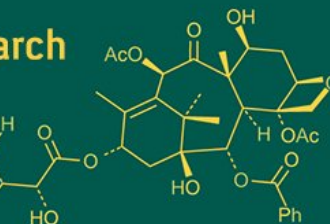
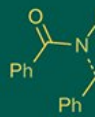


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## Correlation and path coefficient analysis in line × tester derived hybrids of rice (*Oryza sativa* L.)

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### Abstract

The present study was conducted to assess the association among yield and yield contributing traits in rice (*Oryza sativa* L.) using correlation and path coefficient analysis. Forty hybrids developed through Line × Tester mating design involving four lines and ten testers were evaluated along with their parents and two checks (KPH 473 and US 312) in a randomized block design with three replications during Rabi 2022 at the College Farm, College of Agriculture, PJTAU, Rajendranagar, Hyderabad.. Correlation analysis revealed that grain yield per plant showed significant positive associations with plant height, panicle length, spikelet fertility, head rice recovery, and kernel quality traits, indicating their importance in yield improvement. Hence, selection for these traits could be rewarding. Path coefficient analysis further revealed that panicle length, plant height, spikelet fertility, and head rice recovery exerted strong positive direct effects on grain yield, confirming their major contribution to yield expression. Based on both correlation and path analysis, these traits were identified as key selection criteria for improving grain yield in rice breeding programmes. The residual effect in the present study effectively explained both the direct and indirect impacts on the dependent variable to a certain degree.

**Keywords:** Line x tester, correlation coefficient, path analysis, direct selection, residual effect

### Introduction

Rice stands as one of the world's most vital cereal crops, serving as a key food and protein source for approximately half of the global population. Its significance extends beyond nutrition to have substantial economic and food security implications, especially in many Asian countries. Globally, rice is cultivated across 162.76 million hectares, yielding a total of 495.87 million tonnes with an average productivity of 4.55 tonnes per hectare. Despite the considerable advancements in rice production and productivity brought about by the Green Revolution, further improvements have been constrained by a yield plateau, influenced by various biotic and abiotic factors. Ensuring future food security poses a significant challenge, especially for rice breeders in India, where rice is crucial for both food and nutritional security. To overcome the current yield limits, there is a need for rice varieties with higher productivity and adaptable agronomic traits. Hybridization presents a highly effective and practical approach for generating the desired variability which relies on the capacity to identify and select superior genotypes through a careful selection process. Selection criteria are usually based on yield or its components and can be executed either directly or indirectly (Margam *et al.* 2024) [30]. When traits are correlated, selecting for one trait can influence other related traits as well. Grain yield is affected by various component traits and understanding the association between predictor factors and responder variables and their direct and indirect impacts on yield is crucial for effective yield improvement (Meena *et al.* 2020) [19]. While correlation measures the degree of association between two traits, it does not explain the causal relationships. Path coefficient analysis, as introduced by Dewey and Lu (1959) [3], offers insights into the direct and indirect effects of traits on yield. This method, when combined with correlation analysis, helps to clarify the cause-and-effect relationships between different traits (Jayasudha and Sharma, 2010) [10]. Such comprehensive analysis supports breeders for estimating the degree and direction of association thereby employing suitable methods of selection. Therefore, the objective of the current study is to investigate the character associations and path analysis among traits in line x tester hybrids for yield improvement.

## Material and Methods

Forty hybrids were obtained from the crosses involving four lines with ten testers through Line x Tester fashion, the method developed by Kempthorne (1957) [12]. Forty hybrids were raised along with parents and 2 checks (KPH 473, US 312) (Table. 1) in a randomized block design replicated thrice at College farm, college of Agriculture, PJTAU, Rajendranagar, Hyderabad, during *Rabi* 2022. Twenty-five days old seedlings of parents, hybrids and checks were transplanted in the main field with a spacing of 20 x 15 cm. Recommended package of practices with need based plant

protection measures were taken up to raise good crop as previously reported in kumar *et al.* (2023) [16]. The association study was made to assess the relationship among Grain yield/plant (g) with twelve traits viz., Days to fifty percent flowering (DFF), Plant Height (cm), Panicle length (PL) (cm), No. of Productive Tillers per plant (PT), Spikelet fertility (SF%), 1000 grain weight (TGW gm), Kernel length (KL mm), Kernel breadth (KB mm), Kernel L/B ratio (KLB), Hulling (HULL%), Milling (MILL%) and Head rice recovery (HRR%).

