BIHAREAN BIOLOGIST 5 (1): pp.32-35 ©Biharean Biologist, Oradea, Romania, 2011
Article No.: 111103 *http://biologie-oradea.xhost.ro/BihBiol/index.html*

Path coefficient analysis for yield and yield components in diverse rice (*Oryza sativa* L.) genotypes

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Received: 5. December 2010 / Accepted: 14. March 2011 / Available online: 16. March 2011

Abstract. The objective of this study was to determine the relationship between grain yield and yield component in rice (*Oryza sativa* L.). Twenty-six rice genotypes were used in this research. A field experiment was conducted in a randomized complete block design with three replications at the Sari Agricultural Sciences and Natural Resources University. The traits, panicle length (r = 0.818), the total number of spikelet per panicle (r = 0.617), the number of filled grains per panicle (r = 0.790), and the panicle number per plant (r = 0.498) correlated significantly with grain yield. Path coefficient analysis revealed that panicle length had the highest positive direct effect (0.510) on grain yield. Grain yield linearly correlated with panicle length, the number of panicle per plant, and the number of filled grains per panicle. Therefore, these traits may be used in the selection for grain yield in rice.

Key Words: Path coefficient analysis, rice grain yield, yield component, rice genotypes.

Introduction

Path coefficient analysis is a statistical tool developed by Wright (1921). It has been used to organize and present the causal relationship between predictor variables and response variables through a path diagram that is based on experimental results or on prior grounds. The advantage of path analysis is that it permits the partitioning of the correlation coefficient into its components - one component being the path coefficient (or standardized partial regression coefficient) that measures the direct effect of a predictor variable upon its response variable; the second component being the indirect effect(s) of a predictor variable on the response variable through other predictor variables (Dewey & Lu 1959). In agriculture, path analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Samonte et al. 1998, Ezeaku & Mohammed 2006).

Except for Amirthadevarathinam (1983) and Samonte et al. (1998), most of the path analysis on grain yield and yield components (Gravois & Helms 1992, Gravois & McNew 1993, Iftekharuddaula et al. 2002) considered only a few yield components even when several plant growth and development traits and physiological processes also influence yield. In addition, previous path analysis treated yield components as first-order variables and in some cases the presence of multicollinearity resulted in path coefficients greater than one. A path analysis of grain yield and yield-related traits that includes at least second-order variables (predictor variables of first-order variables) in their path diagram has been lacking. In a breeding programme direct estimation of yield which has low heritability is difficult to obtain. Plant breeders commonly select for yield components that indirectly increase yield (Gravois & McNew 1993). Yield component breeding would be most effective if the components involved were highly heritable and positively correlated. Grain yield has been reported to be influenced by productive tillers, panicle length and flowering time (Ibrahim et al. 1990), plant height and the number of panicle per plant (Kumar 1992), the number of effective tillers per plant, grains per panicle and 1000-grain weight (Ram 1992), grains per panicle and productive tillers (Sundaram & Palanisamy 1994), the number of filled grains per panicle and 1000-grain weight (Mehetre et al. 1994, Samonte et al. 1998) and biological yield, harvest index and 1000-grain weight (Surek et al. 1998).

The objective of this study was to determine the relationships between grain yield and yield components. After determining the characters which have high correlation with grain yield and positive effect on it, selection indices may be developed for rice breeding.

Materials and Methods

Plant materials

The rice genotypes used in this study were six local genotypes (Daei-shastak, Dilamani, Hasani, Nok-siah, Sange-tarom and Shastak-mohammadi), five released genotypes with high yield (Khazar, Neda, Phajer, Sahel and Sephidrod) and 15 rice lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15). A field experiment was conducted in a randomized complete design with three replications during the 2009 summer cropping seasons at the Sari Agricultural Sciences and Natural Resources University. The soil texture is a fine montmorillonite. The rice seedlings were transplanted on 19 April 2009, at the three-leaf stage, single seeding was used for each hill, space size was 20 x 20 between rows and within row. The plot size was 3 x 5 = 15 m^{-2}. Fertilizer was applied at planting (46 Kg N ha^{-1}), transplant (23 Kg N ha^{-1}), and at panicle differentiation (23 Kg N ha^{-1}). The permanent flood water level was maintained at 10 cm after transplanting. The data were recorded for grain yield, the number of panicle per plant, plant height, days to maturity, length and width of flag leaf, panicle length, the number of primary and secondary branches per panicle, the total number of spikelets per panicle, the number of filled grain per panicle, length and width of rice grain, 1000-grain weight. These traits were evaluated based on standard evaluation system rice (IRRI 2002).

