J.Natn.Sci.Foundation Sri Lanka 2024 52 (1): 93 - 102
DOI: http://dx.doi.org/10.4038/jnsfsr.v52i1.11649

RESEARCH ARTICLE

Plant Genetics

Path coefficient analysis using traditional and improved rice genotypes for trait effect on grain yield

HAPA Shyamalee[1] and AL Ranawake[2*]
[1] *Agriculture Research Station, Thelijjawila, Sri Lanka.*
[2] *Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya 81100, Sri Lanka.*

Submitted: 03 April 2023; Revised: 06 December 2023; Accepted: 23 December 2023

Abstract: Accessions of traditional rice play a crucial role in preserving the genetic diversity of commercial rice. They contain specific and useful traits that can help to improve the overall yield, which cannot be achieved by relying solely on improved rice varieties. This is because traditional rice accessions display a wide range of morphological characteristics that contribute to their unique yield determinants. Fifty traditional and forty-five improved rice genotypes were evaluated for thirteen agronomic traits (days to 50% flowering, plant height, number of tillers per plant, number of effective tillers per plant, number of leaves per plant, panicle length, flag leaf length, flag leaf width, number of grains per panicle, filled grain percentage, 100-grain weight at maturity, grain length, and grain width) to understand the yield determination of traditional and improved rice genotypes. Path analysis was carried out using IBM SPSS AMOS statistical software to understand the difference in the direct and indirect effect of the studied parameters. The direct effect of effective tillers per plant ($\beta = 0.519$), filled grain percentage ($\beta = 0.496$), and hundred-seed weight ($\beta = 0.403$) on grain yield was high in improved rice varieties. In traditional rice accessions, the direct effect of effective tillers per plant ($\beta = 0.746$) and filled grain percentage ($\beta = 0.395$) on grain yield was high, but there was no direct effect of hundred seed weight. Filled grains per panicle recorded a moderate effect in both traditional ($\beta = 0.246$) and improved ($\beta = 0.266$) rice genotypes. None of the studied parameters directly and negatively affected the yield of improved rice varieties. Still, several traits (flag leaf length, days to 50% flowering, panicle length, seed length, and seed width) negatively affected the yield of traditional rice accessions. The contributions of yield determinants in traditional rice accessions deviated substantially from those observed in improved rice varieties, highlighting the critical role of plant architecture in determining the final yield. Fertile tiller number, filled grain percentage and grains per panicle are possible traits that can be used in direct selection criteria for improved and traditional rice genotypes for high yield.

Keywords: Direct effect, improved rice, indirect effect, path analysis, traditional rice.

INTRODUCTION

The traditional rice accessions maintain diversity within the rice gene pool. These traditional accessions often harbour specific and advantageous traits that serve as a buffer against potential vulnerabilities in improved varieties. The coexistence of traditional and improved rice genotypes, each characterised by a spectrum of morphological variations, presents a unique challenge in understanding the determinants of yield. Given the extensive diversity in morphological characteristics among these genotypes, it becomes essential to find how various agronomic traits contribute to yield in both traditional and improved rice genotypes.

* Corresponding author (lankaranawake@hotmail.com; https://orcid.org/0000-0003-0517-9911)

Path analysis is a statistical technique to study variables' direct and indirect relationship (Valenzuela & Bachmann, 2017). The direct and indirect effects explained by path analysis (path coefficient, β) can be considered as selection criteria for crop improvement (Sudeepthi *et al.,* 2020). Path analysis is a step-forward technique to correlation analysis. Correlation coefficients assess the degree of relationship between or among traits (Mecha *et al.,* 2017; Baye *et al*., 2020). The correlation coefficient tables explain the interrelationship among yield and yield components, which is also helpful for developing an efficient selection strategy. Path analysis divides correlation coefficients into direct and indirect effects (Ulukan *et al.,* 2003), and it explains the hierarchical order of trait contribution to final grain yield (Samonte *et al.,* 1998), while the correlation coefficient interprets the association of traits, but not the comparative impact of each trait on the final yield. Path analysis facilitates indirect selection indicators, and the coefficient decides the selection efficiency between the considered trait and the yield (Li *et al.,* 2019). The promising results of path analysis have been reported in many studies on rice using different yield determinants as parameters (Agahi *et al.,* 2007; Singh *et al.,* 2018; Immanuel *et al.,* 2011). Path analysis separates the direct effect of a trait and indirect effects of the same through other traits for better interpretation of the total effect (Rasel *et al.*, 2018), and it reveals which trait should be considered as positive indicator for yield increment or which traits should be avoided as negative yield indicators.

