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Correlation and path coefficient analysis in rice (*Oryza sativa* L.)

Sonu Kumar, MP Chauhan, Amit Tomar, Ravindra Kumar Kasana and Nimit Kumar

Abstract
The results were indicated that, biological yield per plant, harvest index, spikelet fertility, 1000-grain weight, L/B ratio, plant height and panicle length showed positive and significant correlation with grain yield per plant to emerge as most important associates of grain yield in rice. Path analysis identified biological yield per plant followed by harvest-index as most important direct yield contributing traits and biological yield per plant followed by 1000-grain weight and panicle length exhibited high order of positive indirect effect as most important indirect components which merit due consideration at time of devising selection strategy aimed at developing high yielding varieties in rice. Out of 82 entries tested under natural condition, none were found to be immune or resistant. However, 30 genotypes were found moderately resistant, 47 genotypes moderately susceptible, while 3 genotypes susceptible and rest two genotypes were highly susceptible.

Keywords: Correlation, path coefficient analysis, rice, (*Oryza sativa* L.)

Introduction
Cultivated rice is an annual grass with round and jointed culms, flat leaves and terminal inflorescence. The plant has fibrous root system. The stem is made up of nodes and hollow internodes. The rice has two parts *i.e.*, underground and aerial. The leaves include the blade and the leaf sheath. The uppermost leaf below panicle is called as flag leaf. The paired structure on either side of the base of the leaf blade is auricle. The rice inflorescence is a panicle that is composed of spikelets. A spikelet consists of two sterile lemmas, the rachilla and the floret. The floret includes lemma, pelea and the flower. The flower consists of six stamens. Rice fruit is caryopsis which is enclosed by the lemma and pelea. The mature rice harvested as covered grain is called rough rice. Rice primarily a high-energy or high calorie food. It contains less protein than wheat. The protein content of milled rice is usually 6 to 7 per cent. Rice however, compares favorably with other cereals in amino acids content. The biological value of its protein is high. The fat content of rice is low (2.0 to 2.5 per cent) and much of the fat is lost during milling. Rice contains a low percentage of calcium. Rice grain contains as much B group vitamins as wheat. Milled rice loses valuable proteins, vitamins and minerals in the milling process during which the embryo and the aleurone layer are removed. Much of the loss of nutrients can be avoided through parboiling process. The byproducts of rice milling are used for a variety of purposes. Rice bran is used as cattle and poultry feed. Rice hulls can be used in manufacture of insulation materials, cement, card board and as a litter in poultry keeping. Rice straw can be used as cattle feed as well as litter during winter.
Rice is grown under many different conditions. Rice is the only cereal crop that can grow for long periods of time in standing water. 57% of rice is grown on irrigated land, 25% on rainfed lowland, 10% on the uplands, 6% in deep water, and 2% in tidal wetlands. Rice is cultivated world-wide over an area about 164.72 million hectares with an annual production and productivity of about 745.71 million tones and 4527.10 kg per hectare, respectively **(Anonymous 2013a).**

Materials & Methods
The present experimental materials are consisting four CMS lines having the WA cytoplasmic background *viz*., IR 68885A, IR 58025A, IR 68897A, and IR 79156A used as lines and fifteen promising rice varieties *viz*., NDR 1126, NDR 1127, IR 27723, CR 2499, Sugandha 5, NDR 3112-1, NDR 2701, NDR 2702, NDR 2704, NDR 2706, NDR 370131, NDR 370132, NDR 370133, IR 87651 and NDR 2705 were used as testers, three checks (NDR 2064, NDR 2065

and NDR 359) were the experimental materials of this study. The crosses will be made into "line x tester" mating design (Kempthorne, 1957) to produce 60 crosses. All the Eighty two genotypes were sown in Randomized Block Design (RBD) with three replications at the Instructional farm of Genetics and Plant Breeding, NDUAT Kumarganj Faizabad (U.P.) India, during 2013 *kharif* season. A standard spacing of 15cm x 20cm was adopted for planting. Recommended packages of practices were followed during the crop growth period. Observations were recorded for twelve characters *viz.*, days to 50% flowering, plant height (cm), panicle length (cm). effective tillers per plant, total no. of spikelet per panicle, total number of filled spikelet per panicle, total number of chaffy spikelet per panicle, spikelet fertility %, 100-grain weight (g), harvest index (%), length of spikelet (cm), breadth of spikelet (cm), and grain yield per plant (g days to 50% flowering, days to maturity, plant height, Panicle bearing tillers per plant, panicle length, 1000 grain weight, Spikelet per panicle, Spikelet fertility (%), Harvest-index (%), L/B ratio, Grain yield per plant (g) and Biological yield per plant (g). Correlation and direct & indirect effects were estimated for all twelve characters. The simple correlations (r) between different characters at phenotypic (p) and genotypic (g) levels were worked out as suggested by Searle (1961) [2]. Path coefficient analysis was carried out according to Dewey and Lu (1959) [3].

