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Association mapping of grain yield, yield attributing traits and quality parameters through correlation studies in Rice (*Oryza sativa* L.)

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ABSTRACT

Enhancing grain yield while maintaining superior grain quality and nutritional value remains one of the major challenges in rice improvement programmes. Understanding the interrelationship among yield components, grain quality traits and micronutrient parameters is therefore essential for the development of superior rice cultivars. The present investigation was undertaken to evaluate the pattern of association among grain yield, yield contributing characters, grain quality traits and micronutrient parameters in the rice cross 'IR-64 × Ranbir Basmati'. Six generations comprising P_1, P_2, F_1, F_2, BC_1 and BC_2 were evaluated during kharif 2012 under irrigated conditions at the Directorate of Rice Research, Hyderabad.

Correlation analysis revealed substantial variation in the magnitude and direction of trait associations. Grain yield per plant exhibited strong positive association with productive tillers per plant, filled grains per panicle, plant height and panicle length, indicating the major contribution of these traits towards productivity enhancement. Filled grains per panicle and productive tillers per plant emerged as the most influential yield components due to their comparatively higher positive association with grain yield. Panicle length also contributed indirectly towards yield improvement through its positive association with productive tillers and grain filling efficiency. Kernel breadth exhibited favourable association with grain yield, whereas length/breadth ratio recorded weak negative association. Iron content showed positive but non-significant association with grain yield, while zinc concentration exhibited significant negative association, indicating the complexity involved in simultaneous improvement of yield and micronutrient enrichment.

The study highlighted the importance of productive tillers per plant, filled grains per panicle and panicle length as reliable selection criteria for developing high-yielding rice genotypes with desirable grain quality characteristics. The findings also provide useful information for designing future breeding strategies aimed at balancing productivity, grain quality and nutritional improvement in rice.

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Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops belonging to the family Poaceae and subfamily Oryzoideae. It is a self-pollinated, short-day crop believed to have originated in Southeast Asia and serves as the staple food for more than half of the world's population. In countries like India, rice plays a crucial role in food security, economy, culture and nutrition. Rapid population growth, declining cultivable land and changing consumer preferences have increased the demand for rice varieties possessing high yield potential along with superior grain quality and nutritional value (Fitzgerald *et al*., 2009; Muthayya *et al*., 2014).

During the Green Revolution, major emphasis was placed on enhancing grain production to meet global food requirements. Although substantial improvement in rice productivity was achieved, nutritional quality received comparatively less attention. As a result, micronutrient deficiencies, particularly iron and zinc deficiency, continue to remain a major public health concern in populations depending largely on rice-based diets (Cakmak, 2002; White and Broadley, 2009). Iron deficiency is associated with anaemia and impaired cognitive development, whereas zinc deficiency adversely affects growth, immunity and metabolic functions.

Biofortification has emerged as an effective and sustainable approach for improving micronutrient concentration in staple crops through genetic enhancement (Bouis, 2002; Welch and Graham, 2004). However, simultaneous improvement of grain yield, grain quality and micronutrient content is challenging because these traits are governed by complex genetic relationships. Grain yield in rice is a quantitative trait influenced by several interrelated component characters such as productive tillers per plant, panicle length, filled grains per panicle and test weight. Likewise, grain quality traits including kernel length, kernel breadth and length/breadth ratio significantly influence consumer preference and market value (Jangala et al., 2022). Therefore, understanding the association among these traits is essential for developing efficient breeding strategies.

Correlation analysis is an important biometrical tool used to determine the magnitude and direction of association among different characters and grain yield in rice. Knowledge of the relationship between yield and its contributing traits helps breeders identify desirable characters for effective selection in crop improvement programmes. The importance of character association studies was emphasized by (Dewey and Lu 1959), In this context, the rice cross 'IR-64 × Ranbir Basmati' represents a valuable genetic combination involving high yield potential and superior grain quality. Hence, the present investigation was undertaken to study the association among grain yield, yield contributing traits, grain quality characters and micronutrient parameters to identify important traits useful for the development of high-yielding rice cultivars with desirable grain quality.

