

Deciphering the trait association through correlation approach in Rice (*Oryza sativa* L.)

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ABSTRACT

Improvement of grain yield together with enhancement of micronutrient concentration has become an important objective in rice breeding programmes because rice serves as the major staple food for a large proportion of the world population. The present study was conducted to assess the relationship among grain yield, yield contributing traits, grain quality parameters and grain micronutrient content in the rice cross 'RP Bio-226 × Madhukar'. The experimental material comprised six generations namely P₁, P₂, F₁, F₂, BC₁ and BC₂ which were evaluated during kharif 2012 under irrigated conditions at the Directorate of Rice Research, Hyderabad. Correlation coefficients were estimated to understand the nature and extent of association among the studied characters. The analysis revealed that grain yield per plant exhibited significant positive association with productive tillers per plant, filled grains per panicle and plant height, indicating the importance of these traits in determining productivity. Among all the component characters, productive tillers per plant and filled grains per panicle recorded comparatively stronger positive association with grain yield, suggesting their direct contribution towards increased sink capacity and grain production. Panicle length also showed favourable association with yield and filled grains per panicle. Kernel length and length/breadth ratio exhibited weak positive association with grain yield, whereas kernel breadth showed negative association. Iron concentration recorded positive but non-significant association with grain yield, while zinc concentration exhibited weak negative association. Iron and zinc contents were negatively associated with each other, indicating possible physiological interactions influencing micronutrient accumulation. The findings of the present investigation indicated that productive tillers per plant, filled grains per panicle and panicle length may serve as effective selection criteria for simultaneous improvement of grain yield and nutritional quality in rice biofortification breeding programmes.

Keywords- Rice, correlation analysis, biofortification, grain yield, iron content, zinc content, productive tillers, grain quality.

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple food crops and serves as a primary source of nutrition for more than half of the world's population, particularly in Asia. In India, rice plays a significant role in food security, rural economy and agricultural sustainability. Traditionally, rice improvement programmes have focused mainly on increasing grain yield; however, recent breeding efforts have emphasized the enhancement of nutritional quality due to the increasing prevalence of micronutrient malnutrition. Micronutrient deficiencies, especially iron and zinc deficiency, are major public health concerns in developing countries where rice-based diets are predominant (Cakmak, 2002; White and Broadley, 2009). Iron deficiency leads to anaemia and impaired cognitive development, while zinc deficiency affects immune function and growth. Since polished rice grains generally possess low micronutrient concentration, biofortification has emerged as a sustainable and economical approach to improve the nutritional quality of rice (Bouis, 2002; Welch and Graham, 2004).

Considerable genetic variability exists in rice germplasm for grain iron and zinc content, providing ample scope for the development of nutrient-rich rice cultivars through breeding approaches. However, simultaneous improvement of grain yield and micronutrient concentration is difficult because yield is a complex trait controlled by several interrelated component characters. Therefore, understanding the relationship among yield, quality and micronutrient traits becomes essential for effective selection in breeding programmes.

Correlation analysis is an important statistical tool used to determine the degree and direction of association among different characters. Information on the association among yield, yield contributing traits, grain quality parameters and micronutrient content helps breeders identify desirable traits for indirect selection. Hence, the present investigation was undertaken in the rice cross 'RP Bio-226 × Madhukar' to study the correlation among grain yield, yield contributing traits, grain quality characters and grain micronutrient parameters for identifying useful traits in rice biofortification breeding programmes.