The selection of traits for crop improvement is a complex decision-making process. The promising results of path analysis, as evidenced by previous studies on rice, emphasise its efficacy in guiding selection strategies (Shahidullah *et al.,* 2009; Oladosu *et al.,* 2018; Al-Musawi *et al.,* 2019; Laxmi *et al.,* 2023; Limbongan *et al.,* 2023; Reddy *et al.,* 2023). By presenting the direct and indirect effects of various traits, path analysis elucidates the hierarchical order of trait contributions, and it aids in identifying positive indicators for yield increment and potential negative yield indicators. This approach to trait selection contributes to the development of more efficient and targeted strategies for crop improvement (Chakraborty *et al.,* 2012; Lule *et al.,* 2012; Thangamani & Jansirani 2012; Owere *et al.,* 2015; Eric *et al.,* 2016; Janaki, 2018; Rekha *et al.,* 2019; Nagalakshmi *et al.,* 2020; Sivakumar *et al.,* 2020). The historical context of the Green Revolution emphasises the transformative impact of genetic improvements in rice cultivars.

After the green revolution, the yield potential of introduced rice cultivars was doubled due to genetic improvement for short stature in high-yielding varieties (Khush, 1999; Davies, 2003). The rice variety, IR8 introduced after the Green Revolution, which gave around eight tons per hectare, was short and stiff (Dalrymple, 1985). The introduction of dwarfing genes to rice and wheat was the turning point of the Green Revolution (Khush, 2003). Sd1 (Monna *et al.,* 2002; Spielmeyer *et al.,* 2002) was the dwarf gene in rice which accelerated the yield revolution. Architectural improvement in rice during the Green Revolution demarcated the high-yielding semidwarf varieties from traditional rice accessions. Due to plant architectural changes, improved rice cultivars and traditional rice accessions differ significantly in yield. Hence, yield determinants do not function or contribute at the same magnitudes in the two groups of rice genotypes, improved rice cultivars and traditional rice accessions. The present study examined the specificities of yield determinants in traditional rice accessions and improved rice cultivars. Recognizing that these determinants may not function at uniform magnitudes across the two groups of rice genotypes, path analysis emerges as a tool of choice to unravel the differential impacts of various traits on yield. By scrutinising key agronomic parameters' direct and indirect effects, this research provides a comprehensive understanding of the back-and-forth relationship between plant architecture and yield in traditional and improved rice genotypes.

The study evaluated fifty traditional and forty-five improved rice genotypes, focusing on thirteen key agronomic traits. These traits included essential parameters such as days to 50% flowering, plant height, tiller characteristics, leaf morphology, panicle attributes, and grain dimensions. By systematically analysing these traits, the research aimed to unravel the intricate interactions that ultimately determine the yield in traditional and improved rice genotypes. This exploration serves as an essential step towards enhancing our understanding of the factors governing yield in diverse rice populations. The study aims to bridge the existing knowledge gap regarding the contribution of different traits to yield in traditional and improved rice genotypes. The results from this research may help targeted breeding strategies, ensuring the preservation of beneficial traits in traditional varieties and the continued enhancement of yield in improved cultivars. By exploring the complex relationships within diverse rice populations, the study contributed to the broader discourse on sustainable agriculture and crop improvement strategies in the face of evolving environmental and economic challenges.

MATERIALS AND METHODS

Forty-five (45) improved rice varieties and fifty (50) traditional rice accessions collected from the Plant Genetic Resource Centre, Gannoruwa, Peradeniya, Sri Lanka, were used for the study (Table 1).

Dormancy broken seeds were planted in nursery beds and transplanted in the field according to a randomised complete block design with four replicates and twenty plants per replicate. The field was established under rain-fed conditions at the experimental field, Research Station, Thelijjawila in the *Maha* season 2021/2022. Crop management was done according to the recommendation of the Department of Agriculture for wet zone paddy field cultivation under rainfed conditions (DOA, 2013). Data was collected on twenty plants in each replicate (Table 2).

Table 1: Traditional and improved rice genotypes were used in the study in the 2021/2022 *Maha* season.

Traditional rice accessions		Improved rice varieties	
Dahanala3917	*Mawee3683*	*Bg300*	*Bg314*
Dahanala3304	*Mawee5384*	*Bg352*	*Bg357*
Dikwee3741	*Murungakayan6285*	*Bg359*	*Bg366*
Dikwee3504	*Murungakayan6263*	*Bg369*	*Bg409*
Dikwee2203	*Murungakayan3921*	*Bg94-1*	*Bg358*
Heenati6402	*Murungakayan3900*	*At306*	*Bg310*
Heenati4935	*Murungakayan3490*	*At308*	*Bg379-2*
Heenati4618	*Murungakayan3489*	*At353*	*Bg406*
Heenati3998	*Pokkali3922*	*At354*	*Bg374*
Heenati3707	*Pokkali3881*	*At362*	*Bw267-3*
Kaluwee3876	*Pokkali3573*	*At405*	*Bw312*
Kaluwee3728	*Pokkali3567*	*Bw361*	*Bw302*
Kalubalawee5479	*Pokkali3562*	*Bw363*	*Bw452*
Kalubalawee3976	*Polayal3661*	*Bw364*	*Ld253*
Kalubalawee5480	*Ratawee4580*	*Bw367*	*At309*
Kaluheenati7802	*Ratawee3555*	*Bw372*	*At373*
Kaluheenati5191	*Ratawee3525*	*Bw272-6b*	*At311*
Kaluheenati4991	*Ratawee3466*	*Bw400*	*IR64*
Kaluheenati3471	*Rathuwee3905*	*Bw451*	*IRRI200*
Kuruwee3982	*Rathuwee3473*	*Bw453*	*IRRI192*
Kuruwee3898	*Rathuheenati6250*	*Ld365*	
Kuruwee3552	*Rathuheenati4992*	*Ld368*	
Kuruwee3465	*Suduheenati7799*	*Ld371*	
Mawee8497	*Sudurusamba3671*	*Ld408*	
Mawee3704	*Sudurusamba4362*	*Bg403*	

Table 2: Quantitative traits of rice used for morphological evaluation.

