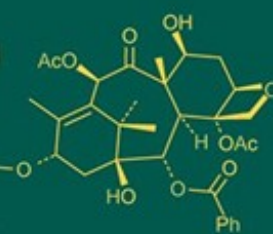
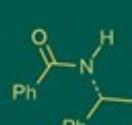


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Correlation analysis for agro-morphological and grain-quality in rice (*Oryza sativa* L.) landraces

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ABSTRACT

Grain yield is a complex trait influenced by several components, including number of tillers per plant, number of grains per plant test weight and other yield contributing characters. Understanding the contribution of individual traits helps identify the traits that can be effectively used as selection criteria in rice breeding programmes. The present study was conducted to assess the association among agro-morphological, yield, grain-quality, cooking-quality and nutritional traits in rice landraces. A total of 45 indigenous landraces and four checks were evaluated during Kharif, 2025 at the ICAR-Indian Institute of Rice Research farm, Patancheru, Hyderabad, in a simple lattice design. Genotypic and phenotypic correlation analyses were performed for 23 traits. Strong positive associations were observed between days to 50% flowering and days to maturity (0.92 *G*; 0.91 *P*), number of tillers and effective tillers (0.91 *G*; 0.87 *P*), and milling percentage and head rice recovery (0.82 *G*; 0.81 *P*). Grain yield per plant showed positive associations with milling percentage (0.62 *G*; 0.61 *P*), hulling percentage (0.58 *G*; 0.57 *P*) and head rice recovery (0.56 *G*; 0.55 *P*). Kernel length showed a strong negative association with kernel breadth (−0.75 *G*; −0.71 *P*), while amylose content was negatively associated with gel consistency (−0.71 *G*; −0.71 *P*). The results indicated that these associated traits could be useful in selection programmes for improving yield, grain quality and nutritional attributes in rice.

Keywords: Rice landraces, Grain yield, Grain quality, Nutritional traits, Genotypic and phenotypic correlation

Introduction

Rice (*Oryza sativa* L.) is an important staple crop and a major source of dietary energy for a large proportion of the world's population. Modern rice breeding increasingly focuses not only on grain yield but also on processing quality, consumer preference, cooking characteristics and nutritional composition. The world population is expected to reach 8 billion by 2030 and rice production must be increased by 50% in order to meet the growing demand (Khush and Brar, 2002) [1]. In order to meet the fastest growing demand for rice grain, development of high yielding genotypes with desirable agronomic traits for diverse ecosystem is therefore a necessity. Improvement of these traits is challenging because they are controlled by multiple genetic and environmental factors and may be positively or negatively associated with one another.

Agro-morphological traits such as plant height, number of tillers, panicle length and maturity duration influence crop productivity and adaptation. Yield-related traits, including effective tillers and grain yield per plant, are important components of breeding selection. At the same time, hulling percentage, milling percentage and head rice recovery determine the quantity and quality of marketable rice obtained after processing. Grain dimensions and cooking properties also influence consumer acceptance. Kernel length, kernel breadth, length-to-breadth ratio, water uptake, volume expansion ratio, elongation ratio, amylose content and gel consistency contribute to the eating and cooking quality of rice. Nutritional traits, particularly protein, iron and zinc contents, are increasingly important in breeding programmes aimed at improving dietary quality.

Correlation analysis provides an initial assessment of the degree and direction of association between traits. A positive correlation suggests that improvement in one trait may be accompanied by improvement in another, whereas a negative correlation may indicate a potential trade-off. However, correlation does not establish causation, and correlated traits should be further evaluated through heritability, path analysis, multi-environment testing and validation in breeding populations.

The present study was undertaken to determine the phenotypic and genotypic associations among agro-morphological, grain quality and nutritional traits in rice genotypes and to identify traits of potential value for selection in rice improvement programmes.