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Materials and Methods

The experimental material for the present investigation comprised six generations derived from the cross 'RP Bio-226 × Madhukar', namely P₁, P₂, F₁, F₂, BC₁ and BC₂. RP Bio-226 is a high-yielding improved rice variety possessing desirable agronomic characters, whereas Madhukar is known for superior grain quality and nutritional attributes. Hybridization was carried out during rabi 2010–2011 at the Directorate of Rice Research (DRR), Hyderabad through clipping emasculum followed by hand pollination. The F₁ plants were selfed to produce the F₂ generation and backcrossed with the respective parents to generate BC₁ and BC₂ populations. The six generations were evaluated during kharif 2012 under irrigated conditions at the DRR experimental farm, Hyderabad 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. Recommended agronomic practices and plant protection measures were followed uniformly throughout the crop growth period. Observations were recorded on five randomly selected plants from each replication for 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, grain iron content, grain zinc content and grain yield per plant. Grain iron and zinc concentrations were estimated using Energy Dispersive X-ray Fluorescence (EDXRF) spectrometry.

Statistical Analysis

Phenotypic and genotypic correlation coefficients were estimated to assess the magnitude and direction of association among grain yield, yield components, and grain quality traits following the method proposed by Burton and Devane. The significance of correlation coefficients was tested using appropriate statistical procedures.

The genotypic and phenotypic correlation coefficients were computed using the following expressions:

$$\text{Phenotypic correlation coefficient: } r_{p(xy)} = \frac{Cov_{p(xy)}}{\sqrt{\sigma_{px}^2 \sigma_{py}^2}}$$

$$\text{Genotypic correlation coefficient: } r_{g(xy)} = \frac{Cov_{g(xy)}}{\sqrt{\sigma_{gx}^2 \sigma_{gy}^2}}$$

Results and Discussion

The correlation analysis revealed considerable variation in the direction and magnitude of association among yield, yield contributing traits, grain quality characters and micronutrient parameters. Since grain yield is governed by several interdependent traits, understanding these relationships is important for identifying efficient selection criteria in rice improvement programmes.

Days to 50 Per Cent Flowering

Days to 50 per cent flowering exhibited positive but non-significant association with grain yield per plant (0.0079), indicating that flowering duration had limited direct influence on productivity in the present material. The trait showed positive association with zinc concentration (0.1125), suggesting that comparatively late flowering genotypes tended to accumulate slightly higher zinc content. Similar observations for grain yield were reported by Madhavilatha et al. (2005) and Chandra et al. (2009).

Plant Height

Plant height recorded significant positive association with grain yield per plant (0.2572), panicle length (0.5174), filled grains per panicle (0.3074) and test weight (0.1889). The strong association between plant height and panicle length indicated that vigorous plants possessed better reproductive growth and greater assimilate production. Positive correlation with filled grains and test weight suggested efficient translocation of photosynthates towards grain development.

The positive relationship between plant height and grain yield implied that moderately taller plants possessed superior sink capacity and reproductive efficiency under the present experimental conditions. Similar findings were reported by Sravan et al. (2012) and Reddy et al. (2013) for grain yield and panicle length, Chandra et al. (2009) and Rahman et al. (2014) for filled grains, and Krishna et al. (2008) and Babu et al. (2012) for test weight.

Panicle Length

Panicle length exhibited positive association with grain yield per plant (0.1466*) and highly significant positive association with filled grains per panicle (0.1952**). Longer panicles generally possess greater spikelet bearing capacity, thereby increasing the probability of higher grain production. The favourable relationship between panicle length and filled grains indicated efficient sink development and better grain setting ability.

The trait also exhibited positive association with test weight, indicating improved assimilate translocation towards developing grains. However, panicle length showed significant negative association with zinc concentration (-0.1867**), suggesting that increased grain number may dilute micronutrient concentration in individual grains. Similar observations were reported earlier by Eradasappa et al. (2007), Chandra et al. (2009), Padmaja et al. (2011), Sravan et al. (2012) and Reddy et al. (2013).

Productive Tillers per Plant

Among the studied characters, productive tillers per plant exhibited one of the strongest positive associations with grain yield per plant (0.6862**). Increased number of productive tillers directly enhanced the number of panicle-bearing stems and thereby increased grain production.