Parameter	Description
Days to 50% flowering	Number of days from seedling to 50% flowering
Plant height (cm)	Measured from the base of the shoot to the tip of the tallest leaf blade from the soil surface to the tip of the tallest panicle (awns excluded)
Number of tillers per plant	Total number of grain-bearing and non-bearing tillers
Number of effective tillers per plant	Panicle bearing tillers were counted
Number of leaves per plant	The number of fully expanded leaves on the main culm on the day of measurement at the maturity stage
Panicle length (cm)	Measured in cm from the rachis's base to the panicle's tip, with an average of five panicles per plant
Flag leaf length (cm)	Distance from the leaf base to the tip of the flag leaf
Flag leaf width (cm)	Measured at the most comprehensive position of the leaf blade of five leaves which were used to measure the length
Number of grains per panicle	Number of total grains of sampled panicle
Filled grain percentage	The number of filled grains of a sampled panicle was calculated as a percentage value.
100-grain weight at maturity	A random sample of 100 seeds, well-developed grains dried to 13% moisture content
Grain length (mm)	The actual measurement of length in millimeters
Grain width (mm)	The actual measurement of width in millimeters is the distance across the fertile lemma and the palea at the widest point.

Source: (IRRI, 2013; PGRC, 1999)

Path analysis was done using IBM SPSS AMOS statistical software (SPSS Inc, 2020) separately for the improved rice varieties and traditional rice accessions to understand the effect of different traits on the final grain yield. Path coefficients were calculated, and the direct and indirect effects were ranked according to the scale developed by Lenka & Misra (1973); 0.00 - 0.09 : negligible, 0.10 - 0.19 : low, 0.20 - 0.29 : moderate, 0.30 - 0.99 : high, and >1.00 : very high. This scale has been used for data interpretation of path analysis by Lule *et al.* (2012), Ranawake *et al*., (2014) Owere *et al*., (2015), and Eric *et al*., (2016) for finger millet, Thangamani & Jansirani (2012) for brinjal, Chakraborty *et al*., (2012) for corn, Janaki (2018) and Rekha *et al*., (2019) for chilli, Sivakumar *et al*., (2020) for turmeric, and Nagalakshmi *et al*., (2020) for cowpea.

RESULTS AND DISCUSSION

Direct and indirect effect of the yield components on the final grain yield of traditional and improved rice genotypes

Path analysis was carried out to determine the direct and indirect effects of traits based on the path coefficients. The path diagram explains the relationship of traits (days to 50% flowering, plant height, number of total tillers per plant, number of effective tillers per plant, number of leaves per plant, panicle length, flag leaf length, flag leaf width, number of grains per panicle, filled grain percentage, 100-grain weight at maturity, seed length, and seed width) to yield. Direct and possible indirect relationships were designed in the path diagram (Figure 1).

The direct and indirect effects of all the traits finally decide the grain yield of rice (Rajamadhan *et al*., 2011). Several studies have used path coefficient values to describe the contribution of yield-attributing characteristics to the final yield of rice genotypes (Kishore *et al.,* 2015; Dhurai *et al.,* 2016; Gour *et al.,* 2017; Rashmi *et al.,* 2017; Saleh *et al.,* 2020). The trait effect is defined by a β value in the path analysis, and the total effect of any trait on final grain yield is a collective effort in many ways (Table 3).

The results revealed that several traits behaved similarly on final grain yield in both traditional and improved rice genotypes. In contrast, a few traits acted differently in traditional rice accessions and improved rice varieties (Table 4).

