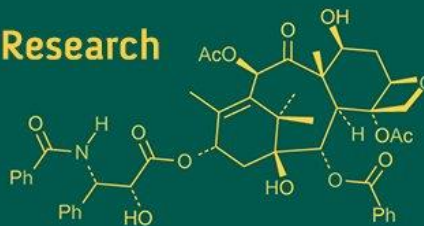


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Trait association studies of grain yield with its related attributes in rice (*Oryza sativa* L.)

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Abstract

The present study was conducted to assess the association among yield and its related attributes in rice (*Oryza sativa* L.) using correlation and path coefficient analysis. 28 genotypes were evaluated in a randomized block design with three replications during *Kharif*, 2025 at three agro-climatic zones of Telangana. Correlation analysis revealed that grain yield per plant showed significant positive associations with panicle length, no. of productive tillers per plant, no. of filled grains per panicle and test weight indicating their importance in yield improvement. Path coefficient analysis further revealed that panicle length, no. of productive tillers per plant, no. of filled grains per panicle, test weight, kernel breadth and kernel L/B ratio exerted strong positive direct effects on grain yield, confirming their major contribution to yield expression. The findings from both correlation and path coefficient analyses indicated that these traits play a major role in determining grain yield. Therefore, they can be considered important selection criteria and should be given priority in rice breeding programmes aimed at developing high-yielding genotypes.

Keywords: *Oryza sativa* L., grain yield, correlation analysis, path coefficient analysis, yield attributes, productive tillers, panicle length, filled grains per panicle, test weight, rice breeding, genotype selection, yield improvement

1. Introduction

Rice is one of the most important cereal crops in the world, serving as the staple food for more than half of the global population and playing a vital role in food and nutritional security, particularly in Asia (FAO, 2025) [6]. According to the FAO (2025) [6], rice is cultivated globally on approximately 165 million hectares, producing about 543 million tonnes (milled basis) with an average productivity of approximately 4.7 t ha⁻¹. Since grain yield is a complex quantitative trait controlled by the interaction of several component characters, an understanding of the relationships among these traits is essential for developing efficient selection strategies (Falconer and Mackay, 1996; Singh and Chaudhary, 1985) [5, 15]. Moreover, these yield-contributing traits are governed by multiple genes and their interactions with the environment, making the study of their association with grain yield indispensable for improving selection efficiency in rice breeding programmes (Wright, 1921; Barde *et al.*, 2024) [18, 1].

Character association analysis helps identify the key traits that contribute to yield and provides a scientific basis for selecting desirable genotypes. It provides information on the degree of association between traits however it does not distinguish whether these relationships are due to direct effects or are mediated through other traits. Path coefficient analysis, originally proposed by Wright (1921) [18] and later applied to plant breeding by Dewey and Lu (1959) [2], partitions the correlation coefficients into direct and indirect effects, thereby providing a clearer understanding of the contribution of individual traits to grain yield.

The combined use of correlation and path coefficient analyses enables breeders to identify the most influential yield-contributing traits and develop efficient selection criteria for crop improvement. Therefore, greater emphasis can be placed on those traits that show a strong association with grain yield, thereby improving the efficiency of selection in rice breeding programmes. With this background, the present study was undertaken to investigate the character associations and path coefficients among grain yield and its component traits in rice genotypes evaluated across multiple environments.

The findings are expected to provide valuable information for identifying key traits that can be effectively utilized in breeding programmes aimed at improving grain yield.

2. Materials and Methods

To examine the correlation and path coefficient relationships among yield and its related traits, a total of 28 rice genotypes comprising of 25 lines and 3 checks were evaluated (Table-1). The experiment was carried out during the *kharif*, 2025 at three locations: Agricultural Research Station, Kampasagar (STZ), Regional Agricultural Research Station, Warangal (CTZ) and Agricultural Research Station, Kunaram (NTZ). These three experimental locations represent the major agro-climatic zones of Telangana, namely the Northern Telangana Zone (NTZ), Central Telangana Zone (CTZ) and Southern Telangana Zone (STZ).