The trait also recorded positive association with filled grains per panicle (0.1512*), indicating that highly tillering genotypes possessed better grain bearing ability. Positive association between productive tillers and grain yield has also been reported by Babu et al. (2012), Gangashetty et al. (2013) and Nagesh et al. (2013). The results clearly indicated that productive tillers per plant is an important yield determining character and may be effectively utilized as a selection criterion in breeding programmes.

Filled Grains per Panicle

Filled grains per panicle showed highly significant positive association with grain yield per plant (0.6543**). The results suggested that increased grain filling efficiency directly contributed towards higher productivity by improving sink strength.

The trait recorded negative association with zinc content (-0.2030**), suggesting that increased grain number might dilute micronutrient concentration within grains.

Nevertheless, the strong positive relationship between filled grains and grain yield confirmed the importance of this character in yield improvement. Similar findings were reported by Garg et al. (2010), Mohanty et al. (2012), Nagesh et al. (2013) and Sarker et al. (2014).

Test Weight

Test weight exhibited positive but non-significant association with grain yield per plant (0.1020). The positive relationship indicated that better grain filling and higher grain weight contributed favourably towards yield improvement.

Test weight also showed highly significant positive association with kernel length (0.4389) and kernel breadth (0.5087), indicating that heavier grains tended to possess comparatively larger grain dimensions. Similar observations were reported by Basavaraja et al. (2011), Rangare et al. (2012) and Chakraborty and Chaturvedi (2014).

Kernel Length

Kernel length recorded positive but non-significant association with grain yield per plant (0.0340), indicating limited direct contribution towards productivity. However, kernel length exhibited significant positive association with length/breadth ratio (0.3232**), suggesting that longer grains contributed towards slender grain shape preferred in premium rice varieties.

These findings were in accordance with the reports of Subudhi et al. (2007) and Mohanty et al. (2012).

Kernel Breadth

Kernel breadth showed negative but non-significant association with grain yield per plant (-0.0146). The trait exhibited highly significant negative association with length/breadth ratio (-0.8142**), indicating that increased grain breadth reduced grain slenderness.

The negative association between kernel breadth and grain yield suggested that broader grains had comparatively lesser contribution towards productivity in the present cross. Similar observations were reported by Krishna et al. (2008), Khatun et al. (2003) and Subudhi et al. (2007).

Length/Breadth Ratio

Length/breadth ratio exhibited positive but non-significant association with grain yield per plant (0.0508).

Although the association was weak, the positive direction indicated that relatively slender grains may contribute marginally towards yield improvement.

The trait may therefore be improved independently without adversely affecting grain yield. Similar findings were reported by Garg et al. (2010) and Nagaraju et al. (2013).

Iron and Zinc Content

Iron content exhibited positive but non-significant association with grain yield per plant (0.0496), indicating that improvement in grain iron concentration may not adversely affect productivity.

Zinc concentration, on the other hand, recorded negative but non-significant association with grain yield per plant (-0.0642), suggesting comparatively weaker interaction between these two traits.

Iron content showed significant negative association with zinc concentration (-0.2225**), which indicated the possibility of physiological competition or differential genetic regulation governing micronutrient accumulation in rice grains. Similar observations for iron content were reported by Patil (2008), while Nagesh et al. (2013) observed negative non-significant association for zinc concentration with grain yield.

The relatively weak association between grain yield and micronutrient traits suggested that simultaneous improvement of productivity and nutritional quality may still be possible through careful selection and recombination breeding.

Grain Yield per Plant

Grain yield per plant exhibited highly significant positive association with plant height (0.2572), productive tillers per plant (0.6862) and filled grains per panicle (0.6543**). These results indicated that increased tillering ability and improved grain filling were the major determinants of productivity in the present material.

Positive but non-significant association of grain yield was observed with days to 50 per cent flowering, panicle length, test weight, kernel length, length/breadth ratio and iron content. Negative but non-significant association was recorded with kernel breadth and zinc concentration.

The results suggested that productive tillers per plant, filled grains per panicle and plant height may serve as effective selection criteria for developing high-yielding rice genotypes.