**Table 1:** Details of the parents of the intra-specific cross studied in the present investigation

| S.No | Lines   | S.No | Hybrids          | S.No | Hybrids          | S.No | Hybrids          |
|------|---------|------|------------------|------|------------------|------|------------------|
| 1.   | CMS 14B | 1.   | CMS 14A × R 4    | 16.  | CMS 64A × R 165  | 31.  | JMS 18A × R 4    |
| 2.   | CMS 64B | 2.   | CMS 14A × R 32   | 17.  | CMS 64A × R 190  | 32.  | JMS 18A × R 32   |
| 3.   | CMS 69B | 3.   | CMS 14A × R 136  | 18.  | CMS 64A × R 220  | 33.  | JMS 18A × R 136  |
| 4.   | JMS 18B | 4.   | CMS 14A × R 139  | 19.  | CMS 64A × SN 127 | 34.  | JMS 18A × R 139  |
| S.No | Testers | 5.   | CMS 14A × R 156  | 20.  | CMS 64A × SN 464 | 35.  | JMS 18A × R 156  |
| 1.   | R 4     | 6.   | CMS 14A × R 165  | 21.  | CMS 69A × R 4    | 36.  | JMS 18A × R 165  |
| 2.   | R 32    | 7.   | CMS 14A × R 190  | 22.  | CMS 69A × R 32   | 37.  | JMS 18A × R 190  |
| 3.   | R 136   | 8.   | CMS 14A × R 220  | 23.  | CMS 69A × R 136  | 38.  | JMS 18A × R 220  |
| 4.   | R 139   | 9.   | CMS 14A × SN 127 | 24.  | CMS 69A × R 139  | 39.  | JMS 18A × SN 127 |
| 5.   | R 156   | 10.  | CMS 14A × SN 464 | 25.  | CMS 69A × R 156  | 40.  | JMS 18A × SN 464 |
| 6.   | R 165   | 11.  | CMS 64A × R 4    | 26.  | CMS 69A × R 165  | S.No | Checks           |
| 7.   | R 190   | 12.  | CMS 64A × R 32   | 27.  | CMS 69A × R 190  | 1.   | KPH 473(Check-1) |
| 8.   | R 220   | 13.  | CMS 64A × R 136  | 28.  | CMS 69A × R 220  | 2.   | US 312 (Check-2) |
| 9.   | SN 127  | 14.  | CMS 64A × R 139  | 29.  | CMS 69A × SN 127 |      |                  |
| 10.  | SN 464  | 15.  | CMS 64A × R 156  | 30.  | CMS 69A × SN 464 |      |                  |

## Statistical analysis

Correlation was worked out using the formulae suggested by Weber and Moorthy (1952) [28]. Partitioning of the correlation coefficients into direct and indirect effects was carried out using the procedure suggested by Wright (1921) [29] and elaborated by Dewey and Lu (1959) [3]. The characterization of path coefficients was carried out as suggested by Lenka and Mishra (1973) [17].