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Materials and methods

The present study was conducted during *Kharif*, 2025 at the ICAR-Indian Institute of Rice Research (IIRR) farm, ICRISAT campus, Patancheru, Hyderabad, Telangana, India. The experimental material comprised 45 indigenous rice landraces along with four check varieties, viz., BPT-5204, DRR Dhan-48, DRR Dhan-60 and DRR Dhan-75. The genotypes were evaluated in a simple lattice design with two replications at a spacing of 15 × 10 cm. Observations on agro-morphological and yield-related traits were recorded from 3 randomly selected plants in each entry, including days to 50% flowering, plant height, number of tillers, number of effective tillers, panicle length, days to maturity, test weight and grain yield per plant. Grain quality traits including hulling, milling and head rice recovery, kernel dimensions, water uptake, volume expansion ratio, elongation ratio, amylose content and gel consistency were also assessed using standard procedures. Nutritional traits such as grain protein, iron and zinc content were estimated using standard laboratory methods. Molecular marker analysis was carried out at ICAR-IIRR, Rajendranagar, Hyderabad, for the detection of bacterial leaf blight resistance-associated genes. The recorded data were subjected to appropriate statistical analyses using R statistical software. Correlation analysis was computed as per [Karl Pearson](#) (1932).

Results and discussions

Corelation

Correlation is a statistical measure that indicates the magnitude and direction of association between two variables. It demonstrates the changes that occur between the correlated variables. The correlation is positive when both variables increase in the same direction and negative when both variables act in opposite directions. The Pearson correlation coefficient (values between -1 and +1), is the most commonly used measure. A Pearson correlation heat map is a visual representation of the strength and direction of relationships between multiple variables/traits using colour. Each cell in the heat map represents the correlation value between a pair of variables. Colour intensity shows the strength of correlation.

- Dark red / blue = strong positive or negative correlation.
- Light colours = weak positive or negative correlation.

Days to 50% flowering (DFF)

Days to 50% flowering recorded positive correlation with days to maturity (0.92) followed by head rice recovery (0.21) and it exhibited negative association with protein content (-0.27) followed by kernel breadth (-0.27) and number of effective tillers (-0.23). The strong positive association between DFF and days to maturity indicates that genotypes with early flowering tend to attain maturity earlier [Sinha et al. \(2013\)](#) [2] also reported high positive correlation of DFF with days to maturity.

Plant height (PH)

Plant height showed positive significant correlation with panicle length (0.41) followed by gel consistency (0.26) and kernel breadth (0.17). It exhibited negative associations with amylose content (-0.26), head rice recovery (-0.25) and hulling percentage (-0.23), indicating that taller plants tend to produce longer panicles but comparatively lower milling quality. Similar results were reported by [Singh et al. \(2020\)](#) [3] with panicle length.

Number of tillers (NT)

The number of tillers exhibited a very high positive correlation with number of effective tillers (0.91) followed by elongation ratio (0.12) and grain yield per plant (0.10). It showed high negative associations with days to maturity (-0.23), days to 50% flowering (-0.21) and hulling percentage (-0.22), indicating that plants with more tillers generally produce more productive tillers. The results were supported by [Kadidaa et al. \(2017\)](#) [4], [Sanghera et al. \(2013\)](#) [5], [Kumar \(2015\)](#) [6].

Number of effective tillers (NET)

Number of effective tillers recorded a positive association with grain yield/plant (0.24) followed by elongation ratio (0.20) indicates number of effective tillers highly influences grain yield. It exhibited negative correlations with days to maturity (-0.27), days to 50% flowering (-0.23) and kernel length (-0.21). The results are in accordance with by [Kadidaa et al. \(2017\)](#) [4], [Ahmad et al. \(2015\)](#) [7].

Panicle length (PL)

Panicle length showed a positive correlation with kernel length after cooking (0.27), kernel breadth (0.24), gel consistency (0.23) and grain yield per plant (0.20). However, it shows negative correlation with amylose content (-0.22) and water uptake (-0.22), suggesting that longer panicles contribute positively to yield performance.

Days to maturity (DM)

Days to maturity demonstrated a very strong positive association with days to 50% flowering (0.92) followed by length/breadth ratio (0.19). However, the trait showed negative correlation with number of effective tillers (-0.27), protein content (-0.26), and number of tillers (-0.23), indicating that flowering duration strongly influences maturity duration.

Yield per plant (Y/P)

Yield per plant resulted positive association with milling percentage (0.62), hulling percentage (0.58) and head rice recovery (0.56) and this trait is negatively associated with protein content (-0.36) and volume expansion ratio (-0.20). The results are in conformity with the reports of [Kadidaa et al. \(2017\)](#) [4], [Puren \(2017\)](#) [8].