Materials and Methods

The experimental material comprised six generations developed from the rice cross 'IR-64 × Ranbir Basmati', namely P_1, P_2, F_1, F_2, BC_1 and BC_2. Among the parental lines, IR-64 is a high-yielding cultivar with desirable agronomic attributes, while Ranbir Basmati is characterized by superior grain quality and aromatic properties. Hybridization was carried out during rabi 2010–2011 at the Directorate of Rice Research using the clipping method of emasculation followed by manual pollination. The F_1 plants were selfed to generate the F_2 population, whereas backcrosses with the respective parents produced the BC_1 and BC_2 generations. The six generations were evaluated during kharif 2012 under irrigated conditions at the experimental farm of the Directorate of Rice Research in a randomized complete block design with two replications. Seedlings were transplanted at a spacing of 20 × 10 cm in rows of 3 m length. Standard agronomic and plant protection practices recommended for rice cultivation were adopted throughout the experimental period to ensure optimum crop growth

Data were recorded from five randomly selected plants in each replication for important agronomic, grain quality and micronutrient traits, including days to 50 per cent flowering, plant height, panicle length, productive tillers per plant, filled grains per panicle, test weight, kernel length, kernel breadth, length/breadth ratio, iron content, zinc content and grain yield per plant. Estimation of grain iron and zinc concentration was carried out using Energy Dispersive X-ray Fluorescence (EDXRF) spectrometry.

Statistical analysis

Genotypic correlation coefficients among different characters were computed according to the procedure described by (Al-Jibouri et al., 1958) The significance of correlation coefficients was tested at 5 and 1 per cent probability levels to determine the strength of association among the traits studied.

Results and Discussion

Correlation analysis revealed substantial variation in the magnitude and direction of association among grain yield, yield contributing traits, grain quality parameters and micronutrient characters in the rice cross 'IR-64 × Ranbir Basmati'. Since grain yield is a complex trait influenced by several interrelated characters, understanding the relationship among these traits is essential for formulating effective selection strategies in rice improvement programmes.

Days to 50 % Flowering

Days to 50 % flowering exhibited positive association with productive tillers per plant (0.1817), test weight (0.1669) and kernel breadth (0.2144**). This indicated that relatively late flowering genotypes tended to possess better grain development and vegetative growth. In contrast, the trait showed significant negative association with length/breadth ratio (-0.1417*), revealing the tendency of late flowering genotypes to produce comparatively bolder grains. Comparable observations were earlier reported by Sakthivel (2001), Chitra *et al.* (2005), Krishna Naik *et al.* (2005) and Sharma and Sharma (2007).

Plant Height

Plant height maintained positive association with panicle length (0.4977), productive tillers per plant (0.2368), filled grains per panicle (0.1657*), test weight (0.1849) and grain yield per plant (0.2601**). The association suggested that vigorous plant growth contributed favourably towards sink development and grain productivity. Taller plants generally supported longer panicles and better grain filling, thereby improving yield performance. However, zinc content exhibited a strong negative relationship with plant height (-0.5274**), which may be attributed to dilution effects in high biomass genotypes. Similar results were documented by Chitra *et al.* (2005), Krishna *et al.* (2008) and Malini *et al.* (2007).

Panicle Length

Panicle length was positively correlated with grain yield per plant (0.2180**), productive tillers per plant (0.1595*) and filled grains per panicle (0.2544). Longer panicles are generally associated with greater grain-bearing capacity, which ultimately contributes towards higher productivity. A highly significant negative association was observed between panicle length and zinc concentration (-0.3491**), indicating possible reduction in micronutrient accumulation with increasing grain number. These findings are in agreement with earlier reports by Janardhanam *et al.* (2001) and Yugandhar Reddy *et al.* (2008).

