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Path Coefficient-Based Identification of Strategic Selection Targets for Yield and Grain Quality Improvement in Rice

Usharani G*[1], Neeraja C N[2], Nagesh P[3], Ramya R[4], Hemanth K R M[5], Madhubabu P[2], Rao D S[2], Babu V R[2], Bharathi M[6], Rani CH V D[7]

[1]Agricultural Research Station, Karimnagar, PJTSAU, Telangana, India

[2]Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana, India

[3]Global Maize Programme, CIMMYT, ICRISAT, Hyderabad, Telangana, India

[4]Regional Sugarcane and Rice Research Station, Rudrur, Telangana, India

[5]KLU, Guntur, Andhra Pradesh, India

[6]Department of Genetics and Plant Breeding, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad, Telangana, India

[7]Department of Plant Molecular Biology and Biotechnology, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad, Telangana, India

[*1]Corresponding Author: Usharani G E-mail: ushagenetics@gmail.com

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Abstract

Rice (Oryza sativa L.) is one of the most important staple food crops worldwide, and improvement of grain yield along with nutritional quality is a major objective in rice breeding programmes. The present investigation was undertaken to estimate the direct and indirect effects of yield contributing and grain quality traits on grain yield in the rice cross Rpbio-226 × Jalmagna through path coefficient analysis. Six generations namely P_1, P_2, F_1, F_2, BC_1 and BC_2 were developed and evaluated during *kharif* 2012 under irrigated conditions at the Directorate of Rice Research (DRR), Hyderabad. Observations were recorded for plant height, days to 50% flowering, panicle length, productive tillers per plant, filled grains per panicle, test weight, kernel dimensions, grain iron content, grain zinc content and grain yield per plant. Path coefficient analysis revealed that productive tillers per plant exhibited the highest positive direct effect on grain yield followed by filled grains per panicle, L/B ratio, kernel breadth and plant height, indicating their importance as major selection criteria for yield improvement. In contrast, days to 50% flowering, panicle length, test weight, kernel length, iron content and zinc content showed negative direct effects on yield. The residual effect (0.4134) indicated that the studied traits contributed substantially toward yield variation. The results suggest that emphasis on productive tillers per plant and filled grains per panicle would be effective for identifying superior high yielding segregants with desirable grain quality traits in rice breeding programmes.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops and serves as the staple food for more than half of the world's population, particularly in Asian countries. It is the third highest worldwide produced crop after maize and sugarcane with an annual production of 758.8 million tons (503.6 million tons of milled rice) (FAOSTAT, 2013). Improvement in grain yield is therefore a major objective in rice breeding programmes. Since grain yield is a complex quantitative trait controlled by several component characters and influenced by environmental conditions, direct selection for yield alone is often less effective.

Path coefficient analysis, originally proposed by Wright (1921) and later utilized in plant breeding by Dewey and Lu (1959), partitions correlation coefficients into direct and indirect effects and helps in understanding the cause-and-effect relationship among characters. Therefore, path analysis is considered an effective biometrical tool for identifying important yield contributing traits in rice.

Several researchers during 2010-2013 reported the usefulness of path coefficient analysis in rice improvement programmes. Babu et al. (2012) observed that productive tillers per plant and filled grains per panicle exerted positive direct effects on grain yield. Similarly, Seyoum et al. (2012) emphasized the importance of traits such as panicle length, grains per panicle and test weight as major contributors to grain yield in rice. Hence, the present study was undertaken to determine the association among yield and its component characters and to estimate their direct and indirect effects through path coefficient analysis in rice.

MATERIALS AND METHODS

Experimental Material

The experimental material for the present study comprised six generations derived from the rice cross RP Bio-226 × Jalmagna. RP Bio-226 (Improved Samba Mahsuri), developed from the cross BPT 5204 × SS1113 and released in 2007, is a high-yielding semi-dwarf rice variety possessing superior grain quality with comparatively low grain iron and zinc content. In contrast, Jalmagna, a traditional genotype released in 1969, is characterized by high grain iron and zinc concentration, longer crop duration and distinct plant architecture.