Results & Discussions

The estimates of simple correlation coefficients (phenotypic and genotypic) computed between twelve characters under study are presented in Table-1 and Table-2.

In general, genotypic correlations were higher than phenotypic ones in magnitude for all the characters. The characters which showed negative correlation at genotypic level also showed negative correlation at phenotypic level. Grain yield per plant possessed positive and highly significant correlation with biological yield per plant (0.968**), harvest index (0.815**), spikelet fertility (0.793**), 1000-grain weight (-0.767**), L/B ratio (-0.755**), plant height (0.600**) and panicle length (0.323**). While negative and highly significant or significant correlation associated with days to maturity (-0.298**), days to 50% flowering (-0.248**) and panicle bearing tillers per plant (-0.154*). Negative and non-significant associated only with spikelet per panicle (-0.104). Days to 50% flowering showed positive and highly significant correlation with days to maturity (0.935**) and negative and highly significant correlation with panicle length (-0.370**), plant height (-0.314**), harvest index (-0.306**), spikelet fertility (-0.287**), grain yield per plant (-0.248**), biological yield per plant (-0.229**), L/B ratio (-0.217**) and 1000-grain weight (-0.214**). But spikelet per panicle (0.075) was found positive and non-significant while panicle bearing tillers per plant (-0.025) showed negative and non-significant association at both levels. Days to Maturity showed negative and highly significant correlation with panicle length (-0.370**), harvest index (-0.347**), spikelet fertility (-0.311**), plant height (-0.298**), grain yield per plant (-0.298**), biological yield per plant (-0.267**), 1000-grain weight (-0.244**) and L/B ratio (-0.225**) while significant correlated with spikelet per panicle (0.125*). But panicle bearing tillers per plant (-0.031) showed negative and non-significant correlation at both levels. Plant height had highly significant and positive correlation with spikelet fertility (0.731**), biological yield per plant (0.668**), 1000-grain weight (0.635**), harvest index (0.631**), L/B ratio (0.612**) and grain yield per plant (0.612**). Whereas positively non-significant association was found panicle length (0.121) and spikelet per panicle (0.067) and negative non-significant association with panicle bearing tillers per plant (-0.217) at both levels. These results were also similar to Agahi *et al.* (2007) [4], Babar *et al.* (2009) [8], Bhadrudal *et al.* (2011) [12], Basavaraja *et al.* (2011) [10], Bagheri *et al* (2011) [9], Arvind *et al.* (2011) [7], Akinwale *et al.* (2011) [6], Akhtar *et al.* (2011) [5], Bekelebtal *et al.* (2013) [11] and Bhatia *et al.* (2013).

Panicle bearing tillers per plant showed highly significant and negative correlation with 1000-grain weight (-0.393**), spikelet fertility (-0.391**), L/B ratio (-0.388**), harvest index (-0.364**) and biological yield per plant (-0.180**), while significant and negative association with grain yield per plant (-0.154*) at both levels. Whereas positively non-significant association was found for panicle length (0.096) and spikelet fertility (0.086). Panicle length had highly significant positive correlation with harvest index (0.334**), grain yield per plant (0.323**), 1000-grain weight (0.257**), spikelet fertility (0.241**), L/B ratio (0.228**) and biological yield per plant (0.226**) but spikelet per panicle (0.002) was found positive and non-significant correlation. Spikelet per panicle showed highly significant and negative correlation with harvest index (-0.193**) and 1000-grain weight (-0.175**) but was found negative and significant correlation with L/B ratio (-0.138*) and spikelet fertility (-0.129*) at both levels. Spikelet fertility showed highly significant and positive correlation with harvest index (0.954**), 1000-grain weight (0.814**), L/B ratio (0.901**), biological yield per plant (0.799**) and grain yield per plant (0.793**). 1000-grain weight exhibited highly significant and positive correlation with harvest index (0.893**), L/B ratio (0.853**), grain yield per plant (0.767**) and biological yield per plant (0.756**). Biological yield per plant had highly significant and positive association with grain yield per plant (0.968**), harvest index (0.762**) and L/B ratio (0.762**). Harvest index (%) had highly significant and positive association with L/B ratio (0.815**) and grain yield per plant (0.815**). These results were also similar to Agahi *et al.* (2007) [4], Babar *et al.* (2009) [8], Bhadrudal *et al.* (2011) [12], Basavaraja *et al.* (2011) [10], Bagheri *et al* (2011) [9], Arvind *et al.* (2011) [7], Akinwale *et al.* (2011) [6], Akhtar *et al.* (2011) [5], Bekelebtal *et al.* (2013) [11] and Bhatia *et al.* (2013) [13, 20].