## Results and Discussion

### Correlation coefficient analysis

In order to identify the key traits useful for crop improvement through appropriate breeding programmes, selection based on correlation analysis is essential as it provides a clear understanding of the strength and direction of association between grain yield and its component traits (Table 2; Figure 1). The correlation analysis revealed several significant associations among the studied traits. Days to fifty per cent flowering showed a strong positive and highly significant correlation with plant height ( $r = 0.593^{**}$ ), and positive significant associations with hulling percentage ( $r = 0.308^{*}$ ) and milling percentage ( $r = 0.286^{*}$ ), indicating that later flowering genotypes tended to be taller and associated with better grain quality traits. Plant height exhibited a highly significant positive correlation with panicle length ( $r = 0.556^{**}$ ) and grain yield per plant ( $r = 0.490^{**}$ ), while it showed a significant negative association with productive tillers ( $r = -0.366^{**}$ ). It also recorded positive significant correlations with kernel breadth ( $r = 0.294^{*}$ ), hulling percentage ( $r = 0.281^{*}$ ), and head rice recovery ( $r = 0.282^{*}$ ). Similar positive associations between plant height, panicle length, and grain yield have been reported by Saketh *et al.* (2023) [31], Devi *et al.* (2022) [4], Deepthi *et al.* (2022) [2], Faysal *et al.* (2022) [6], Heera *et al.* (2023) [9], and Thuy *et al.* (2023) [23]. Panicle length showed

significant positive correlations with kernel length ( $r = 0.265^{*}$ ) and grain yield per plant ( $r = 0.551^{**}$ ). Productive tillers did not exhibit any significant positive association with grain yield and showed a negative association with plant height, supporting earlier findings by Kiran *et al.* (2023) [13]. Spikelet fertility recorded highly significant positive correlations with thousand grain weight ( $r = 0.497^{**}$ ), kernel breadth ( $r = 0.368^{**}$ ), hulling percentage ( $r = 0.370^{**}$ ), milling percentage ( $r = 0.389^{**}$ ), head rice recovery ( $r = 0.414^{**}$ ), and grain yield per plant ( $r = 0.399^{**}$ ), indicating its strong influence on both yield and quality traits. Thousand grain weight showed highly significant positive correlations with kernel length ( $r = 0.427^{**}$ ) and kernel breadth ( $r = 0.374^{**}$ ). Kernel length was positively associated with kernel breadth ( $r = 0.392^{**}$ ) and kernel length-breadth ratio ( $r = 0.498^{**}$ ), whereas kernel breadth exhibited a highly significant negative correlation with kernel length-breadth ratio ( $r = -0.597^{**}$ ), indicating their inverse relationship. Among quality traits, hulling percentage showed a very strong positive association with milling percentage ( $r = 0.963^{**}$ ), while both hulling percentage and milling percentage were positively and significantly correlated with head rice recovery ( $r = 0.686^{**}$  and  $r = 0.700^{**}$ , respectively), reflecting their close interdependence.

Grain yield per plant exhibited highly significant positive correlations with plant height ( $r = 0.490^{**}$ ), panicle length ( $r = 0.551^{**}$ ), spikelet fertility ( $r = 0.399^{**}$ ), and head rice recovery ( $r = 0.460^{**}$ ). It also showed significant positive correlations with kernel breadth ( $r = 0.318^{*}$ ), hulling percentage ( $r = 0.327^{*}$ ), and milling percentage ( $r = 0.329^{*}$ ). Similar positive associations between single plant yield and plant height, panicle length, and thousand grain weight have been reported by Kumar *et al.* (2024) [15, 18], Panika *et al.* (2022) [22], Sahithi *et al.* (2023) [23], Pathak *et*

*al.* (2024) <sup>[22]</sup>, Abdul Fiyaz *et al.* (2011) <sup>[32]</sup>, Farheen *et al.* (2023) <sup>[5]</sup>, Kiran *et al.* (2023) <sup>[13]</sup>, Kondi *et al.* (2022) <sup>[14]</sup>, Surjaye *et al.* (2022) <sup>[26]</sup>, and Satish Chandra *et al.* (2024) <sup>[24]</sup>. Overall, the results indicate that plant height, panicle length, spikelet fertility, and grain quality parameters exhibited strong and consistent positive associations with grain yield, suggesting their importance as key selection criteria for yield improvement in rice breeding programmes.