Development of Generations

The parental lines were raised during rabi 2010–2011 at the ICAR-Indian Institute of Rice Research (formerly Directorate of Rice Research, DRR), Hyderabad. Hybridization was carried out through clipping emasculation followed by hand pollination. The F_1 plants were selfed to obtain the F_2 generation, while backcrossing with the respective parents generated BC_1 and BC_2

populations. Thus, six generations namely P_1, P_2, F_1, F_2, BC_1 and BC_2 were developed for the investigation.

Experimental Design and Crop Management

The six generations were evaluated during *kharif* 2012 at the DRR Farm, ICRISAT campus, Hyderabad, under irrigated conditions in a randomized complete block design (RCBD) with two replications. Twenty-six to thirty-day-old 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 to maintain a healthy crop stand.

Recording of Observations

Observations were recorded on five randomly selected plants from each replication for different agronomic, yield and grain quality traits. The characters studied included plant height (PH), days to 50 per cent flowering (DFF), panicle length (PL), productive tillers per plant (PTP), filled grains per panicle (FGP), grain yield per plant (GYP), test weight (TW), kernel dimensions (KD), grain iron concentration (GI) and grain zinc concentration (GZ).

Estimation of Grain Iron and Zinc Content

Grain iron and zinc concentrations were estimated using Energy Dispersive X-ray Fluorescence (EDXRF) spectrometry following standard procedures.

Statistical analysis

Path coefficient analysis was carried out to estimate the direct and indirect effects of different traits on grain yield per plant following the method of Dewey and Lu (1959). Grain yield per plant was considered as the dependent variable and the remaining characters as independent variables.

RESULTS AND DISCUSSION

Path coefficient analysis was carried out to partition the correlation coefficients into direct and indirect effects in order to determine the relative contribution of yield component traits and grain quality parameters towards single plant yield. Since grain yield is a complex quantitative trait governed by numerous interacting characters, correlation analysis alone may not provide a clear understanding of the true nature of association among traits. Therefore, path coefficient analysis serves as an effective tool for identifying characters exerting substantial direct influence on yield and thereby aids in formulating efficient selection strategies (Dewey and Lu, 1959). In the present cross, productive tillers per plant, filled grains per panicle, L/B ratio, kernel breadth and plant height recorded positive direct effects on yield, suggesting their importance as major selection indices for yield improvement. The residual effect (0.4134) indicated that the characters included in the study explained a substantial proportion of variability in yield.

Among all the traits studied, productive tillers per plant exhibited the highest positive direct effect (0.3912) on yield per plant together with a strong positive association with yield. The trait also manifested considerable positive indirect contributions through plant height, panicle length, filled grains, test weight and L/B ratio. These findings suggest that enhancement of productive tillering could substantially improve grain yield directly as well as indirectly through favourable interaction with other component characters. Similar observations emphasizing the pivotal role of productive tillers in rice yield improvement have been reported by Gangashetty *et al.* (2013), Pandey *et al.* (2012) and Nagesh *et al.* (2013). Therefore, direct selection for increased productive tillers may be highly effective in isolating superior segregants in this cross.

Filled grains per panicle also exerted a high positive direct effect (0.2988) coupled with positive association with grain yield. In addition, it expressed favourable indirect effects through plant height, productive tillers, panicle length, test weight and grain quality attributes. The strong direct contribution of filled grains indicates its fundamental role in determining sink capacity and final grain productivity. The results imply that genotypes possessing greater grain filling efficiency would contribute substantially toward higher yield realization. Comparable findings highlighting the importance of filled grains in rice yield determination were earlier reported by Garg *et al.* (2010), Nagaraju *et al.* (2013). Hence, this character can be considered a reliable criterion for simultaneous improvement of productivity in segregating generations.