Table 1: List of genotypes used in experiment

Code	Genotype	Code	Genotype
G1	KPS-05	G15	KPS-2874
G2	KPS-11	G16	KPS-6251
G3	KPS-12	G17	KPS-10329
G4	KPS-15	G18	KPS-10631
G5	KPS-17	G19	KPS-10642
G6	KPS-20	G20	KPS-12673
G7	KPS-25	G21	KPS-14433
G8	KPS-40	G22	KPS-14625
G9	KPS-42	G23	KPS-14785
G10	KPS-45	G24	KPS-14920
G11	KPS-46	G25	KPS-14932
G12	KPS-48	G26	JGL-24423 (Check)
G13	KPS-53	G27	KNM-1638 (Check)
G14	KPS-54	G28	WGL-14 (Check)

The experiment was conducted using a Randomized Block Design (RBD) with three replications at each location. Each experimental plot measured 4.5 m², and the 28 rice genotypes were transplanted by maintaining a spacing of 20 cm between rows and 15 cm between plants. Normal agronomical practices and plant protection measures with external inputs such as supplementary irrigation and fertilizers were given at appropriate time to maintain a consistent and healthy crop stand. Based on the data recorded from all 28 genotypes, correlation and path coefficient analyses were performed to assess the relationships among grain yield and its associated traits.

Correlation coefficients among the studied traits were estimated following the procedure described by Singh and Chaudhary (1994). The significance of the correlation coefficients was tested by comparing the calculated values with the corresponding tabulated values at (n-1) degrees of freedom at the 5% and 1% probability levels. Path coefficient analysis was performed according to the method originally proposed by Wright (1921)^[18] and subsequently elaborated by Dewey and Lu (1959)^[2]. This analysis was used to partition the correlation coefficients into direct and indirect effects, thereby identifying the traits that contributed most effectively to grain yield.

3. Results and Discussion

A clear understanding of the relationships among yield and its component traits is essential for developing effective selection criteria in crop improvement programmes. Although correlation analysis provides information on the

association between traits, it does not clearly distinguish whether a trait influences grain yield directly or through its association with other traits. Therefore, relying solely on correlation coefficients may sometimes lead to misleading conclusions and reduce the efficiency of indirect selection. To overcome this limitation, path coefficient analysis, as proposed by Wright (1921)^[18] partitions the total correlation into direct and indirect effects. This approach provides a better understanding of the contribution of individual traits to grain yield, especially when several traits simultaneously influence yield. Such information is valuable for identifying the most important traits to be considered in selection programmes aimed at improving grain yield.

3.1 Correlation Studies

Based on the observations recorded from 28 rice genotypes, character association analysis was carried out to assess the relationships between grain yield and its component traits. The analysis was performed to identify the traits associated with higher grain yield and to understand the factors contributing to improved yield performance in the hybrids. The results of the correlation analysis are presented in Table 2.

The correlation analysis over three locations revealed distinct relationships among grain yield and its component traits (Table X). Among the traits evaluated, the number of filled grains per panicle recorded the highest positive correlation with grain yield ($r = 0.8431^{**}$) followed by the number of productive tillers per plant ($r = 0.8348^{**}$). This suggests that both these traits play a major role in determining grain yield. Panicle length also showed a strong positive association with grain yield ($r = 0.6340^{**}$) indicating that genotypes with longer panicles generally possess greater yield potential. Similarly, test weight exhibited a significant positive correlation ($r = 0.4860^{**}$) highlighting the contribution of grain weight to overall productivity. Similar positive associations between these yield-contributing traits and grain yield have been reported by Kanwar and Nag (2019), Saleh *et al.* (2020)^[13], Naik *et al.* (2021)^[11], Barde *et al.* (2024)^[1], and Kumar *et al.* (2025). These positive associations indicate that improvements in these traits are likely to result in higher grain yield and, therefore, they may serve as effective selection criteria in rice breeding programmes.

