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Genetic Relationships of Rice Yield and Yield Components in RILs Population Derived from a Cross between KDML105 and CH1 Rice Varieties

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Abstract

There are many rice characteristics that contribute to the grain yield. This study aimed to characterize relationships of yield and yield components into direct and indirect effects, and to estimate the magnitude of genotypic and phenotypic variation, heritability and genetic advance. The study was conducted with 232 recombinant inbred lines (RILs) derived from a cross between low yield but good cooking quality, KDML105, and new plant type with high yield, CH1 rice variety. These lines were planted in RCBD with 3 replications. Data were collected for agronomic traits, yield components and yield. The results indicate that path coefficient analysis elucidated a positive direct effect on the number of panicles per plant (0.540) and the number of filled grains per panicle (0.510). Percentages of their direct effect were 62.11 and 74.68 %, respectively. These 2 traits demonstrate high significant value which could be used as selection criteria for yield improvement. Moreover, high values of heritability along with high genetic advance were observed for plant height, grain yield and the number of filled grains per panicle. Thus, these characters may serve as selection criteria combined with flag leaf length for improved high yield potential of rice.

Keywords: Correlation, path coefficient analysis, rice, yield, yield components

Introduction

Improvement of grain yield through development of new varieties is the main target of rice breeding programs. In hybridization programs, knowledge of the interrelationships among yield and other characters is necessary. Understanding the relationship between yield and its components is of paramount importance in making the best use of these relationships in rice selection [1]. However, grain yield is a complex trait, controlled by many genes and highly affected by environment. In addition, grain yield is also related to other characters such as growth duration and yield components [2]. The success of any breeding strategy in rice mainly depends upon the degree of associated characters as well as their magnitude and nature of variation [3,4]. Genetic variability, correlation and path coefficients are pre-requisites for improvement of any crop including rice in any trait by selection of superior genotypes. Yield components directly or indirectly increase grain yield if the components are highly heritable and genetically independent or positively correlated with grain yield. It is very difficult to judge whether the observed variability is highly heritable or not. Moreover, knowledge of heritability is essential for selection based improvement as it indicates the extent of transmissibility of a character into future generations. Knowledge of correlation between yield and its contributing characters is essential for plant selection. Partitioning of total correlation into direct and indirect effects by path analysis helps in making the selection more effective [5]. Positive correlation between 2 or more characters will facilitate the selection because it will be followed by an increase in other properties. Conversely, if the correlation is negative, it is difficult to obtain the expected character. If there is no correlation, then the selection becomes ineffective. In rice breeding programs, information on traits correlation has always been helpful as a basis for selection. Path coefficient analysis partitions the total correlation into a direct and indirect matrix presenting correlation in a more meaningful way [6]. In this study, the genetic variability and correlation coefficients among yield and its components were examined, and the levels of the direct and indirect effects of the independent characters on rice yield were estimated for finding the key factors in the formulation for high-yielding potential in rice. Information on the association of characters, direct and indirect effects contributed by each character towards yield will be an added advantage in aiding the selection process to improve rice yield.

Materials and methods

Field studies were conducted in the dry season at a farmer's field in Khumthong subdistrict, Ladkrabang district, Bangkok, Thailand (Lat: 13.719297, Lng: 100.850079). Randomized complete block design (RCBD) with 3 replications was used. Materials tested were 232 recombinant inbred lines (RILs) derived from a cross between low yield but good cooking quality, KDML105 and new plant type with high yield, CH1 rice variety. The 25 days-old seedlings were transplanted one seedling per hill with a spacing of 25×25 cm^2, in a plot size of 1×2 m^2 for each line. Ammonium phosphate fertilizer was supplied at a rate of 312 kg/ha 1 day before transplanting. Nitrogen fertilizer was supplied in the form of urea at a rate of 93 kg/ha at booting stage. During growth, pests and diseases were chemically controlled. Data on 2 plants which were randomly chosen in the mid row from each replicate were recorded on plant height (PH), number of tillers per plant (NT), number of panicles per plant (NP), flag leaf length (FLL), panicle length (PL), number of filled grain per panicle (NFG), seed setting rate (SSR), 1,000-grain weight (GW) and grain yield per plant. The path and correlation coefficient analyses were done using GENRES version 7.01 software. Genotypic and phenotypic coefficients of variation were estimated as per Sing and Chaudhary [7]. The broad sense heritability and genetic advance (GA) in percent of mean were calculated as suggested by Jonson *et al*. [8].