Plant height recorded a moderate positive direct effect (0.0362) and showed positive significant association with yield per plant. The positive relationship was reinforced through favourable indirect effects mediated via panicle length, productive tillers, filled grains and test weight. The agreement between direct effect and correlation coefficient suggests the existence of a genuine relationship between plant height and yield, thereby indicating that selection based on optimum plant stature may contribute to yield enhancement. Similar findings were documented by Padmaja *et al.* (2011), Basavaraja *et al.* (2012) and Nagaraju *et al.* (2013). However, while utilizing plant height in breeding programmes, caution is required to maintain desirable architecture and lodging resistance.

In contrast, panicle length showed a negative direct effect (−0.0703) despite exhibiting positive correlation with yield. This suggests that its apparent association with yield was primarily due to indirect effects mediated through other component traits rather than its own direct contribution. Positive indirect effects through days to 50% flowering and micronutrient traits partially compensated for its unfavourable direct influence. Similar negative direct effects of panicle length on yield have been reported by Krishna *et al.* (2008), Chandra *et al.* (2009), Padmaja *et al.* (2011). Therefore, simple selection exclusively based on panicle length may not be sufficiently effective unless combined with other favourable yield determinants.

Days to 50% flowering exhibited a negative direct effect (−0.0462) and negative association with yield per plant, indicating that delayed flowering was generally unfavourable for productivity in this cross. Although the trait recorded minor positive indirect contributions through plant height, panicle length, test weight and iron content, these were insufficient to offset the negative direct influence. Similar reports of negative direct effects of flowering duration on grain yield were provided by Yadav *et al.* (2011), Babu *et al.* (2012), Bekele *et al.* (2013). This suggests that early to medium flowering genotypes may be advantageous for realizing higher yield potential under the genetic background of this cross.

Among grain quality parameters, L/B ratio demonstrated a positive direct effect (0.1026) together with positive association with yield. The trait expressed favourable indirect effects through flowering, plant height, panicle length and productive tillers, indicating that grain shape characteristics may contribute positively to productivity without compromising quality attributes. Similar observations were reported by Krishna *et al.* (2008) and Nagaraju *et al.* (2013). Therefore, L/B ratio could be utilized as a supplementary selection criterion where simultaneous improvement of yield and grain quality is targeted.

Kernel breadth exhibited a positive direct effect (0.0598) but showed negative nonsignificant association with yield, indicating masking effects of adverse indirect influences operating through productive tillers, L/B ratio and iron content. Nevertheless, positive indirect effects through kernel length, test weight and plant height were observed. Earlier studies by Bhattacharyya *et al.* (2007), Krishna *et al.* (2008) and Ekka *et al.* (2011) also reported favourable direct effects of kernel breadth on yield. These results indicate that kernel breadth may contribute positively under suitable trait combinations but requires cautious utilization in selection programmes.

Test weight recorded a negative direct effect (−0.0360) despite maintaining positive association with yield. Its positive correlation largely resulted from indirect contributions through flowering, kernel length and zinc content, whereas negative indirect effects through plant height, productive tillers and panicle length diminished its overall influence. Similar trends were observed by Garg *et al.* (2010), Basavaraja *et al.* (2011) and Seyoum *et al.* (2012) .The findings indicate that test weight alone may not serve as a dependable criterion for direct selection toward yield enhancement in this cross.

Both kernel length and iron content exhibited negative direct effects on yield, indicating antagonistic relationships with productivity under the present genetic background. Kernel length (−0.0704) contributed positively only through limited indirect pathways such as productive tillers, test weight and L/B ratio, while iron content (−0.1162) displayed unfavourable direct influence despite minor positive indirect effects through flowering and grain shape attributes. Likewise, zinc content expressed a small negative direct effect (−0.0232), suggesting complexity in simultaneously improving micronutrient density and yield. Similar findings for micronutrient traits have been reported by Bekele *et al.* (2013) and Nagesh *et al.* (2013). These results underline the need for balanced selection approaches to achieve concurrent improvement of productivity and nutritional quality in biofortified rice breeding programmes.