**Table 2:** Genotypic correlation coefficient of different characters with single plant yield

|      | DDF     | PH       | PL      | PT     | SF      | TGW     | KL      | KB       | KLB    | HULL    | MILL    | HRR    | GYP |
|------|---------|----------|---------|--------|---------|---------|---------|----------|--------|---------|---------|--------|-----|
| DDF  | 1       |          |         |        |         |         |         |          |        |         |         |        |     |
| PH   | 0.593** | 1        |         |        |         |         |         |          |        |         |         |        |     |
| PL   | 0.191   | 0.556**  | 1       |        |         |         |         |          |        |         |         |        |     |
| PT   | -0.246  | -0.366** | -0.159  | 1      |         |         |         |          |        |         |         |        |     |
| SF   | 0.163   | 0.213    | -0.134  | -0.187 | 1       |         |         |          |        |         |         |        |     |
| TGW  | -0.086  | 0.079    | 0.114   | -0.045 | 0.497** | 1       |         |          |        |         |         |        |     |
| KL   | 0.095   | 0.166    | 0.265*  | -0.137 | 0.118   | 0.427** | 1       |          |        |         |         |        |     |
| KB   | 0.178   | 0.294*   | 0.136   | -0.012 | 0.368** | 0.374** | 0.392** | 1        |        |         |         |        |     |
| KLB  | -0.05   | -0.098   | 0.119   | -0.131 | -0.225  | 0.04    | 0.498** | -0.597** | 1      |         |         |        |     |
| HULL | 0.308*  | 0.281*   | 0.05    | -0.126 | 0.370** | -0.105  | 0.124   | 0.262    | -0.126 | 1       |         |        |     |
| MILL | 0.286*  | 0.25     | 0.013   | -0.089 | 0.389** | -0.098  | 0.08    | 0.258    | -0.164 | 0.963** | 1       |        |     |
| HRR  | 0.23    | 0.282*   | 0.215   | -0.157 | 0.414** | 0.029   | 0.072   | 0.207    | -0.122 | 0.686** | 0.700** | 1      |     |
| GYP  | 0.222   | 0.490**  | 0.551** | -0.257 | 0.399** | 0.167   | 0.236   | 0.318*   | -0.084 | 0.327*  | 0.329*  | 0.46** | 1   |

\* Significant at 5%, \*\* Significant at 1%;  
**DDF**- Days to fifty percent flowering, **PH**- Plant height (cm), **PL**- Panicle length (cm), **PT**- Number of productive tillers per plant, **SF**- Spikelet fertility, **TGW**- Thousand grain weight (gm), **KL**-Kernel length (mm), **KB**- Kernel breadth (mm), **KLB**- Kernel L/B ratio, **HULL**-Hulling (%), **MILL** -Milling (%), **HRR**- Head rice recovery (%) and **GYP**- Grain yield per plant (gm)