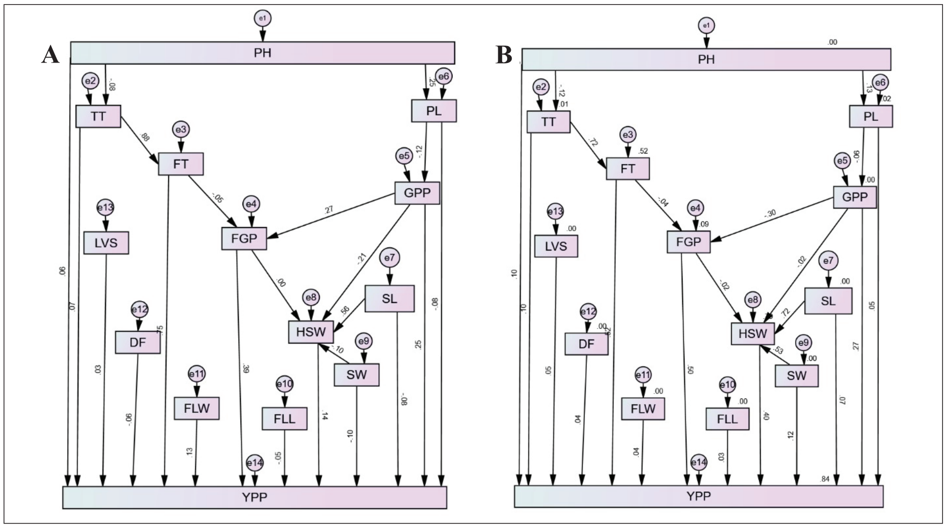

Figure 1: Path diagrams for traditional rice accessions (A) and improved rice varieties (B) obtained from SPSS AMOS software. PH: plant height, TT: number of total tillers per plant, FT: number of effective tillers per plant, LVS: number of leaves per plant, PL: panicle length, FLL: flag leaf length, FLW: flag leaf width, GPP: number of grains per panicle, FGP: filled grain percentage, HSW: hundred-grain weight, YPP: yield per plant, DF: number of days to 50% flowering, SL: grain length, SW: grain width

Table 3: The direct, indirect, and total effect of traits on single plant grain yield of traditional and improved rice genotypes as determined by path analysis.

	Yield per plant									
	Traditional rice β value					Improved rice β value				
Trait	D	I	T	DL	r	D	I	T	DL	r
FT	0.746	-0.02	0.726	High	.819**	0.519	-0.018	0.501	High	.569**
FGP	0.395	0	0.395	High	434**	0.496	-0.008	0.488	High	.446**
GPP	0.246	0.077	0.323	Moderate	.448**	0.266	-0.154	0.112	Moderate	.089
HSW	0.139	0	0.139	Low	-.022	0.403	0	0.403	High	.406**
FLW	0.127	0	0.127	Low	.185	0.037	0	0.037	Negligible	.065
TT	0.074	0.642	0.716	Negligible	.731**	0.095	0.361	0.456	Negligible	.411**
PH	0.063	-0.086	-0.023	Negligible	.019	0.101	-0.01	0.054	Low	.035
LVS	0.03	0	0.03	Negligible	.247	0.047	0	0.047	Negligible	.349*
FLL	-0.054	0	-0.054	Negligible	-.044	0.032	0	0.032	Negligible	.014
DF	-0.057	0	-0.057	Negligible	.105	0.037	0	0.037	Negligible	-.126
PL	-0.079	-0.039	-0.119	Negligible	-.079	0.053	-0.007	0.046	Negligible	-.043
SL	-0.085	0.078	-0.006	Negligible	-.015	0.066	0.289	0.355	Negligible	.270
SW	-0.095	-0.015	-0.11	Negligible	-.173	0.124	0.212	0.336	Low	.117

* Correlation is significant at the α = 0.05 level (two-tailed)

** Correlation is significant at the α = 0.01 level (two-tailed)

D: direct effects. I: indirect effects, T: total effects, DL: direct effect level, PH: plant height (cm), TT: number of total tillers per plant, FT: number of effective tillers per plant, LVS: number of leaves per plant, PL: panicle length (cm), FLL: flag leaf length (cm), FLW: flag leaf width (cm), GPP: number of grains per panicle, FGP: filled grain percentage, HSW: hundred-grain weight (g), YPP: yield per plant (g), DF: number of days to 50% flowering, SL: grain length (mm), SW: grain width (mm)

Table 4: Direct effect traits on single plant grain yield of traditional and improved rice genotypes as determined by path analysis.

Direct effect	Traditional rice	Improved rice
High	FT (0.746), FGP (0.395)	FT (0.519), FGP (0.496), HSW (0.403)
Moderate	GPP (0.246)	GPP (0.266)
Low	HSW (0.139), FLW (0.127)	PH (0.101), SW (0.124)
Negligible	TT (0.074), PH (0.063), LVS (0.03), FLL (-0.054), DF (-0.057), PL (-0.079), SL (-0.085), SW (-0.095)	FLW (0.037), TT (0.095), LVS (0.047), FLL (0.032), DF (0.037), PL (0.053), SL (0.066)

PH: plant height (cm), TT: number of total tillers per plant, FT: number of effective tillers per plant, LVS: number of leaves per plant, PL: panicle length (cm), FLL: flag leaf length (cm), FLW: flag leaf width (cm), GPP: number of grains per panicle, FGP: filled grain percentage, HSW: hundred-grain weight (g), YPP: yield per plant (g), DF: number of days to 50% flowering, SL: grain length (mm), SW: grain width (mm)

Traits that similarly and directly affected the grain yield of traditional and improved rice genotypes

Effective tillers and filled grain percentage directly affected grain yield similarly in traditional and improved rice genotypes, and the magnitude of the effect was high. Grains per panicle also similarly affected the grain yield of both rice genotypes, and the effect was moderate. In a similar study, Kishore *et al.* (2015) reported that the number of grains per panicle, hundred seed weight, and the number of effective tillers per plant showed high direct effects on the grain yield in a positive direction. In addition, Roy *et al.* (2015) reported the positive impact of effective tiller number per plant on the final yield. Similar findings have been obtained in many studies in rice (Oladosu *et al.,* 2018; Limbongan *et al*., 2023; Reddy *et al*., 2023).