Productive Tillers per Plant

Productive tillers per plant exhibited strong positive association with grain yield per plant (0.5256), emphasizing its major contribution towards productivity. The trait also maintained favourable association with filled grains per panicle and iron content (0.3042), indicating the possibility of simultaneous improvement of yield and micronutrient concentration through appropriate selection. A negative association with length/breadth ratio (-0.1668*) suggested that highly tillering genotypes tended to produce bolder grains. Similar trends were reported by Panwar and Mashiat Ali (2007) and Gangashetty *et al.* (2013).

Filled Grains per Panicle

Filled grains per panicle exhibited highly significant positive association with grain yield per plant (0.5878**), highlighting the importance of grain filling efficiency in determining yield. Increased number of filled grains enhanced sink strength and improved overall productivity. However, the trait showed negative association with zinc concentration (-0.2648**), suggesting that increased grain number may reduce micronutrient concentration per grain. Similar observations were reported by Sharma and Sharma (2007) and Krishna *et al.* (2008).

Test Weight

Test weight showed positive association with kernel length (0.2193) and kernel breadth (0.3714), indicating that heavier grains possessed larger grain dimensions. The negative relationship with length/breadth ratio (-0.1796*) suggested that bold grains contributed more towards grain weight than slender grains. These findings corroborate the reports of Krishna Naik *et al.* (2005).

Kernel Length

Kernel length exhibited highly significant positive association with length/breadth ratio (0.6035**), indicating that increased kernel length contributed towards slender grain type, which is generally preferred in premium quality rice varieties. However, the trait showed significant negative association with zinc concentration (-0.2196**), suggesting possible variation in micronutrient accumulation among different grain quality characters. Similar results were earlier reported by Krishna Veni and Shobha Rani (2006) and Krishna *et al.* (2008).

Kernel Breadth

Kernel breadth maintained positive association with grain yield per plant (0.1820) and iron content (0.1872), indicating that comparatively bolder grains contributed favourably towards productivity as well as iron concentration. A highly significant negative association was observed between kernel breadth and length/breadth ratio (-0.8084), which revealed the inverse relationship between grain boldness and slenderness. Kernel breadth also showed negative association with zinc concentration (-0.2063). Similar observations were reported by Khatun *et al.* (2003), Subudhi *et al.* (2007) and Umarani *et al.* (2014).

Length/Breadth Ratio

Length/breadth ratio exhibited weak negative association with grain yield per plant (-0.1143), indicating that improvement in grain shape may not directly enhance yield. However, the trait maintained slight positive association with zinc content (0.0386), suggesting better micronutrient accumulation in comparatively slender grains. Similar findings were also reported by Sharma and Sharma (2007).

Iron and Zinc Content

Iron content maintained positive association with grain yield per plant (0.0906) and zinc concentration (0.1376), indicating the possibility of simultaneous improvement of both micronutrients through selection.

On the other hand, zinc content exhibited highly significant negative association with grain yield per plant (-0.2908**), reflecting the difficulty in combining high yield and enhanced zinc concentration in a single genotype. Similar observations were reported by Gangashetty *et al.* (2013) and Nagesh *et al.* (2013).

Grain Yield per Plant

Grain yield per plant exhibited significant positive association with plant height, panicle length, productive tillers per plant, filled grains per panicle and kernel breadth. Among these, productive tillers per plant and filled grains per panicle showed the strongest association, indicating their importance as reliable selection criteria for yield improvement. Zinc content maintained significant negative association with grain yield, whereas length/breadth ratio exhibited weak negative relationship. Therefore, careful breeding strategies are necessary to achieve simultaneous improvement in yield, grain quality and micronutrient concentration.