Results

The correlation analysis among yield and its contributing characters are shown in **Table 1**. Grain yield was positively correlated with number of tillers per plant, number of panicles per plant, number of filled grain per panicle and seed setting rate. Therefore, rice yield will increase as these characteristics increase. Grain yield was negatively correlated with plant height and flag leaf length. Therefore, yield can be increased by reduced plant height and flag leaf length in rice. The panicle length and grain weight were not significantly correlated with yield. Thus the improvement of yield is a complex character for which, direct selection is not effective. Correlation coefficients were separated into genotypic and phenotypic level (**Table 2**). The genotypic correlation coefficients in most cases were higher than their phenotypic correlation coefficients indicating the genetic reason of association. In some cases phenotypic correlation coefficients were higher than genotypic correlation indicating a suppressing effect of the environment which modified the expression of the characters at phenotypic level. The perusal of genotypic and phenotypic correlation analysis revealed that grain yield per plant had highly significant positive phenotypic and positive genotypic correlation with number of panicles per plant (P = 0.406**, G = 0.430**), number of tillers per plant (P = 0.316**, G = 0.316**), number of filled grain per panicle (P = 0.380**, G = 0.553**), and seed setting rate (P = 0.197**, G = 0.234**) indicating the importance of these traits for yield improvement in rice.

Table 1 Simple phenotypic correlation between characters of rice lines.

Characters	PH	NT	NP	FLL	PL	NFG	SSR	GW	yield
PH	1	-0.549**	-0.528**	0.388**	0.509**	-0.194**	-0.430**	-0.018	-0.377**
NT		1	0.883**	-0.375**	-0.378**	-0.102	0.271**	-0.024	0.316**
NP			1	-0.448**	-0.343**	-0.032	0.310**	-0.042	0.418**
FLL				1	0.530**	0.042	-0.204**	-0.120	-0.161*
PL					1	0.134*	-0.229**	-0.039	-0.036
NFG						1	0.434**	0.038	0.466**
SSR							1	0.091	0.214**
GW								1	0.044
yield									1

Note: PH = plant height; NT = number of tillers per plant; NP = number of panicles per plant; FLL = flag leaf length; PL = panicle length; NFG = number of filled grain per panicle; SSR = seed setting rate; GW = 1,000-grain weight
*, ** significant at 0.05 and 0.01 probability level, respectively

Table 2 Phenotypic (P) and genotypic (G) correlation coefficients among grain yield and its components in rice.

Characters		PH	NT	NP	FLL	PL	NFG	SSR	GW	Yield
PH	P	1.000	-0.416**	-0.404**	0.330**	0.429**	-0.145**	-0.323**	-0.008	-0.273**
	G	1.000	-0.673**	-0.642**	0.434**	0.590**	-0.231**	-0.531**	-0.026	-0.467**
NT	P		1.000	0.820**	-0.229**	-0.230**	-0.074	0.149**	-0.022	0.316**
	G		1.000	0.957**	-0.526**	-0.551**	-0.129**	0.416**	-0.026	0.316**
NP	P			1.000	-0.293**	-0.200**	-0.015	0.178**	-0.029	0.406**
	G			1.000	-0.607**	-0.508**	-0.048	0.466**	-0.057	0.430**
FLL	P				1.000	0.452**	0.067	-0.148**	-0.072	-0.105*
	G				1.000	0.613**	0.020	-0.263**	-0.169**	-0.216**
PL	P					1.000	0.147**	-0.146**	-0.017	-0.023
	G					1.000	0.121**	-0.328**	-0.062	-0.100*
NFG	P						1.000	0.443**	0.036	0.380**
	G						1.000	0.428**	0.110*	0.553**
SSR	P							1.000	0.039	0.197**
	G							1.000	0.150**	0.234**
GW	P								1.000	0.014
	G								1.000	0.077
Yield	P									1.000
	G									1.000

Note: PH = plant height; NT = number of tillers per plant; NP = number of panicles per plant; FLL = flag leaf length; PL = panicle length; NFG = number of filled grain per panicle; SSR = seed setting rate; GW = 1,000-grain weight; *, ** significant at 0.05 and 0.01 probability level respective