Plant height ($r = 0.1156$), kernel length ($r = 0.2455$) and kernel breadth ($r = 0.2576$) exhibited weak positive but non-significant correlations with grain yield, indicating that these traits had limited direct influence on yield improvement. Similar positive associations between plant height and grain yield were reported by Kafi *et al.* (2021)^[8], Vennela *et al.* (2021)^[17] and Shanmugam *et al.* (2024)^[14], whereas Manivelan *et al.* (2022)^[10] observed positive associations of kernel length with grain yield, and Vennela *et al.* (2021)^[17] also reported a positive association of kernel breadth with grain yield. Similarly, the length-to-breadth ratio (L/B) was negatively associated with grain yield ($r = -0.1988$), suggesting that grain shape had little contribution to yield performance under the present study. A contrasting positive association of kernel L/B ratio with grain yield was reported by Manivelan *et al.* (2022)^[10], indicating that the contribution of grain shape to yield may vary with genetic background and environmental conditions.

In contrast, days to 50% flowering showed a negative non-significant association with grain yield ($r = -0.4481$) indicating that delayed flowering tended to reduce grain yield under the pooled environmental conditions. This negative association suggests that relatively early flowering genotypes may have an advantage in achieving higher productivity. While significant negative correlations were observed with number of productive tillers ($r = -0.5753^{**}$) and number of filled grains per panicle ($r = -0.4001^{*}$) suggesting that late-flowering genotypes generally produced fewer productive tillers and filled grains, ultimately leading to reduced grain yield. These findings are in agreement with

the reports of Saleh *et al.* (2020)^[13], Sharma *et al.* (2024)^[16], and Prasad *et al.*, who also observed negative associations between days to 50% flowering and major yield-contributing traits.

The interrelationships among yield-contributing traits further revealed that panicle length was positively and significantly associated with number of productive tillers ($r = 0.6356^{**}$) number of filled grains per panicle ($r = 0.5866^{**}$) test weight ($r = 0.5476^{**}$) kernel length ($r = 0.4606^{*}$) and kernel breadth ($r = 0.3878^{*}$) indicating that selection for increased panicle length may simultaneously improve other important yield-contributing traits.

Table 2: Simple correlation coefficients among grain yield and its components over 3 locations

	DDF	PH	PL	NPT	NFG	TW	KL	KB	L/B	GY
DDF	1.0000	-0.0633	-0.1797	-0.5753**	-0.4001*	-0.0980	-0.0061	0.0018	0.0297	-0.4481
PH		1.0000	0.1846	0.2109	0.0839	0.0294	0.0389	-0.3331	0.5761	0.1156
PL			1.0000	0.6356**	0.5866**	0.5476**	0.4606*	0.3878*	-0.1780	0.6340**
NPT				1.0000	0.8244**	0.3960*	0.1360	0.0908	-0.0555	0.8348**
NFG					1.0000	0.1649	-0.0588	-0.0754	0.0264	0.8431**
TW						1.0000	0.8996**	0.8294**	-0.3897*	0.4860**
KL							1.0000	0.8105**	-0.2511	0.2455
KB								1.0000	-0.7663**	0.2576
L/B									1.0000	-0.1988
GY										1.0000

* Significant at 5% level and **Significant at 1% level

DDF: days to 50% Flowering, PH: Plant Height, PL: Panicle Length, NPT: No. of Productive tillers per plants, NFG: No. of filled grains per panicle, TW: Test Weight, KL: Kernel Length, KB: Kernel Breadth, Kernel L/B: Kernel Length to Breadth ratio, GY: Grain Yield

A very strong positive association was observed between number of productive tillers and number of filled grains per panicle ($r = 0.8244^{**}$) suggesting that genotypes producing more productive tillers also tended to produce more filled grains, thereby contributing substantially to grain yield. Test weight also showed strong positive correlations with kernel length ($r = 0.8996^{**}$) and kernel breadth ($r = 0.8294^{**}$) reflecting the close relationship between grain size attributes and grain weight. Furthermore, kernel length and kernel breadth were positively associated ($r = 0.8105^{**}$) whereas the length-to-breadth ratio exhibited a strong negative correlation with kernel breadth ($r = -0.7663^{**}$).

3.2 Path Coefficient Analysis

Path coefficient analysis was performed using pooled data from the three test locations to partition the correlation coefficients into direct and indirect effects of yield-attributing traits on grain yield (Table 3).