The direct and indirect effects of twelve characters on grain yield per plant estimated by path coefficient analysis using phenotypic as well as genotypic correlation coefficients are given in Table-3 and table-4.

The direct and indirect effects of different characters on grain yield per plant at phenotypic level are presented in Table-3. The highest positive direct effect on grain yield per plant was exerted by biological yield per plant (0.926) followed by harvest index (0.577), while the highest negative direct effect on grain yield per plant was exerted by spikelet fertility (-0.432) followed by plant height (-0.037) and spikelet per panicle (-0.018). The direct effects of remaining ten characters were too low to be considered important. Harvest index (0.439) followed by 1000-grain weight (0.014) exhibited high order of positive indirect effect on grain yield per plant via biological yield per plant, while negative indirect effect on grain yield per plant was exerted by spikelet fertility (-0.345) followed by plant height (-0.025). Biological yield per plant (0.705) followed by 1000-grain weight (0.017) and

panicle length (0.013) exhibited high order of positive indirect effect on grain yield per plant via harvest index, while negative indirect effect on grain yield per plant was exerted by spikelet fertility (-0.412), plant height (-0.023) and panicle bearing tillers per plant (-0.011). The remaining estimates of indirect effects in this analysis were too low to be considered of any consequence. The estimates of residual factors were negligible. These results are similar to Zaid *et al.* (2006) [23], Kiami *et al.* (2012) [16], Kiami and Nemadzadeh (2012) [15], Krishnamurthy and Kumar (2012) [18], Syon *et al.* (2012) [21], Sudharani *et al.* (2013) [22], Bhatia *et al.* (2013) [13, 20], Lakshmi *et al.* (2014) [19], Gopikannan and Ganesh (2014) [14] and Kolom *et al.* (2014) [17].

Table 1: Estimates of phenotypic correlation coefficients between 12 characters of rice (*Oryza sativa* L.).

Character	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle bearing tillers/plant	Panicle length (cm)	Spikelet/ panicle	Spikelet fertility (%)	1000-Grain Weight (g)	Biological yield/ plant (g)	Harvest index (%)	L/B ratio	Grain yield/ plant (g)
Days to 50% flowering	1.000	0.935**	-0.314**	-0.025	-0.370**	0.075	-0.287**	-0.214**	-0.229**	-0.306**	-0.217**	-0.248**
Days to maturity		1.000	-0.298**	-0.031	-0.370**	0.125*	-0.311**	-0.244**	-0.267**	-0.347**	-0.225**	-0.298**
Plant height (cm)			1.000	-0.217	0.121	0.067	0.731**	0.635**	0.668**	0.631**	0.612**	0.600**
Panicle bearing tillers/plant				1.000	0.096	0.086	-0.391**	-0.393**	-0.180**	-0.364**	-0.388**	-0.154*
Panicle length (cm)					1.000	0.002	0.241**	0.257**	0.226**	0.334**	0.228**	0.323**
Spikelets/panicle						1.000	-0.129*	-0.175**	-0.040	-0.193**	-0.138*	-0.104
Spikelet fertility (%)							1.000	0.914**	0.799**	0.954**	0.901**	0.793**
1000-Grain Weight(g)								1.000	0.756**	0.893**	0.853**	0.767**
Biological yield/plant (g)									1.000	0.762**	0.762**	0.968**
Harvest index (%)										1.000	0.875**	0.815**
L/B ratio											1.000	0.755**
Grain yield/plant (g)												1.000

*, ** Significant at 5 % and 1 % probability levels, respectively.