Path coefficient analysis furnishing the cause and effect of different yield components provides a better index for selection rather than mere correlation coefficients. The path coefficients which show the direct and indirect effects of yield components on grain yield and the diagrammatic presentation of the effects of variables on yield are presented in **Table 3** and **Figure 1**. The results indicate that the number of panicles per plant had the highest positive direct effect (0.540) on grain yield followed by the number of filled grain per panicle (0.510). Their ranked percentages of direct effect were 62.11 and 74.68 %, respectively. On the other hand, plant height and number of tillers per plant had a negative direct effect (–0.196 and –0.123, respectively) on grain yield. Although the number of tillers per plant had a negative direct effect on grain yield, it exerted a high positive indirect effect (0.477) through the number of panicles per plant. Their ranked percentages of direct effect was 55.85 %. It means that the higher the number of tillers per plant the greater the indirect yield by increasing the number of panicles per plant.

Table 3 Direct and indirect effects of yield components on grain yield.

Characters	Direct effect	Indirect effect								Correlation with grain yield
		PH	NT	NP	FLL	PL	NFG	SSR	GW	
PH	-0.196		0.068	-0.285	0.004	0.042	-0.099	0.090	-0.001	-0.377**
	(24.97 %)		(8.60 %)	(36.33 %)	(0.49 %)	(5.38 %)	(12.58 %)	(11.49 %)	(0.15 %)	
NT	-0.123	0.108		0.477	-0.004	-0.031	-0.052	-0.057	-0.002	0.316**
	(14.40 %)	(12.65 %)		(55.85 %)	(0.47 %)	(3.63 %)	(6.09 %)	(6.67 %)	(0.23 %)	
NP	0.540	0.104	-0.109		-0.004	-0.028	-0.016	-0.065	-0.003	0.418**
	(62.11 %)	(11.91 %)	(12.50 %)		(0.51 %)	(3.28 %)	(1.89 %)	(7.50 %)	(0.31 %)	
FLL	0.010	-0.076	0.046	-0.242		0.044	0.021	0.043	-0.008	-0.161*
	(2.04 %)	(15.52 %)	(9.41 %)	(49.35 %)		(8.99 %)	(4.38 %)	(8.74 %)	(1.57 %)	
PL	0.083	-0.100	0.046	-0.185	0.005		0.068	0.048	-0.002	-0.036
	(15.41 %)	(18.52 %)	(8.63 %)	(34.40 %)	(0.98 %)		(12.65 %)	(8.95 %)	(0.46 %)	
NFG	0.510	0.038	0.012	-0.017	0.0004	0.011		-0.091	0.002	0.466**
	(74.68 %)	(5.56 %)	(1.83 %)	(2.54 %)	(0.06 %)	(1.62 %)		(13.34 %)	(0.36 %)	
SSR	-0.210	0.084	-0.033	0.168	-0.002	-0.019	0.221		0.006	0.214**
	(28.25 %)	(11.33 %)	(4.49 %)	(22.54 %)	(0.27 %)	(2.56 %)	(29.77 %)		(0.78 %)	
GW	0.064	0.004	0.003	-0.023	-0.001	-0.003	0.020	-0.019		0.044^{ns}
	(46.97 %)	(2.63 %)	(2.14 %)	(16.68 %)	(0.88 %)	(2.35 %)	(14.35 %)	(14.00 %)		
Residual effect: 0.549										

Note: *, ** significant at 0.05 and 0.01 probability level, respectively; ns = non significant.