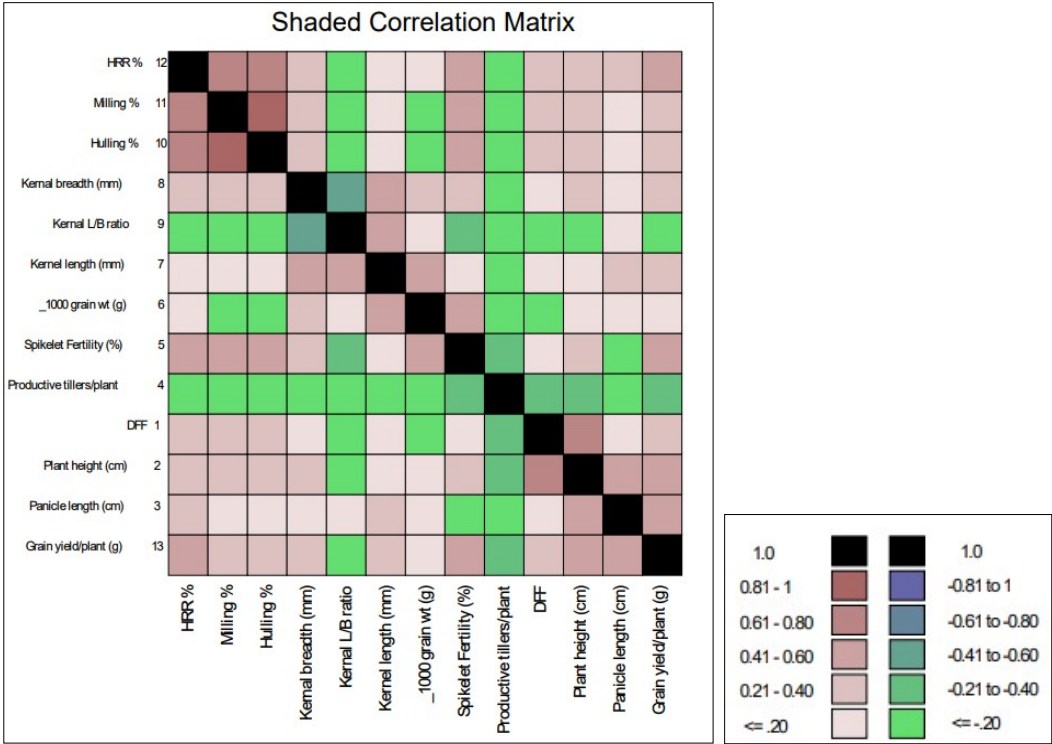


**Fig 1:** Correlogram visualizing the correlation among yield and yield traits

**Path Coefficient Analysis**

Simple correlation alone does not adequately explain the nature of relationships among yield contributing traits. Therefore, phenotypic correlation coefficients were further partitioned into direct and indirect effects using path coefficient analysis. This approach helps in distinguishing the true direct influence of each trait on grain yield from its indirect effects mediated through other characters, thereby providing a clearer understanding of cause-and-effect relationships (Wright, 1921) <sup>[29]</sup>. The estimates of path coefficient analysis for yield and yield component characters are presented in Table 3 and Figure 2. The results revealed considerable variation in the magnitude and

direction of direct effects among the traits studied. Among all the traits, panicle length exhibited the highest positive direct effect (0.5738) on grain yield, indicating its major role in yield determination. This was followed by plant height (0.5092), spikelet fertility (0.4119), and head rice recovery (0.4790), all of which showed strong positive direct effects on grain yield. Similar findings of strong positive direct effects on grain yield were also reported by Hani and Thouseem (2024) <sup>[8]</sup>, Kumar *et al.* (2024) <sup>[15, 18]</sup>, Sudeepthi *et al.* (2020) <sup>[25]</sup>, and Bhargava *et al.* (2021) <sup>[1]</sup>. Moderate positive direct effects were observed for kernel breadth (0.3368), hull content (0.3723), kernel length (0.2414), and days to 50% flowering (0.2283), indicating

that these traits contribute positively to grain yield either directly or indirectly through their association with other traits. Among the remaining traits, thousand grain weight (0.1689) also exhibited a positive direct effect, suggesting its supportive role in yield expression, which is in agreement with the findings of Kalaiselvan *et al.* (2019) <sup>[11]</sup> and Parimala *et al.* (2020) <sup>[21]</sup>. In contrast, productive tillers (-0.3017) and kernel length-breadth ratio (-0.0925) showed negative direct effects on grain yield, indicating limited direct contribution to yield improvement and a greater influence through indirect pathways. Similar negative direct effects for these traits have also been reported by Hani and Thouseem (2024) <sup>[8]</sup>, while negative effects of productive

tillers were earlier observed by Kalaiselvan *et al.* (2019) <sup>[11]</sup> and Parimala *et al.* (2020) <sup>[21]</sup>. The indirect effects indicated that several traits influenced grain yield through their associations with key yield components such as panicle length, spikelet fertility, and kernel traits, highlighting the importance of trait interrelationships in yield formation. Overall, the study suggests that panicle length, spikelet fertility, plant height, head rice recovery, kernel traits, and days to 50% flowering are the major contributors to grain yield in rice due to their strong positive direct effects. These traits should therefore be given priority in selection programmes aimed at genetic improvement and yield enhancement in rice.