Among the traits studied, number of productive tillers per plant exerted the highest positive direct effect on grain yield (0.4706) followed by number of filled grains per panicle (0.3205) kernel breadth (0.2694) length-to-breadth ratio (0.2092) and test weight (TW) (0.1699). The strong positive direct effects of number of productive tillers per plant and number of filled grains per panicle together with their significant positive correlations with grain yield, indicate that these traits are the major contributors to yield improvement. Therefore, direct selection for increased productive tillers and a higher number of filled grains per

panicle would be effective for enhancing grain yield across different environments. Similar findings have been reported by Naik *et al.* (2021)^[11], Jangala *et al.* (2022)^[7], Barde *et al.* (2024)^[1], Dhruw *et al.* (2025)^[3], and Tiwari *et al.* (2025)^[16], who also identified these traits as major contributors to grain yield through their positive direct effects.

Unlike the traits with positive direct effects, days to 50% flowering (-0.1034), plant height (-0.0215), panicle length (-0.0138) and kernel length (-0.1621) exhibited negative direct effects on grain yield. The negative direct effect of days to 50% flowering is partially consistent with the negative association between flowering time and grain yield reported by Sharma *et al.* (2024)^[16]. However, the negative direct effects of plant height, panicle length and kernel length observed in the present study contrast with the findings of Vennela *et al.* (2021)^[17], Manivelan *et al.* (2022)^[10], Sadhana *et al.* (2022)^[12] and Dora *et al.* (2025)^[4], who reported positive direct effects of these traits on grain yield. Although panicle length showed a negative direct effect (-0.0138) it maintained a strong positive correlation with grain yield (0.5792) largely because of the favourable indirect effect through number of productive tillers (0.2729) number of filled grains per panicle (0.2063) and test weight (0.0844). This indicates that the contribution of panicle length to grain yield is mainly mediated through its favourable association with other important yield components rather than through its own direct influence. Therefore, panicle length may be considered an indirect selection criterion for improving grain yield.

Table 3: Path coefficients for grain yield and its components in across 3 locations

	DDF	PH	PL	NPT	NFG	TW	KL	KB	L/B	GY
DDF	-0.1034	-0.0030	0.0052	-0.2182	-0.1196	-0.0272	0.0089	0.0016	0.0016	-0.4540
PH	-0.0145	-0.0215	0.0006	-0.0183	-0.0535	-0.0134	-0.0009	-0.0609	0.0819	-0.1005
PL	0.0389	0.0009	-0.0138	0.2729	0.2063	0.0844	-0.0546	0.0589	-0.0147	0.5792
NPT	0.0480	0.0008	-0.0080	0.4706	0.2547	0.0864	-0.0195	0.0183	0.0043	0.8556
NFG	0.0386	0.0036	-0.0089	0.3740	0.3205	0.0714	-0.0033	-0.0113	0.0040	0.7887
TW	0.0165	0.0017	-0.0069	0.2394	0.1347	0.1699	-0.1284	0.1870	-0.0537	0.5603
KL	0.0057	-0.0001	-0.0047	0.0565	0.0065	0.1346	-0.1621	0.2047	-0.0318	0.2093
KB	-0.0006	0.0049	-0.0030	0.0319	-0.0134	0.1180	-0.1231	0.2694	-0.1520	0.1320
L/B	-0.0008	-0.0084	0.0010	0.0097	0.0061	-0.0436	0.0247	-0.1958	0.2092	0.0021

Residual effect = 0.45, Bold values represent the direct effects
DDF: days to 50% Flowering, PH: Plant Height, PL: Panicle Length, NPT: No. of Productive tillers per plants, NFG: No. of filled grains per panicle, TW: Test Weight, KL: Kernel Length, KB: Kernel Breadth, Kernel L/B: Kernel Length to Breadth ratio, GY: Grain Yield