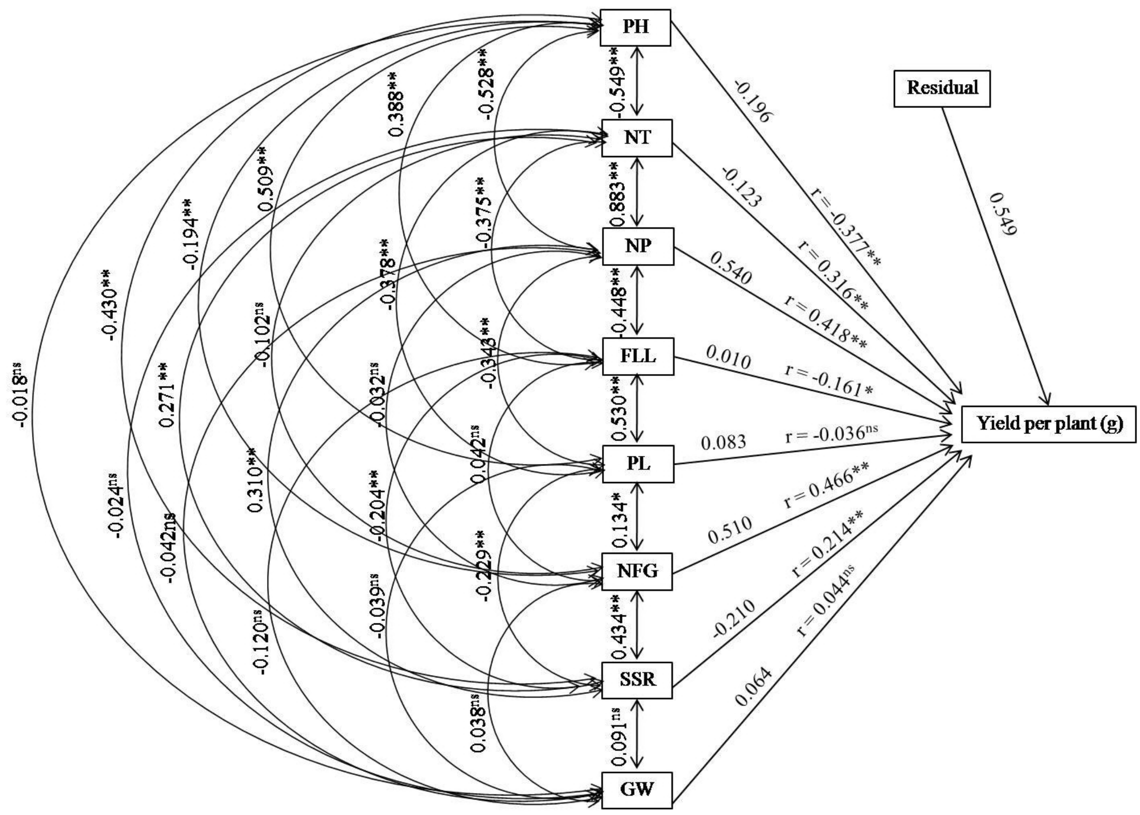

Figure 1 Path coefficient diagram of 8 selected agronomic traits in rice, where: PH = plant height; NT = number of tillers per plant; NP = number of panicles per plant; FLL = flag leaf length; PL = panicle length; NFG = number of filled grain per panicle; SSR = seed setting rate; GW = 1,000-grain weight; *, ** significant at 0.05 and 0.01 probability level, respectively; ns = non significant.

Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance (% of mean) of 9 characters of 232 RILs were calculated (**Table 4**). GCV ranged from 4.83 for thousand-grain weight to 21.13 for yield. Among the studied characters, grain yield per plant showed the highest value of GCV followed by plant height and the number of filled grain per panicle. The PCV ranged from 7.07 for thousand-grain weight to 31.35 for yield. Phenotypic coefficients of variation were higher than genotypic coefficients of variation for all characters.

The selection efficiency is higher when the parameters have higher heritability. High heritability estimates were observed for all the traits studied. Heritability values were over 50 % for plant height, number of filled grain per panicle and flag leaf length. So these estimates are helpful in making selection on the basis of phenotypic performance. The estimation of genetic advance is shown as percentage of the mean (**Table 4**). Plant height (39.58), grain yield (29.35), number of filled grain per panicle (28.02) and flag leaf length (21.15) were high. While, the number of tillers per plant, number of panicles per plant and seed setting rate were moderate and thousand-grain weight were low.

Table 4 Estimates of parameters of variability for different traits in rice.

