0.0868 | 0.0514 | -0.2123 | 0.2266\* |
|  | **P** | -0.0226 | -0.2086 | -0.2299 | -0.1725 | 0.1256 | -0.4192 | 0.1090 | -0.4230 | **-0.7095** | 0.2587 | 0.1047 | -0.0485 | 0.1899 | 0.1690 |
| **L/B** | **G** | -0.1106 | 0.0030 | 0.0556 | 0.0198 | -0.2777 | 0.0933 | -0.2496 | 0.2822 | -0.0590 | **0.4575** | -0.0257 | 0.0944 | -0.1872 | -0.1689 |
|  | **P** | 0.1413 | 0.0129 | -0.0770 | 0.0209 | 0.2606 | -0.1137 | 0.2838 | -0.3801 | 0.2640 | **-0.7242** | 0.0048 | -0.1156 | 0.2397 | -0.1075 |
| **HP** | **G** | 0.0343 | -0.0037 | -0.0070 | -0.0264 | -0.0485 | 0.0414 | -0.0508 | 0.0280 | 0.0255 | 0.0104 | **-0.1851** | -0.1081 | -0.0322 | 0.2367\* |
|  | **P** | -0.0097 | -0.0002 | 0.0002 | 0.0082 | 0.0157 | -0.0123 | 0.0127 | -0.0091 | -0.0101 | -0.0004 | **0.0682** | 0.0352 | 0.0097 | 0.2463\* |
| **MP** | **G** | -0.0271 | 0.0107 | 0.0061 | 0.0643 | 0.0053 | -0.0113 | 0.0139 | 0.0532 | 0.0218 | 0.0552 | 0.1563 | **0.2676** | 0.0235 | 0.2208\* |
|  | **P** | -0.0163 | 0.0064 | -0.0011 | 0.0351 | 0.0017 | -0.0046 | 0.0044 | 0.0306 | 0.0108 | 0.0254 | 0.0820 | **0.1588** | 0.0153 | 0.1965 |
| **HRR** | **G** | 0.0387 | 0.0315 | 0.0448 | -0.0261 | -0.0625 | 0.0624 | -0.0317 | 0.0893 | 0.0520 | 0.0631 | -0.0268 | -0.0136 | **-0.1543** | -0.1608 |
|  | **P** | 0.0251 | 0.0200 | 0.0269 | -0.0082 | -0.0342 | 0.0391 | -0.0185 | 0.0578 | 0.0284 | 0.0351 | -0.0150 | -0.0102 | **-0.1060** | **-0.1400** |
|  |  | **Genotypic Residual effect =0.4687 Phenotypic Residual effect = 0.6458 Bold values are direct effects** |

**\*: Significant at 5 per cent level; \*\*: Significant at 1 per cent level**

DFF: Days to 50 % flowering, PH: Plant height, PL: Panicle length, NPT: Number of productive tillers per plant, NGP: Number of filled grains per panicle, 1000 GW: 1000 grain weight, KL: Kernel length, KB: Kernel breadth, L/B: Length/Breadth Ratio, HP: Hulling percentage, MP: Milling percentage, HRR: Head rice recovery, GYP: Grain yield per plant.

1. **Conclusion**

The present investigation revealed considerable genetic variability among the genotypes for all the yield and quality traits studied, indicating the potential for improvement through selection. Correlation analysis showed that grain yield per plant had strong positive associations with plant height, panicle length, number of grains per panicle, kernel breadth, hulling percentage and milling percentage, suggesting these traits can serve as reliable indicators for yield improvement. Path coefficient analysis further confirmed that panicle length, kernel breadth, spikelet fertility, milling percentage and kernel L/B ratio exerted positive direct effects on grain yield, highlighting their importance in determining yield performance. High estimates of heritability along with high genetic advance were observed for grain yield per plant, 1000 grain weight, plant height and head rice recovery, suggesting the predominance of additive gene action and the effectiveness of selection for these traits. Over all the study identified panicle length, kernel breadth, spikelet fertility and 1000 grain weight as key traits contributing to grain yield.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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