Statistical analysis

The path coefficient analyses were conducted as described by Williams et al. (1990) for the data. A mixed stepwise regression procedure (SAS Institute 1995) with a probability to enter and remove variables was set at 0.05, and was used to select the initial 13 yield-related traits. The stepwise regression was necessary because of multicollinearity between predictor variable. A path analysis without the use of stepwise regression produced path coefficients > 1.0, while the exclusion of one of the highly correlated variables from the path analysis still produced path coefficients > 1.0.

Results and Discussion

The correlation between all pairs of variables is show in Table 1. The traits significantly correlated with grain yield were

Table 1. Phenotypic correlations among the traits.

Traits	X1. The number of panicle per plant	X2. Plant height	X3. Days to maturity	X4. Length of flag leaf	X5. Width of flag leaf	X6. Panicle length	X7. Number of primary branches per panicle	X8. Number of secondary branches per panicle	X9. Total number of spikelets per panicle	X10. Number of filled grain per panicle	X11. Length of paddy	X12. Width of paddy	X13. 1000-grain weight	X14. Grain yield
X1.	1.0													
X2.	-0.508**	1.0												
X3.	0.289	-0.620**	1.0											
X4.	-0.588**	0.411*	-0.548**	1.0										
X5.	0.167	-0.245	0.089	-0.084	1.0									
X6.	0.212	-0.104	0.190	-0.198	0.002	1.0								
X7.	0.134	-0.511**	0.725**	-0.264	0.137	0.273	1.0							
X8.	0.437*	-0.379	0.546**	-0.349	0.288	0.542**	0.590**	1.0						
X9.	0.285	-0.193	0.116	-0.114	0.130	0.720**	0.277	0.634**	1.0					
X10.	0.228	-0.132	0.092	-0.087	0.114	0.682**	0.271	0.579**	0.987**	1.0				
X11.	-0.215	0.064	0.183	0.333	-0.079	0.254	0.299	0.034	-0.081	-0.067	1.0			
X12.	-0.141	-0.093	0.020	-0.163	0.095	-0.143	0.087	0.00	-0.185	-0.184	-0.379	1.0		
X13.	-0.358	-0.059	-0.058	0.436**	-0.044	-0.109	0.009	-0.221	-0.283	-0.272	0.319	0.522**	1.0	
X14.	0.498**	-0.279	0.277	-0.307	-0.032	0.818**	0.245	0.357**	0.817**	0.790**	0.053	-0.269	-0.254	1.0

* and **; Significant at 0.05 and 0.01 levels, respectively.

Table 2. Direct (diagonal) and indirect effects of various traits on grain yield.