The number of productive tillers per plant also contributed to grain yield indirectly by increasing the number of filled grains per panicle (0.2547) and test weight (0.0864) highlighting its important role in improving yield. Similarly, the number of filled grains per panicle had positive indirect effects through the number of productive tillers (0.3740) and test weight (0.0714) indicating that these traits work together to enhance grain yield. Test weight had a positive direct effect (0.1699) and also contributed indirectly through number of productive tillers (0.2394) and number of filled grains per panicle (0.1347). These findings indicate that heavier grains, together with improved tillering ability and grain filling, contribute substantially to enhanced grain yield. These results are

consistent with the findings of Manivelan *et al.* (2022)^[10] and Dora *et al.* (2025)^[4]. Kernel breadth exhibited a relatively high positive direct effect (0.2694) but its overall association with grain yield remained comparatively low (0.1320) suggesting that several unfavourable indirect effects, particularly through kernel length (-0.1231) and length-to-breadth ratio (-0.1520) reduced its overall contribution. Similarly, the length-to-breadth ratio recorded a positive direct effect (0.2092) but its overall correlation with grain yield was negligible (0.0021) indicating that its positive direct effect was reduced by negative indirect effects through kernel breadth (-0.1958) and test weight (-0.0436).

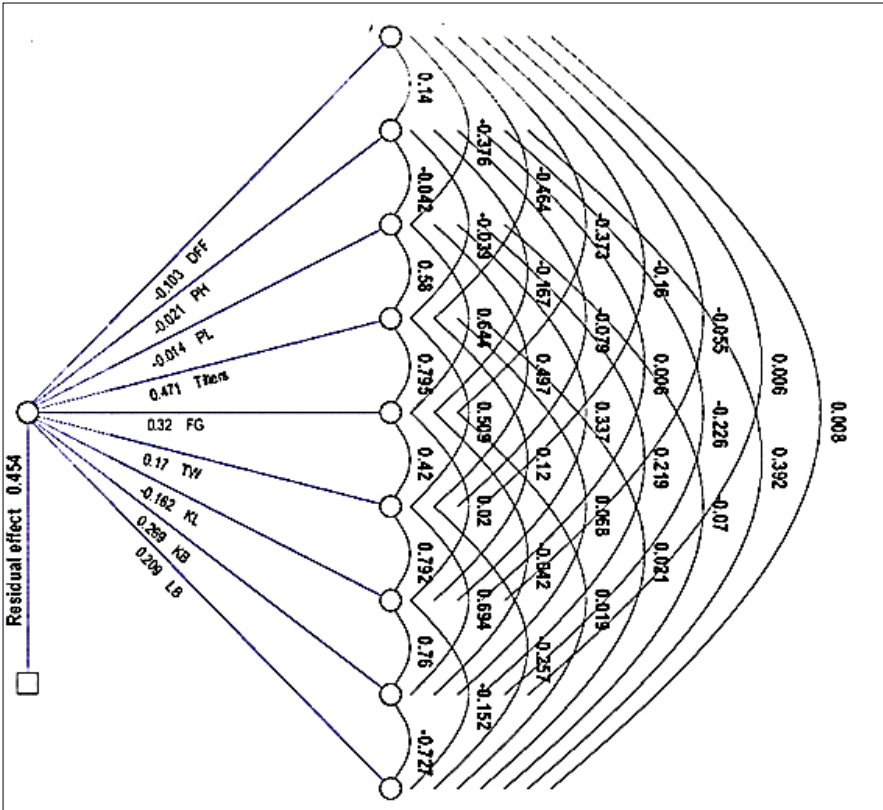


Fig 1: Path diagram for grain yield in rice

Conclusion

Overall, the pooled correlation and path coefficient analyses consistently identified the number of productive tillers per plant, number of filled grains per panicle and test weight as the major contributors to grain yield across the three environments. These traits not only exhibited strong positive

associations with grain yield but also exerted favourable direct and indirect effects, highlighting their importance in determining yield performance. Although panicle length showed a positive association with grain yield, its contribution was mainly through its indirect influence on productive tillers and filled grains per panicle. Therefore,

simultaneous selection for productive tillers, filled grains per panicle, test weight and panicle length is likely to be the most effective approach for improving grain yield and developing high-yielding rice genotypes with broad adaptation across diverse environments.

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