Table 1: Estimates of genotypic correlation coefficients among yield, its contributing characters and grain quality parameters for IR-64 × Ranbir Basmati

Trait	Days to 50% Flowering	Plant Height	Panicle Length	Productive Tillers/ Plant	Filled Grains	Test Weight	Kernel Length	Kernel Breadth	L/B Ratio	Iron Content	Zinc Content	Yield / Plant
Days to 50% Flowering	1.0000	0.1094	0.0082	0.1817*	-0.0818	0.1669*	0.0822	0.2144**	-0.1417*	0.1175	-0.0320	0.0520
Plant Height		1.0000	0.4977**	0.2368**	0.1657*	0.1849**	0.0667	0.2143**	-0.1187	0.0640	-0.5274**	0.2601**
Panicle Length			1.0000	0.1595*	0.2544**	0.0367	0.1276	0.1877**	-0.0601	-0.0199	-0.3491**	0.2180**
Productive Tillers/ Plant				1.0000	0.1396*	0.0228	-0.0880	0.1555*	-0.1668*	0.3042**	-0.0188	0.5256**
Filled Grains					1.0000	-0.1468*	0.0009	0.1083	-0.0730	0.0128	-0.2648**	0.5878**
Test Weight						1.0000	0.2193**	0.3714**	-0.1796*	0.0906	-0.0826	0.1035
Kernel Length							1.0000	-0.0403	0.6035**	0.0233	-0.2196**	0.0326
Kernel Breadth								1.0000	-0.8084**	0.1872**	-0.2063**	0.1820**
L/B Ratio									1.0000	-0.1313	0.0386	-0.1143
Iron Content										1.0000	0.1376	0.0906
Zinc Content											1.0000	-0.2908**

**Significant at 5 per cent level ** Significant at 1 per cent level*

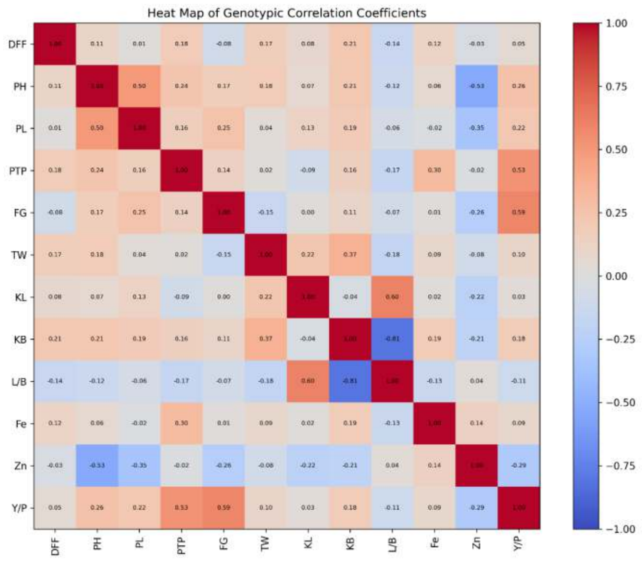

Fig. heat map of genotypic correlation

Conclusion

The present study on correlation analysis in the rice cross 'IR-64 × Ranbir Basmati' demonstrated the existence of significant association among grain yield, yield contributing traits, grain quality parameters and micronutrient characters. Among the different traits studied, productive tillers per plant and filled grains per panicle exhibited strong positive association with grain yield, emphasizing their importance in improving productivity. Plant height and panicle length also contributed positively towards yield through their favourable relationship with major yield components Grain quality traits showed variable association with yield and micronutrient parameters. Kernel breadth maintained positive association with grain yield, whereas length/breadth ratio exhibited a weak negative relationship. Iron content showed positive association with grain yield, while zinc concentration was negatively associated, indicating the challenges involved in simultaneous improvement of yield and zinc enrichment.

Based on the overall association pattern, productive tillers per plant, filled grains per panicle, panicle length and plant height can be considered as reliable selection criteria for the development of high-yielding rice genotypes with desirable grain quality attributes. The findings of the present investigation may therefore be useful in future rice breeding and biofortification programmes aimed at improving both productivity and nutritional quality.

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