Characters	Mean	Phenotypic variance	Genotypic variance	Variability		Heritability (%)	GA (% of mean)
				PCV	GCV		
PH	113.39	543.19	507.76	20.55	19.87	93.48	39.58
NT	17.53	14.92	6.36	22.04	14.38	42.58	19.33
NP	15.34	10.70	4.66	21.32	14.08	43.59	19.14
FLL	40.08	55.53	30.66	18.59	13.82	55.22	21.15
PL	25.79	8.43	3.58	11.25	7.34	42.53	9.86
NFG	129.58	981.08	552.06	24.17	18.13	56.27	28.02
SSR	73.29	102.42	42.60	13.81	8.91	41.59	11.83
GW	26.63	3.54	1.66	7.07	4.83	46.76	6.81
Yield	34.38	116.17	52.80	31.35	21.13	45.45	29.35

Note: PH = plant height; NT = number of tillers per plant; NP = number of panicles per plant; FLL = flag leaf length; PL = panicle length; NFG = number of filled grain per panicle; SSR = seed setting rate; GW = 1,000-grain weight

Discussion

The results of correlation analysis at phenotypic and genotypic level showed that the number of tillers per plant, number of panicles per plant, number of filled grain per panicle and seed setting rate were positively correlated with grain yield. The results are consistent with the findings of Prasad *et al*. [3] and Zahid *et al*. [4] who showed positive correlations with these traits. Similar to the results of this study, negative correlation of yield per plant was reported with plant height and flag leaf length by Qamar *et al*. [9]. The negative correlation of plant height with yield indicates that tallness in rice reduces the yield due to lodging susceptibility. Thus semi dwarf genotype will be preferred to boost up paddy yields in rice [4,6]. Negative direct effect of flag leaf length on paddy yield showed that paddy yield in fine grain rice can be increased with reduction in flag leaf length [10]. The improvement in the flag leaf length trait through plant breeding has led to a drastic increase in grain yield and flag leaf length has been recognized as one of the key factors in the formulation of new plant types for high-yielding potential in rice [11]. We need to develop plants with new plant type concepts as a guide for breeding improved rice yields. The choice of traits to breed for an ideal plant type for irrigated lowlands needs special perspectives like reduced flag leaf length and plant height in rice.

Genotypic correlation coefficients were partitioned by using the method of path coefficient analysis to find out the direct and indirect effects of yield contributing traits towards the grain yield. The path coefficient analysis at phenotypic level showed that the number of panicles per plant and number of filled grain per panicle exerted higher positive direct effects on grain yield. Many researchers have observed similar results [4,12,13] The direct positive effect of the number of panicles per plant and number of filled grain per panicle on grain yield per plant and positive correlation between these 2 traits indicates that a direct selection through this trait would be much effective for the improvement of grain yield per plant. Direct effect of plant height and number of tillers per plant on grain yield was found to be negative. These results support the findings of Prasad *et al*. [3]. Although the number of tillers per plant had a negative direct effect on grain yield, its indirect effect through the number of panicles per plant was higher and positive which consequently increased the correlation coefficient of the number of tillers per plant with yield. This result indicates that increasing effective tillers per plant is a highly reliable component of grain yield. Hence, an increased effective tiller should be given priority attention in rice improvement programs because of their major influence on yield [5].

The extent of genetic variation in yield components is better judged by the estimation of the genotypic coefficient of variation in relation to its phenotypic coefficient of variation. A small difference between GCV and PCV was observed in plant height, 1,000-grain weight and flag leaf length indicating that variations among the genotypes were mostly due to genetic factors; a high significant effect of genotype on phenotypic expression with very little effect of environment. On the other hand, large differences between GCV and PCV were observed for the number of tillers per plant, number of panicles per plant, panicle length, seed setting rate and grain yield. This indicates the influence of the environment on these characters. High GCV observed for some traits such as plant height and grain yield in this investigation indicates their high variability and that further selection could be used to improve the genotypes for the traits, while low GCV indicates limited improvement for the traits through selection [14,15]. Effective selection can be achieved only when additive effects are sufficiently higher than the environment effect. Jonson *et al*. [8] also showed that the effectiveness of selection depends not only on heritability but also on genetic advance. Moreover, high GCV together with high heritability and genetic advance provide more information than other parameters alone [16]. High heritability together with high genetic advance observed in this investigation for traits such as plant height and number of filled grains indicates that these characters are mainly controlled by additive types of genes. Plant height and number of filled grain per panicle are found to be important characters to be taken into consideration for effective selection of superior rice genotypes on the basis of phenotypic performance.

Conclusions

The results suggest that the number of panicles per plant and number of filled grain per panicle can be used as reliable selection criteria for improving grain yield in rice. The presence of higher heritability and genetic advance estimates for plant height, grain yield, number of filled grain per panicle and flag leaf length indicates that these characters can be exploited more efficiently through selection in further generations.

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