Test weight (TW)

Test weight showed highly significant positive association with panicle length (0.40) followed by kernel length after cooking (0.34). Whereas negative association with protein content (-0.27) and iron content (-0.24). The positive association shows that bold grains contribute to higher test weight. Heavier, well-filled grains also tend to elongate more after cooking, resulting in higher kernel length after cooking. Similar results were reported by [Sinha et al. \(2015\)](#) [9].

Hulling percentage (H)

Hulling percentage showed high strong positive association with milling percentage (0.89) followed by head rice recovery (0.64) and grain yield per plant (0.58). However, it exhibited negative correlations with plant height (-0.23) and number of tillers (-0.22), indicating that improved hulling efficiency contributes to better milling quality. Similar relationships between hulling and milling percentages have been reported earlier in rice by [Juliano \(1985\)](#) [10] and [Khush et al. \(1979\)](#) [11].

Milling percentage (M)

Milling percentage correlated high with hulling percentage (0.89) followed by head rice recovery (0.82), grain yield per plant (0.62) and iron content (0.30). Meanwhile, it showed negative correlations with volume expansion ratio (-0.38) and plant height (-0.23). Grains that hull readily and with minimal breakage maintain a higher proportion of unbroken kernels during milling, hence increasing milling efficiency. [Juliano \(1985\)](#) [10] and [Khush et al. \(1979\)](#) [11] previously established similar correlation between hulling and milling percentages in rice.

Head rice recovery (HRR)

Head rice recovery exhibited a strong positive association with milling percentage (0.82) followed by hulling percentage (0.64). Enhanced milling efficiency increases the overall recovery of milled rice, while stronger grains are less susceptible to breakage during processing, thereby improving head rice recovery. Negative correlations were observed with kernel breadth (-0.43), volume expansion ratio (-0.36) and plant height (-0.25). Similar relationships have been reported by [Juliano \(1985\)](#) [10] and [Khush et al. \(1979\)](#) [11].

Kernel length (KL)

Kernel length exhibited a strong positive association with kernel length after cooking (0.72) followed by length/breadth ratio (0.60) and test weight (0.32). The trait recorded negative correlations with kernel breadth (-0.75) and iron content (-0.21). This agrees with the finding of [Sinha et al. \(2015\)](#) [9].

Kernel breadth (KB)

Kernel breadth showed positive correlations with gel consistency (0.23) and water uptake (0.14). It showed a strong negative association with kernel length/breadth ratio (-0.75) followed by head rice recovery (-0.43), days to 50% flowering (-0.27) and milling percentage (-0.25). Similar relationships were reported by [Sinha et al. \(2015\)](#) [9].

Length/ Breadth ratio (L/B)

The Length/Breadth ratio had strong positive association with kernel length (0.60) followed by kernel length after cooking (0.39) and recorded negative association with kernel breadth (-0.75) followed by gel consistency (-0.23).

Water uptake (WU)

Water uptake was positively associated to test weight (0.25) followed by kernel length after cooking (0.19) indicating grains with higher density and well-developed endosperm structure tend to absorb more water during cooking. It expressed negative association with gel consistency (-0.22) followed by Iron content (-0.25). Similar relationships have been reported by [Juliano \(1985\)](#) [10] and [Bhattacharya \(2011\)](#) [12].

Volume expansion ratio (VER)

Volume expansion ratio showed a positive association with elongation ratio (0.20). It recorded negative association with milling percentage (-0.38) followed by yield per plant (-0.20).

Elongation ratio (ER)

Elongation ratio showed strong positive association with kernel length after cooking (0.67), indicating grains that elongate more during cooking naturally attain greater cooked kernel length as also reported by [Juliano \(1985\)](#) [10] and [Bhattacharya \(2004\)](#). It showed weak negative correlations with grain yield per plant (-0.09), head rice recovery (-0.06) and hulling percentage (-0.12).

Kernel length after cooking (KLAC)

Kernel length after cooking recorded a strong positive correlation with kernel length (0.72) followed by elongation ratio (0.67) and length / breadth score (0.39). It exhibited negative associations with

zinc content (-0.38), iron content (-0.32) and gel consistency (-0.22).