The effect of the total tiller number, number of leaves per plant, flag leaf length, days to 50% flowering, panicle length and grain length on the final grain yield was negligible for both traditional and improved rice genotypes (Table 4).

The direct effect of traits that differently affected grain yield of traditional and improved rice genotypes

The direct effect of hundred-grain weight on grain yield in traditional rice accessions was low. However, the direct effect of hundred-grain weight on improved rice varieties was high. The reason would be that improved rice varieties have already been modified for desirable seed characteristics such as plumpness or fullness. The traditional rice seeds have yet to be enhanced for such characteristics. Further, the effect of the flag leaf width on final grain yield was negligible in improved rice varieties. At the same time, it was low (effect on yield was more than in improved rice varieties) in traditional rice accessions. This is because improved rice varieties have been architecturally designed for optimum yield so that the canopy, including flag leaf, contributes to a higher yield. Still, traditional rice accessions still need to be architecturally designed for optimum yield, and the contribution of flag leaf to the grain yield would be naturally more significant than the effect of flag leaf on improved rice varieties. The effect of seed width on the final grain yield of traditional and improved rice genotypes was negligible and low, respectively. Desirable seed characteristics, such as plumpness, could be better in traditional rice accessions. Even though the seed width is broader in some traditional rice accessions, their contribution to the seed weight may less if seed plumpness is poor. Here, the effect of seed width on the final yield of traditional rice accessions is negligible. At the same time, it is low (effect is more than for traditional rice accessions) in improved rice varieties. The effect of hundred seed weight was low on the final yield of traditional rice accessions, and high for improved rice accessions (Table 4). This may be due to the same phenomenon explained for seed width.

The effect of plant height on final grain yield in traditional rice accessions was negligible and there was a low effect of the plant height on the final grain yield of improved rice varieties (Table 4). This difference can be justified by the difference in their plant architecture. The plant height of the improved rice varieties was designed for the optimum yield during the green revolution. As a result, the sink-source relationship of improved rice varieties has been optimized. Still, the sink-source relationship of traditional rice cultivars has yet to be optimized, and partitioning dry matter for seed production is inefficient.

Table 5: Traits whose direct effect was high, moderate, or low on yield, and the effect of other traits on them (indirect effects on yield)

Traits with indirect effect (Traditional)						Traits with indirect effect (improved)					
	Trait	D	I	T	DL			D	I	T	DL
*FT	PH	-	-0.068	-0.068		*FT	PH	-0.083	-0.083	0	Negligible
(High)	TT	0.884	0	0.884	High	(High)	TT	0.72	0	0.72	High
*FGP	PH	-	-0.005	-0.005		*FGP	PH		0.005	0.005	
(High)	PL	-	-0.033	-0.033		(High)	PL	-	0.019	0.019	
	TT	-	-0.045	-0.045			TT	-	-0.026	-0.026	
	GPP	0.27	0	0.27	Moderate		GPP	-0.296	0	-0.296	Moderate
	FT	-0.051	0	-0.051	Negligible		FT	-0.037	0	-0.037	Negligible
*GPP	PH	-	-0.031	-0.031		*GPP	PH		0.008	-0.008	Negligible
(Moderate)	PL	-0.121	0	-0.121	Low	(Moderate)	PL	-0.064	0	-0.064	Negligible
						*HGW	PL	-	0.001	0.001	
						(High)	GPP	-0.024	0.006	-0.018	Negligible
							FT	-	0.001	0.001	
							SW	0.526	0	0.526	High
							SL	0.716	0	0.716	High
							FGP	-0.019	0	-0.019	

D: direct effects. I: indirect effects, T: total effects, DL: direct effect level, PH: plant height (cm), TT: number of total tillers per plant, FT: number of fertile tillers per plant, LVS: number of leaves per plant, PL: panicle length (cm), FLL: flag leaf length (cm), FLW: flag leaf width (cm), GPP: number of grains per panicle, FGP: filled grain percentage, HSW: hundred seed weight (g), YPP: yield per plant (g), SL: grain length (mm), SW: grain width (mm)

* Traits with direct effect on yield

Hence, according to the results obtained by this study, considering the direct effect of yield attributing traits, effective tillering ability, hundred seed weight, filled grain percentage, and grains per panicle should be considered as selection criteria for breeding for higher yield in improved rice varieties.

The traits that recorded a high, moderate, or low indirect effect on the yield via other traits (effective tiller number, filled grain percentage, grains per panicle, hundred seed weight) with direct effect.

Total tiller number, grains per panicle, panicle length, grain width and grain length indirectly affected the yield via another trait of traditional or improved rice genotypes (Table 5). According to Shahidullah *et al.* (2009), the direct effect of the number of tillers on the final yield was insignificant. However, the number of panicles recorded an indirect effect through the number of tillers on final yield, and the greatest direct effect on the yield was recorded from the total number of tillers. Oladosu *et al.,* (2018) also reported a maximum indirect effect on yield by the tillers per hill through the number of panicles per plant. Grain-related characteristics directly or indirectly affect the final yield of rice.