**Table 3:** Phenotypic path coefficient analysis representing direct and indirect effects on single plant yield by its related traits in F<sub>2</sub> population of cross RNR-15048 x Dokra-Dokri

|      | DFF     | PH      | PL      | PT      | SF      | TGW     | KL      | KB      | KLB     | HULL    | MILL    | HRR%    |
|------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| DFF  | -0.0326 | -0.0196 | -0.0065 | 0.0086  | -0.0054 | 0.0028  | -0.0031 | -0.006  | 0.0017  | -0.011  | -0.0101 | -0.0075 |
| PH   | -0.0006 | -0.0009 | -0.0005 | 0.0004  | -0.0002 | -0.0001 | -0.0002 | -0.0003 | 0.0001  | -0.0003 | -0.0003 | -0.0003 |
| PL   | 0.1289  | 0.3752  | 0.6493  | -0.1221 | -0.0876 | 0.0749  | 0.1785  | 0.0871  | 0.0897  | 0.0472  | 0.0167  | 0.1468  |
| PT   | 0.0287  | 0.0422  | 0.0205  | -0.1089 | 0.0222  | 0.0057  | 0.0161  | 0.0024  | 0.0144  | 0.0168  | 0.0122  | 0.0186  |
| SF   | 0.0857  | 0.1133  | -0.0704 | -0.1064 | 0.5215  | 0.2612  | 0.0621  | 0.1969  | -0.1205 | 0.2134  | 0.2216  | 0.2185  |
| TGW  | 0.0195  | -0.0181 | -0.0263 | 0.0118  | -0.1139 | -0.2275 | -0.098  | -0.087  | -0.0096 | 0.0262  | 0.0245  | -0.0066 |
| KL   | 0.0899  | 0.1607  | 0.2572  | -0.1387 | 0.1114  | 0.4031  | 0.9357  | 0.3753  | 0.473   | 0.1242  | 0.0789  | 0.0676  |
| KB   | -0.1505 | -0.2506 | -0.1104 | 0.018   | -0.3108 | -0.3149 | -0.3302 | -0.8231 | 0.4798  | -0.2559 | -0.2398 | -0.1769 |
| KLB  | 0.0517  | 0.1003  | -0.1378 | 0.1318  | 0.2304  | -0.042  | -0.5042 | 0.5813  | -0.9973 | 0.1616  | 0.1893  | 0.1268  |
| HULL | -0.1526 | -0.143  | -0.0328 | 0.0696  | -0.1843 | 0.0518  | -0.0598 | -0.1401 | 0.073   | -0.4505 | -0.437  | -0.3229 |
| MILL | 0.14    | 0.1245  | 0.0116  | -0.0507 | 0.1917  | -0.0487 | 0.0381  | 0.1315  | -0.0856 | 0.4377  | 0.4513  | 0.3269  |
| HRR  | 0.0203  | 0.0252  | 0.0199  | -0.015  | 0.0368  | 0.0025  | 0.0063  | 0.0189  | -0.0112 | 0.063   | 0.0636  | 0.0878  |
| GYP  | 0.2283  | 0.5092  | 0.5738  | -0.3017 | 0.4119  | 0.1689  | 0.2414  | 0.3368  | -0.0925 | 0.3723  | 0.371   | 0.479   |

Residual effect: 0.5861; Direct effects are represented in bold values

**DFF**- Days to fifty percent flowering, **PH**- Plant height (cm), **PL**- Panicle length (cm), **PT**- Number of productive tillers per plant, **SF**- Spikelet fertility, **TGW**- Thousand grain weight (gm), **KL**-Kernel length (mm), **KB**- Kernal breadth (mm), **KLB**- Kernal L/B ratio, **HULL**- Hulling (%), **MILL** -Milling (%), **HRR**- Head rice recovery (%) and **GYP**- Grain yield per plant (gm)