Traits	X1. The number of panicle per plant	X2. Plant height	X3. Days to maturity	X4. Length of flag leaf	X5. Width of flag leaf	X6. Panicle length	X7. Number of primary branches per panicle	X8. Number of secondary branches per panicle	X9. Total number of spikelets per panicle	X10. Number of filled grain per panicle	X11. Length of paddy	X12. Width of paddy	X13. 1000-grain weight	Correlation with grain yield
X1.	**0.338**	-0.021	0.076	-0.021	-0.015	0.108	-0.011	-0.068	0.017	0.092	0.024	0.021	-0.048	0.498**
X2.	-0.173	**0.041**	-0.164	0.014	0.021	-0.054	0.04	0.058	-0.013	-0.054	-0.008	0.014	-0.008	-0.279
X3.	0.097	-0.026	**0.262**	-0.020	-0.008	0.097	-0.058	-0.085	0.007	0.037	-0.021	-0.004	-0.008	0.277
X4.	-0.200	0.016	-0.145	**0.035**	0.007	-0.102	0.02	0.053	-0.008	-0.036	-0.038	0.025	0.058	-0.307
X5.	0.056	-0.011	0.023	-0.003	**-0.088**	0.007	-0.011	-0.045	0.008	0.048	0.008	-0.015	-0.006	-0.032
X6.	0.071	-0.005	0.049	-0.008	-0.001	**0.510**	-0.022	-0.084	0.045	0.277	-0.029	0.022	-0.015	0.818**
X7.	0.045	-0.022	0.190	-0.010	-0.03	0.139	**-0.079**	-0.092	0.017	0.11	-0.034	-0.014	0.001	0.245
X8.	0.148	-0.016	0.143	-0.013	-0.023	0.276	-0.047	**-0.155**	0.039	0.236	-0.004	0.00	-0.03	0.557**
X9.	0.096	-0.008	0.030	-0.005	-0.012	0.367	-0.022	-0.098	**0.062**	0.402	0.009	0.028	-0.038	0.817**
X10.	0.077	-0.006	0.024	-0.004	-0.011	0.348	-0.022	-0.09	0.061	**0.407**	0.007	0.028	-0.037	0.790**
X11.	-0.073	0.002	0.048	0.011	0.006	0.129	-0.024	-0.006	-0.006	-0.028	**-0.114**	0.058	0.042	0.053
X12.	-0.048	-0.004	0.005	-0.006	-0.009	-0.074	-0.007	0.00	-0.012	-0.075	0.034	**-0.155**	0.069	-0.269
X13.	-0.122	-0.003	-0.016	0.015	0.003	-0.056	-0.001	0.034	-0.018	-0.111	-0.037	-0.081	**0.133**	-0.254

Residual effects = 0.3

panicle length (r = 0.818), the total number of spikelets per panicle (r = 0.817), the number of filled grains per panicle (r = 0.790), and the number of panicle per plant (r = 0.498). Previous papers have mentioned rice grain yield as a function of maximum tiller density, number of filled grains per panicle (Samonte et al. 1998), and panicle length (Iftekharuddaula et al. 2002).

Table 2 shows the results of the path analysis for the examined traits. Path coefficient analysis of yield and its components revealed that panicle length had the highest positive direct effect (0.510) on grain yield. High positive direct effect of this character was nullified by the negative indirect effect of number of secondary branches per panicle (-0.084), however its indirect effect via the number of filled grain per panicle, the number of panicle per plant, days to maturity and the total number of spikelets per panicle was very high, bringing the total correlation to r = 0.818 with yield (Table 2). Similar results were reported by Ibrahim et al. (1990) and Iftekharuddaula et al. (2002). The number of filled grain per panicle was the second most important character, it showed high positive direct effect (0.407) on yield. Its indirect effect via panicle length, the total number of spikelets per panicle and the number of panicle per plant was very high, whereas its effect via number of secondary branches per panicle was negative. This was similar to previous reports (Sundaram & Palanisamy 1994, Mehetre et al. 1994, Samonte et al. 1998). The number of panicle per plant was the third most important trait which showed high positive direct effect (0.338) on yield. Its indirect effect via plant height, length of flag leaf and 1000-grain weight was negative, where as its effect via panicle length, the number of filled grain per panicle and days to maturity was positive.

Though the correlation coefficient (0.817) of the total number of spikelets per panicle with yield was highly significant, its direct contribution (0.062) was not high, whereas it was mainly supplemented indirectly via the number of filled grain per panicle and panicle length with correlation coefficient 0.987 and 0.720, respectively. The direct effect of number of secondary branches per panicle on yield was negative and low in spite of positive correlation coefficient (0.557). This was mainly because of negative indirect effect of the number of primary branches per panicle, 1000-grain weight, width of flag leaf, length of flag leaf and plant height, while very small contribution via length of flag leaf, the number of filled grain per panicle, the number of panicle per plant and days to maturity were revealed by this character. The number of primary branches per panicle was another character which had negative direct effect on yield. It showed positive indirect effect via days to maturity, panicle length, the number of filled grain per panicle and the number of panicle per plant, while the negative forces of this character were number of secondary branches per panicle, length of paddy, width of flag leaf and plant height. The direct influence of days to maturity was positive. Its negative indirect effect were mainly number of secondary branches per panicle (-0.083) and number of primary branches per panicle (-0.058).

The organization of the 13 traits into first-, second-, and third- order variables in the path analysis provided more information than if all traits were treated only as first-order variables.