Amylose content (AC)

Amylose content exhibited a positive association with water uptake (0.24). However, it recorded a strong negative correlation with gel consistency (-0.71) followed by protein content (-0.28), indicating that rice with higher amylose content generally produces firmer cooked rice. Similar relationships between amylose content and gel consistency have been reported by [Cagampang et al. \(1973\)](#) [13] and [Little et al. \(1958\)](#) [14].

Gel consistency (GC)

Gel consistency recorded a positive correlation with zinc content (0.22) and kernel breadth (0.23). It exhibited a strong negative association with amylose content (-0.71) followed by water uptake (-0.22). This suggests gel consistency and amylose content are strongly influencing each other. [Cagampang et al. \(1973\)](#) [13] and [Little et al. \(1958\)](#) [14] also found an association between amylose content and gel consistency.

Protein content (PRO)

Protein content recorded positive and strong association with iron content (0.32) followed by zinc content (0.30). Further, it showed negative correlations with grain yield per plant (-0.36), amylose content (-0.28), test weight (-0.27) and days to 50% flowering (-0.27). Similar positive relationships between grain protein and mineral contents have been reported by [Welch et al. \(2004\)](#) [15] and [Sperotto et al. \(2012\)](#) [16].

Iron content (Fe)

Iron content recorded a high positive correlation with zinc content (0.38) followed by milling percentage (0.30) and head rice recovery (0.20). It exhibited negative associations with volume expansion ratio (-0.34), water uptake (-0.25) and kernel breadth (-0.24), indicating that iron-rich genotypes may simultaneously possess higher zinc content and superior milling quality.

Zinc content (Zn)

Zinc content showed positive correlations with gel consistency (0.22), hulling percentage (0.16) and kernel breadth (0.15). It was negatively associated with elongation ratio (-0.34), number of effective tillers (-0.28) and grain yield per plant (-0.16), suggesting that improvement in zinc content may slightly reduce yield-related traits.

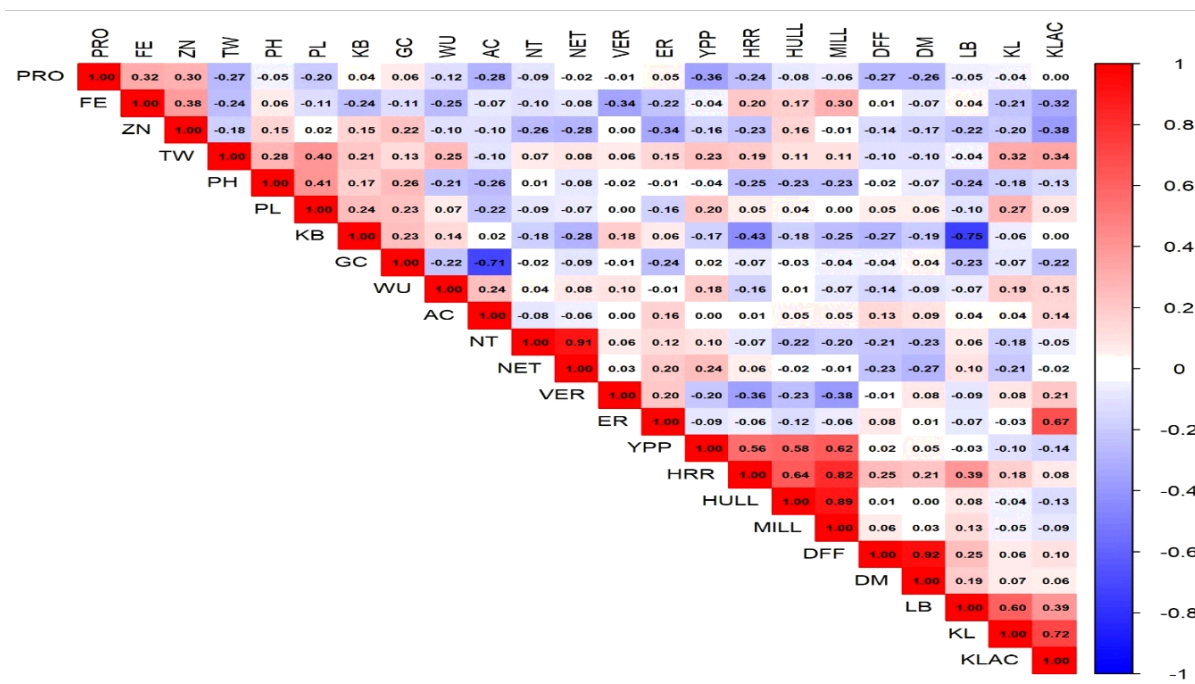


Figure 1. Genotypic correlation coefficients among agro-morphological, yield, grain-quality, cooking-quality and nutritional traits in rice genotypes.