Table.1.1 Estimates of genotypic correlation coefficients among yield, its contributing characters and grain quality parameters for Rpbio-226 X Madhukar

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	0.0458	0.0301	0.0380	-0.0523	-0.0272	0.0022	-0.0255	0.0363	-0.0077	0.1125	0.0079
Plant Height		1.0000	0.5174**	0.0514	0.3074**	0.1889**	0.0934	0.1489*	-0.1020	-0.0957	-0.1083	0.2572**
Panicle Length			1.0000	-0.0074	0.1952**	0.1590*	0.0192	0.1095	-0.0915	0.0542	-0.1867**	0.1466*
Productive Tillers/ Plant				1.0000	0.1512*	-0.0262	-0.0467	0.0174	-0.0097	-0.0637	0.1246	0.6862**
Filled Grains					1.0000	-0.0729	-0.0464	-0.0728	0.0295	0.0553	-0.2030**	0.6543**
Test Weight						1.0000	0.4389**	0.5087**	-	0.1520*	0.0662	0.1020
Kernel Length							1.0000	0.1495*	0.3232**	0.0764	-0.0426	0.0340
Kernel Breadth								1.0000	-	0.0235	0.1253	-0.0146
L/B Ratio									1.0000	0.0132	-0.0707	0.0508
Iron Content										1.0000	-0.2225**	0.0496
Zinc Content											1.0000	-0.0642

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

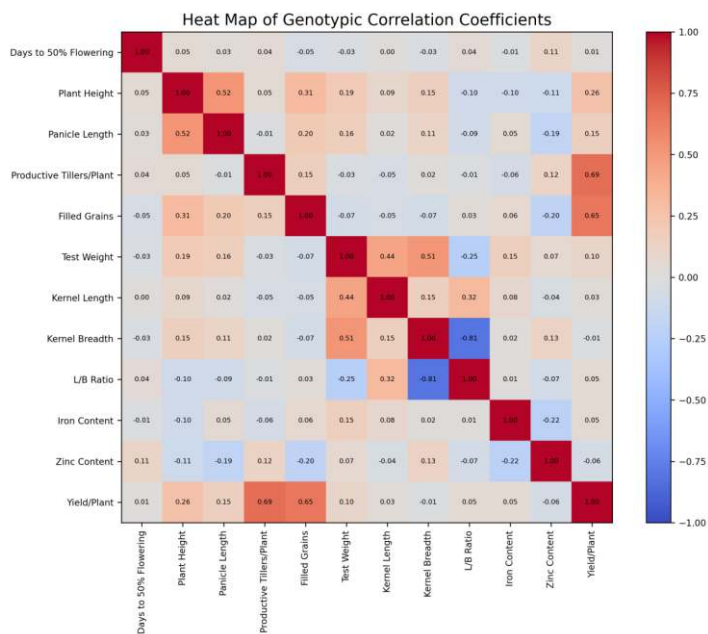


Fig. 1: Heat Map of Genotypic Correlation Coefficients

Conclusion

The present investigation on correlation analysis in the rice cross 'RP Bio-226 × Madhukar' revealed significant association among grain yield, yield contributing traits, grain quality parameters and micronutrient content. Grain yield per plant exhibited strong positive association with productive tillers per plant, filled grains per panicle and plant height, indicating the major role of these characters in determining productivity. Panicle length also contributed favourably towards yield improvement through its positive association with filled grains per panicle and grain yield. Iron content showed positive but non-significant association with grain yield, whereas zinc concentration exhibited weak negative association with yield. The absence of strong adverse relationship between yield and micronutrient traits suggested the feasibility of simultaneous improvement of productivity and nutritional quality. Overall, productive tillers per plant, filled grains per panicle, plant height and panicle length may be considered as reliable selection criteria for the development of high-yielding and nutritionally improved rice genotypes in future biofortification breeding programmes.

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