Total tiller number per plant

The total tiller number per plant affected the effective tiller number equally in both traditional and improved rice genotypes, and the magnitude of the effect was high.

Grains per panicle

Grains per panicle moderately and positively affected filled grain percentage in traditional rice genotypes. Contrarily, grains per panicle moderately and negatively affected the filled grain percentage in improved rice varieties. Since improved rice varieties fill the seed to its maximum plumpness, filling becomes difficult when the number of seeds increases. However, in traditional rice accessions, since they do not fill the seeds to their maximum capacity, they can still fill many grains at least partially. The number of grains per panicle recorded a positive indirect effect through panicle number in the study reported by Al-Musawi *et al.* (2019). However, Laxmi *et al.* (2023) reported a positive direct impact of grains of panicle on final yield.

Panicle length

There was a low effect of panicle length on grains per panicle in traditional rice accessions, while the effect was negligible in improved rice varieties. However, Reddy *et al.,* (2023) reported a positive direct effect of panicle length on rice yield. The panicle length of traditional rice recorded a broad variation, while it was comparatively narrow in improved rice varieties (unpublished data by the author). A limited variation in panicle length may not affect grains per panicle in improved rice varieties. The number of spikelets within a panicle exhibited variability in traditional rice accessions corresponding to variations in panicle length. This may create such a difference in the effect of panicle length on grains per panicle in traditional and improved rice genotypes (Table 5).

Grain width and grain length

Grain width and length highly affected hundred grain weight in improved rice varieties, and the effect was negligible in traditional rice accessions. This difference may be due to the plumpness in improved rice varieties, as opposed to the partial filling nature in traditional rice accessions.

Days to 50% flowering showed a negligible effect on the final yield of traditional and improved rice genotypes (Table 4). However, Al-Musawi *et al.,* (2019) found a weak negative direct effect of days to 50% flowering on final yield, and a significant indirect effect on days to 50% flowering on final yield through plant height.

CONCLUSIONS

The direct and indirect effects of traits on the final grain yield of traditional rice accessions and improved rice varieties were different. The number of effective tillers per plant, filled grain percentage and grains per panicle were the traits that directly affected grain yield of both traditional and improved rice genotypes. Hundred seed weight had a high direct effect on the grain yield of improved rice varieties. Total tillers per plant and grains per panicle were the common traits that recorded a high indirect effect on yield in traditional and improved rice genotypes. Grain length and width indirectly but highly affect the yield of improved rice varieties, The direct and indirect effect of traits in traditional and improved rice genotypes on yield can be utilized as selection for breeding materials for higher yield.

Acknowlegement

Authors would like to acknowledge NRC/12/027, Ruhuna University Internationalization research grant, Indo-Sri Lanka Programme of Cooperation, ICGEB/CRP/SRI/13-01 for financial assistance and Plant Genetic Resources Centre, Gannoruwa, Sri Lanka for providing planting materials.

REFERENCES

Agahi K., Fotokian M.H. & Farshadfar E. (2007). Correlation and path coefficient analysis for some yield-related traits in rice genotypes (*Oryza sativa* L.). *Asian Journal of Plant Sciences* **6**: 513–517.
DOI: https://doi.org/10.3923/ajps.2007.513.517

Al-Musaw B. & Al-Anbari M. (2019). Estimating path coefficient analysis for some quantitative traits in Rice (*Oryza sativa* L.) genotypes. *Revista Bionatura 2022* **7**(4): 39.
DOI: https://doi.org/10.21931/RB/2022.07.04.39

Baye A., Berihun B., Bantayehu M. & Derebe B. (2020). Genotypic and phenotypic correlation and path coefficient analysis for yield and yield-related traits in advanced bread wheat (*Triticum aestivum* L.) lines. *Cogent Food and Agriculture* **6**(1): 1752603.
DOI: https://doi.org/10.1080/23311932.2020.1752603

Chakraborty M. & Sah R.P. (2012). Genetic component in baby corn (*Zea mays* L.). *Plant Archives* **12**(1)**:** 291–294.

Dalrymple D.G. (1985). The development and adoption of high-yield varieties of wheat and rice in developing countries. *Agricultural and Applied Economics Association* **1**: 1–15.
DOI: https://doi.org/10.22004/ag.econ.278578

Davies W.P. (2003). An historical perspective from the green revolution to the gene revolution. *Nutrition Reviews* **61**(6):124–134.
DOI: https://doi.org/10.1301/nr.2003.jun.s124-s134

DOA Sri Lanka (2013). *New Fertilizer Recommendations*. Available at *https://doa.gov.lk/rrdi_fertilizerrecomendation/*, Accessed 30 November 2023.

Dhurai S., Reddy D.M. & Ravi S. (2016). Correlation and path analysis for yield and quality characters in rice (*Oryza sativa* L.). *Rice Genomics and Genetics* **7**(4): 1–6.

Eric M.O., Pangirayi T., Paul S., Mwangi G. & Abhishek R. (2016). Correlations, path coefficient analysis and heritability for quantitative traits in finger millet landraces. *Philippine Journal of Science* **145**(02): 197–208.