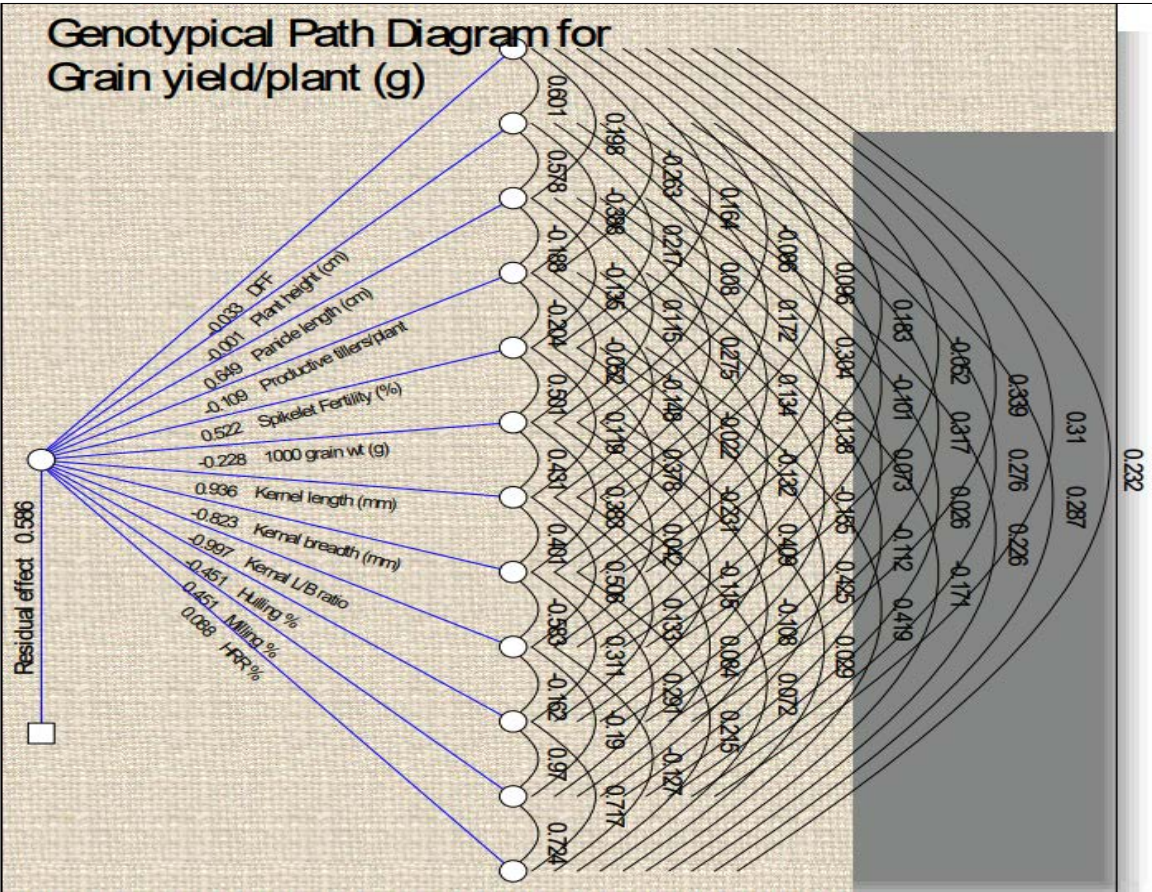


**Fig 2:** Genotypical path diagram depicting direct and indirect effect of different traits on Single plant yield

## Conclusion

The present study on rice (*Oryza sativa* L.) revealed that grain yield is influenced by several yield component traits. Correlation analysis showed significant positive associations of grain yield with plant height, panicle length, spikelet fertility, head rice recovery, and kernel quality traits. Path coefficient analysis further confirmed that panicle length, plant height, spikelet fertility, and head rice recovery had strong positive direct effects on grain yield, indicating their major role in yield determination. Other traits contributed either indirectly or showed comparatively lower influence. Overall, panicle length, spikelet fertility, plant height, and head rice recovery were identified as key traits for selection in rice breeding programmes aimed at yield improvement.

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## Competing Interests

Authors have declared that no competing interests exist.

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