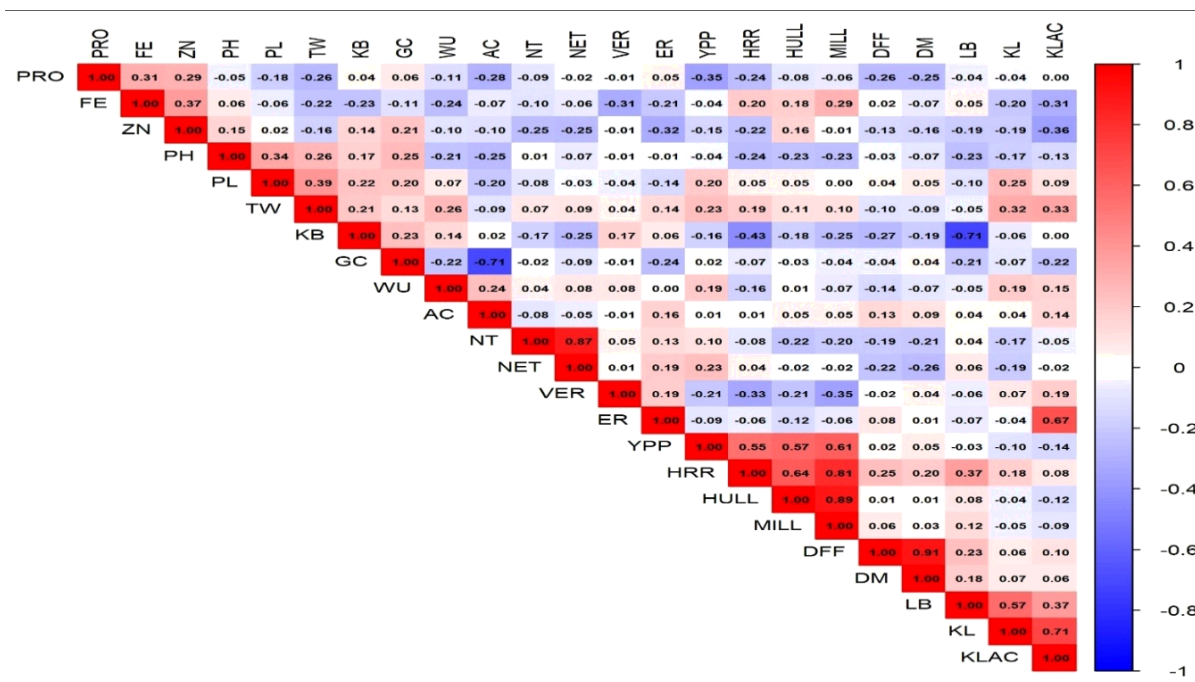


Figure 2. Phenotypic correlation coefficients among agro-morphological, yield, grain-quality, cooking-quality and nutritional traits in rice genotypes.

Conclusion

The correlation analysis revealed several strong and significant associations among the studied traits. A strong positive correlation was observed between the number of tillers and number of effective tillers ($r = 0.91$ G; 0.87 P), indicating that genotypes producing a greater number of tillers generally tended to produce more productive tillers. Days to 50% flowering also exhibited a strong positive correlation with days to maturity ($r = 0.92$ G; 0.91 P), suggesting that genotypes with delayed flowering generally tended to mature later. Similarly, head rice recovery and milling percentage ($r = 0.82$ G; 0.81 P), showed a strong positive association ($r = 0.82$ G; 0.81 P), indicating that improvement in one trait may be accompanied by improvement in the other. Kernel length was also positively correlated with kernel length after cooking ($r = 0.72$ G; 0.71 P), suggesting a close associa-

tion between grain dimensions before and after cooking. The correlation analysis indicated that number of effective tillers, days to 50% flowering, days to maturity, kernel length, head rice recovery, and milling percentage are important traits to consider in selection programmes for rice improvement. The strong positive associations among these traits suggest that simultaneous improvement of multiple desirable traits may be possible through appropriate selection.

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