Gour L., Koutu G.K., Singh S.K., Patel D.D., Shrivastava A. & Singh Y. (2017). Genetic variability, correlation and path analyses for selection in elite breeding materials of rice (*Oryza sativa* L.) genotypes in Madhya Pradesh. *The*

Pharma Innovation Journal **6**(11)**:** 693–696.

Immanuel S.C., Nagarajan P., Thiyagarajan K., Bharathi M. & Rabindran R. (2011). Genetic parameters of variability, correlation and path coefficient studies for grain yield and other yield Attributes among rice blast disease resistant genotypes of rice (*Oryza sativa* L.). *African Journal of Biotechnology* **10**: 3322–3334.
DOI: https://doi.org/10.5897/AJB10.2575

IRRI (2013). *Standard Evaluation System For Rice.* Available at *http://www.knowledgebank.irri.org/images/docs/rice-standard-evaluation.*

Janaki M., Ramana C.V., Naidu L.N., Babu J.D., Rao K.K. & Krishna K.U. (2018). Character association and path co-efficient analysis studies on yield and yield attributing characters in chilli (*Capsicum annuum* L.). *Electronic Journal of Plant Breeding* **9**(2): 558–563.

Khush G. (2003). Productivity Improvements in Rice. *Nutrition Reviews* **61:** 114–116.
DOI: https://doi.org/10.1301/nr.2003.jun.s114-s116

Khush G.S. (1999). Green revolution: Preparing for the 21st century. *Genome* **42**(4): 646–655.
DOI: https://doi.org/10.1139/g99-044

Kishore N., Srinivas T., Nagabhushanam U., Pallavi M. & Sameera S. (2015). Genetic variability, correlation and path analysis for yield and yield components in promising rice (*Oryza sativa* L.) genotypes. *SAARC Journal of Agriculture* **13**: 99–108.
DOI: https://doi.org/10.3329/sja.v13i1.24184

Laxm T.G., La G.M. & Bara B.M. (2023). Direct and indirect effects of yield contributing traits in rice (*Oryza sativa* L.). *International Journal of Plant & Soil Science* **35**(19): 2091–2099.
DOI: https://doi.org/10.9734/ijpss/2023/v35i193760

Lenka D. & Mishra B., (1973). Path coefficient analysis of yield in rice varieties. *Indian Journal of Agricultural Science* **43**(4):376.

Li R., Li M., Ashraf U., Liu S. & Zhang J. (2019). Exploring the relationships between yield and yield-related traits for rice varieties released in china from 1978 to 2017. *Frontiers in Plant Science* **10**: 00543.
DOI: https://doi.org/10.3389/fpls.2019.00543

Limbongan Y.L., Parari T.Y. & Sjahril R. (2023). Performance of agronomic characteristics and path analysis of the highland new plant types of rice. *IOP Conference Series: Earth and Environmental Science* **1230**(1):012122.
DOI: https://doi.org/10.1088/1755-1315/1230/1/012122

Lule D., Tesfaye K., Fetene M. & De Villiers S. (2012). Inheritance and association of quantitative traits in finger millet (*Eleusine coracana* Subsp. Coracana) landraces collected from eastern and south eastern Africa. *International Journal of Genetics* **2**(2): 12-21.

Mecha B., Alamerew S. & Assefa E. (2017). Correlation and path coefficient studies of yield and yield associated traits in bread wheat (*Triticum aestivum* L .) genotypes. *Advances in Plants and Agricultture Research* **6**(5):128–136.
DOI: https://doi.org/10.15406/apar.2017.06.00226

Monna L., Kitazawa N., Yoshino R., Suzuki J., Masuda H., Maehara Y., Tanji M., Sato M., Nasu S. & Minobe Y. (2002). Positional cloning of rice semi dwarfing gene, sd-1: Rice "green revolution gene" encodes a mutant enzyme involved in gibberellin synthesis. *DNA Research* **9**:11–17.
DOI: https://doi.org/10.1093/dnares/9.1.11

Nagalakshmi R., Kumari R.U. & Kumar R.A. (2020). Correlation and path analysis in cowpea (*Vigna unguiculata unguiculata* (L.) Walp). *The Bioscan* **15**(3): 397–401.

Oladosu Y., Rafii M.Y., Magaji U., Abdullah N., Miah G., Chukwu S.C., Hussin G., Ramli A. & Kareem I. (2018). Genotypic and phenotypic relationship among yield components in rice under tropical conditions. *BioMed Research International* **15**(2018): 8936767.
DOI: 10.1155/2018/8936767

Owere L., Tongoona P., Derera J. & Wanyera N. (2015). Variability and trait relationships among finger millet accessions in Uganda. *Uganda Journal of Agricultural Sciences* **16**(2):161–176.

PGRC (1999). *Characterization Catalogue On Rice (Oryza sativa L.) Germplasm*. Plant Genetic Resources Centre, Sri Lanka.

Rajamadhan R., Eswaran R. & Anandan A. (2011). Investigation of correlation between traits and path analysis of rice (*Oryza sativa* L.) grain yield under coastal salinity. *Electronic Journal of Plant Breeding* **2**:538–542.