Overall, path coefficient analysis revealed that productive tillers per plant, filled grains per panicle, L/B ratio, kernel breadth and plant height were the most important traits contributing positively and directly toward grain yield in the cross Rpbio-226 × Jalmagna. Hence, greater emphasis on these characters during selection would facilitate the identification of superior recombinant lines possessing high yield potential along with desirable grain quality traits. Traits showing negative direct effects such as days to 50% flowering, panicle length, test weight, kernel length, iron content and zinc content may require restricted or simultaneous selection approaches to neutralize undesirable indirect influences and maximize breeding efficiency.

CONCLUSION

The present study demonstrated the effectiveness of path coefficient analysis in identifying important yield contributing traits in the rice cross Rpbio-226 × Jalmagna. Among the characters studied, productive tillers per plant and filled grains per panicle exerted high positive direct effects on grain yield, indicating their major role in determining productivity. L/B ratio, kernel breadth and plant height also contributed positively toward yield improvement. In contrast, days to 50% flowering, panicle length, test weight, kernel length, iron content and zinc content exhibited negative direct effects, suggesting the need for cautious selection while improving both yield and micronutrient content simultaneously. Overall, the results revealed that selection based on productive tillers per plant, filled grains per panicle and associated favourable traits would be effective for the development of high yielding rice genotypes possessing desirable grain quality characteristics.

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Table 1. Estimates of direct and indirect effects of yield contributing traits and grain quality parameters on yield in rice for Rpbio-226 X Jalmagna

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	**-0.0462**	0.0022	0.0025	-0.0018	-0.0004	0.0006	-0.0008	-0.0013	-0.0026	0.0040	-0.0087	**-0.0141**
Plant Height	-0.0017	**0.0362**	0.0250	0.0135	0.0166	0.0189	0.0007	0.0025	0.0018	-0.0003	-0.0019	**0.2633****
Panicle Length	0.0038	-0.0485	**-0.0703**	-0.0258	-0.0270	-0.0317	-0.0014	-0.0008	-0.0080	0.0001	0.0040	**0.2118****
Productive Tillers/ Plant	0.0153	0.1454	0.1437	**0.3912**	0.1606	0.1528	-0.0312	-0.0158	0.0302	0.0063	0.0162	**0.4940****
Filled Grains	0.0023	0.1371	0.1147	0.1227	**0.2988**	0.0945	0.0173	0.0032	0.0093	0.0086	0.0095	**0.4330****
Test Weight	0.0005	-0.0188	-0.0162	-0.0141	-0.0114	**-0.0360**	0.0037	-0.0015	-0.0003	-0.0023	0.0019	**0.2033****
Kernel Length	-0.0011	-0.0015	-0.0014	0.0056	-0.0041	0.0072	**-0.0704**	-0.0531	0.0389	0.0031	-0.0040	**-0.0898**
Kernel Breadth	0.0017	0.0041	0.0007	-0.0024	0.0006	0.0026	0.0451	**0.0598**	-0.0513	-0.0010	0.0031	**-0.0943**
L/B Ratio	0.0057	0.0050	0.0117	0.0079	0.0032	0.0007	-0.0567	-0.0881	**0.1026**	-0.0096	-0.0088	**0.1334**
Iron Content	0.0101	0.0009	0.0002	-0.0019	-0.0033	-0.0076	0.0051	0.0019	0.0108	**-0.1162**	-0.0156	**-0.1104**
Zinc Content	-0.0044	0.0012	0.0013	-0.0010	-0.0007	0.0012	-0.0013	-0.0012	0.0020	-0.0031	**-0.0232**	**-0.0274**

Genotypic residual effect = 0.4134 **Bold values**- direct effects Normal values-indirect effects

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

Figure 1. Direct effects of yield contributing traits and grain quality parameters on grain yield per plant in rice cross Rpbio-226 × Jalmagna