The yield components (the number of panicle per plant, plant height, days to maturity, length of flag leaf, length of panicle, total number of spikelets per panicle, number of filled grain per panicle and 1000-grain weight) had a direct effect on yield if other components were kept constant. But the magnitude of direct effect of length of panicle was maximum. An overall analysis of path coefficient in this investigation suggested that panicle length, the number of filled grain per panicle and the number of panicle per plant should be given the maximum consideration for yield improvement and appropriate selection indices should be formulated using these traits.

In this study a stepwise regression model was used to facilitate the interpretation of grain yield (Table 3). There was significant linear relationship between yield (y) and panicle length (X_6) and the number of panicle per plant (X_1) and the number of filled grain per panicle (X_{10}). The following model was obtained:

$$\hat{y} = 81.214 + 0.489 (X_6) + 0.306 (X_1) + 0.387 (X_{10})$$

Panicle length had the highest R^2 percent and explained 66.8% from total variations relative to grain yield (Table 3). Also this trait had the highest positive direct effect (0.510) and the highest correlation coefficient (r = 0.818) with grain yield. These results showed that regression analysis agreed with path analysis in this study (Ezeaku and Mohammed 2006).

Estimates of genotypic and phenotypic coefficient of variation and genetic advance due to selection are presented in Table 4. The success of plant breeding operations relies heavily on extent of genetic variability present in a crop species for a particular trait. In fact plant breeding uses selection for improving the architecture of a crop by management of available genetic variability (Gravois & McNew 1993, Mehetre et al. 1994). In the present study, the genotypic coefficient of variation (GCV) was less than its corresponding estimates of PCV for all traits indicating significant role of environment in the expression of these traits. Relatively higher estimates of GCV for The number of panicle per plant, Plant height, Length of flag leaf, panicle length, Number of primary branches per panicle and Days to maturity suggest that the selection can be effective for these traits. Lines or geno-

Table 3. The stepwise regression for selection of traits which explain variation of rice yield.

Model	Traits	R^2 (%)		Mean square	Constant	Regression coefficient of traits
		Relative	Cumulative			
1	Panicle length (X_6)	66.8	66.8	110658.39 **	23.382	0.489 **
2	The number of panicle per plant (X_1)	11.1	77.9	64467.37 **	-5.451	0.306 **
3	Number of filled grain panicle (X_{10})	7.9	85.8	47338.73 **	81.214	0.387 **
$\hat{y} = 81.214 + 0.489 (X_6) + 0.306 (X_1) + 0.387 (X_{10})$						

T able 4. Estimates of some genetic parameters in rice.

Traits	Mean	Range	GCV (%)	PCV (%)	Expected genetic advance
X1. The number of panicle per plant	20.49	9-33	30.08	31.89	11.97
X2. Plant height	121.07	93-179	23.98	24.45	19.25
X3. Days to maturity	71.78	52-89	17.25	17.57	42.22
X4. Length of flag leaf	37.07	22.2-57.5	23.49	23.71	80.61
X5. Width of flag leaf	1.54	1.20-2.10	15.59	15.64	23.05
X6. Panicle length	24.70	18.30-33.0	21.94	22.18	65.95
X7. Number of primary branches per panicle	10.46	7-14	19.21	19.97	14.11
X8. Number of secondary branches per panicle	39.73	22-59	8.58	8.86	1.63
X9. Total number of spikelets per panicle	168.18	115-261	10.0	11.23	0.28
X10. Number of filled grain per panicle	147.64	105-225	10.73	11.34	0.53
X11. Length of paddy	9.54	8.0-11.8	8.69	10.84	3.54
X12. Width of paddy	2.57	2.0-3.2	14.17	14.28	6.94
X13. 1000-grain weight	23.97	18.9-35.0	14.66	15.65	2.96
X14. Grain yield	730.83	607.5-976.3	11.58	11.59	174.06

GCV: Genotypic coefficient of variation, PCV: Phenotypic coefficient of variation

types with longer panicle length, high number of panicle per plant and high number of filled grain per panicle will have high grain yield (Kumar 1992, Gravois & McNew 1993). Therefore these traits are good criteria for selection of genotypes with high yield.

Conclusion

In summary, our results suggest that a plant type for increasing grain yield should have high panicle length; and it should also have high the total numbers of spikelets per panicle, high number of filled grains per panicle and the number of panicle per plant. Among these traits, panicle length may be used for the indirect selection of grain yield.

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