Ranawake A.L., Amarasinghe U.G.S. and Senanayake S.G.J.N. (2014). Ranking traditional rice cultivars based on yield and some morphological traits using path analysis, multi-criteria decision making model and compromise programming. *American Journal of Experimental Agriculture* **4**(12):1579–1592.
DOI: https://doi.org/10.9734/AJEA/2014/11325

Rasel M., Hassan L., Hoque M.I.U. & Saha S.R. (2018). Estimation of genetic variability, correlation and path coefficient analysis in local landraces of rice *(Oryza sativa* L.) for the improvement of salinity tolerance. *Journal of Bangladesh Agriculture University* **16**: 41–46.
DOI: https://doi.org/10.3329/jbau.v16i1.36479

Rashmi D., Saha S., Loitongbam B., Singh S. & Singh P.K. (2017). Genetic variability study for yield and yield components in rice (*Oryza sativa* L.). *International Journal of Agriculture Environment and Biotechnology* **10**(2): 171–176.
DOI: https://doi.org/10.5958/2230-732x.2017.00020.1

Reddy V.R., Rani T.S., Kumari C.A. & Soundharya B. (2023). Correlation and path analysis for yield and yield attributes in maintainer lines of rice (*Oryza sativa* L.). *International Journal of Bio-Resource & Stress Management* **6**(10): 2369–2376.
DOI: https://doi.org/10.20546/ijcmas.2017.610.279

Rekha G.K., Ramana C.V., Naidu L.N., Umajyothi K., Paratpararao M. & Sasikala K. (2019). Character association studies for yield and quality traits in chilli. *International Journal of Current Microbiological & Applied Sciences* **8**(8): 569–574.
DOI: https://doi.org/10.20546/ijcmas.2019.808.068

Roy R.K., Majumder R.R., Sultana S., Hoque M.E. & Ali, M.S. (2015). Genetic variability, correlation and path coefficient analysis for yield and yield components in transplant aman rice (*Oryza sativa* L.). *Bangladesh Journal of Botany* **44**: 529–535.
DOI: https://doi.org/10.3329/bjb.v44i4.38566

Saleh M.M., Salem K.F.M. & Elabd A.B. (2020). Definition of selection criterion using correlation and path coefficient analysis in rice (*Oryza sativa* L.) genotypes. *Bulletin of the National Research Center* **44**: 143.
DOI: https://doi.org/10.1186/s42269-020-00403-y

Samonte S.O.P., Wilson L.T. & McClung A.M. (1998). Path analyses of yield and yield-related traits of fifteen diverse rice genotypes. *Crop Science* **38**(5):1130–1136.
DOI: https://doi.org/10.2135/cropsci1998.0011183x003800050004x

Shahidullah S.M., Hanafi M.M., Ashrafuzzaman M., Ismail M.R. & Salam M.A. (2009). Tillering dynamics in aromatic rice genotypes. *International Journal of Agriculture and Biology* **11(5)**: 509–514.

Singh R., Yadav V., Mishra D.N. & Yadav A. (2018). Correlation and path analysis in rice (*Oryza sativa* L.). *Journal of Pharmacognosy and Phytochemistry* **2018** (7):2084–2090

Sivakumar V., Ravindrakuma, C.C., Chandrasekhar C. & Bhagavan B.V.K. (2020). Character association and path coefficient analysis studies on yield and yield attributing characters in Turmeric (*Curcuma longa* L.) *Inernational Journal of Chemical Studies* **8**: 2587–2589.

Spielmeyer W., Ellis M.H. & Chandler P.M. (2002). Semidwarf (sd-1), “green revolution” rice, contains a defective gibberellin 20-oxidase gene. *Proceedings of National Academiy of Science of U.S.A.* **99**: 9043–9048.
DOI: https://doi.org/10.1073/pnas.132266399

SPSS Inc, (2020). Software, IBM SPSS Statistics for Windows (Version 27.0). SPSS Inc. Chicago, USA.

Sudeepthi K., Srinivas T., Kumar B.N.V.S.R.R., Jyothula D.P.B. & Umar S.N. (2020). Assessment of genetic variability, character association and path analysis for yield and yield component traits in rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding* **11**: 65–69.
DOI: https://doi.org/10.37992/2020.1101.026

Thangamani C. & Jansirani P. (2012). Correlation and path coefficient analysis studies on yield and attributing characters in brinjal (*Solanum melongena* L.). *Electronic Journal of Plant Breeding* **3**: 939–944.

Ulukan H., Guler M. & Keskin S. (2003). A Path Coefficient Analysis Some Yield and Yield Components in Faba Bean (*Vicia faba L.*) Genotypes. *Pakistan Journal of Biological Sciences* **6**:1951–1955.
DOI: https://doi.org/10.3923/pjbs.2003.1951.1955

Valenzuela S. & Bachmann I. (2017). Path Analysis, In: *The International Encyclopedia of Communication Research Methods,* pp.1–9. Wiley, USA.
DOI: https://doi.org/10.1002/9781118901731.iecrm0181