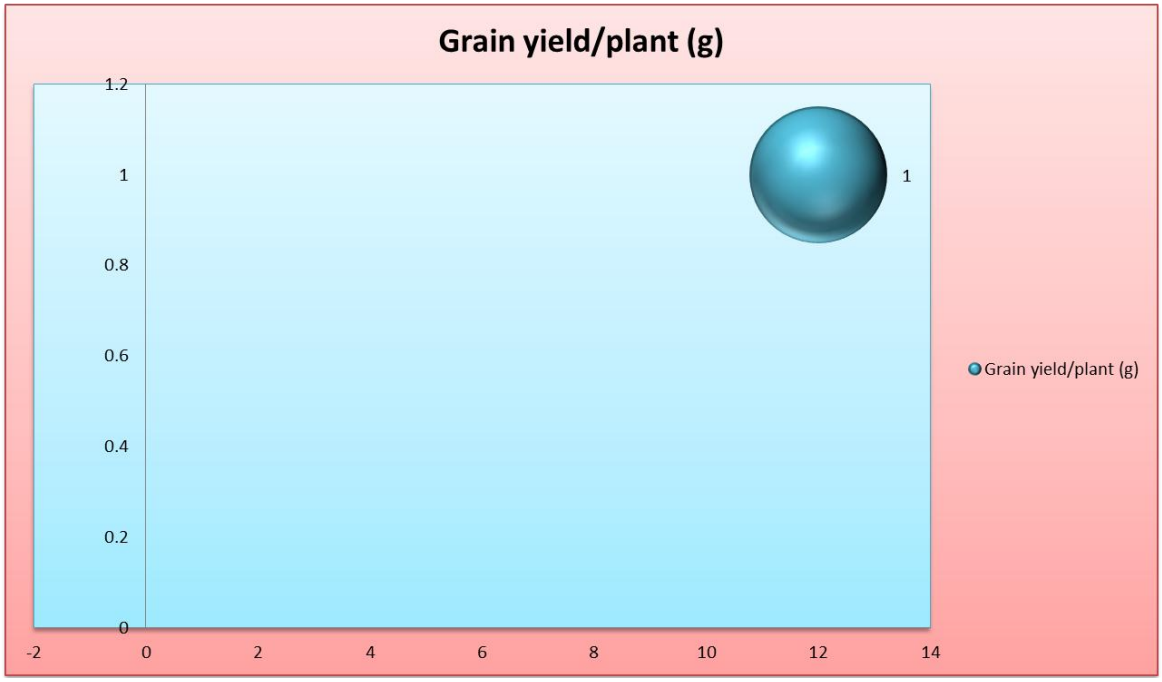

Fig 1.1: Graphical representation of phenotypic correlation coefficients between 12 characters of rice (*Oryza sativa* L.).

Table 2: Estimates of genotypic correlation coefficients between 12 characters of rice (*Oryza sativa* L.).

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle bearing tillers/plant	Panicle length (cm)	Spikelet/ panicle	Spikelet fertility (%)	1000-Grain Weight (g)	Biological yield/ plant (g)	Harvest index (%)	L/B ratio	Grain yield/ plant (g)
Days to 50% flowering	1.000	0.942	-0.326	-0.023	-0.388	0.075	-0.289	-0.219	-0.237	-0.309	-0.220	-0.255
Days to maturity		1.000	-0.310	-0.031	-0.393	0.126	-0.314	-0.248	-0.276	-0.352	-0.228	-0.305
Plant height (cm)			1.000	-0.229	0.131	0.068	0.745	0.651	0.692	0.645	0.626	0.618
Panicle bearing tillers/plant				1.000	0.108	0.089	-0.400	-0.405	-0.194	-0.376	-0.401	-0.161
Panicle length (cm)					1.000	0.000	0.251	0.268	0.235	0.357	0.243	0.335
Spikelets/panicle						1.000	-0.130	-0.177	-0.041	-0.195	-0.139	-0.105
Spikelet fertility							1.000	0.921	0.816	0.963	0.909	0.805

(%)												
1000-Grain Weight(g)								1.000	0.777	0.908	0.865	0.780
Biological yield/plant (g)									1.000	0.791	0.784	0.980
Harvest index (%)										1.000	0.888	0.834
L/B ratio											1.000	0.771
Grain yield/plant (g)												1.000

*, ** Significant at 5 % and 1 % probability levels, respectively.

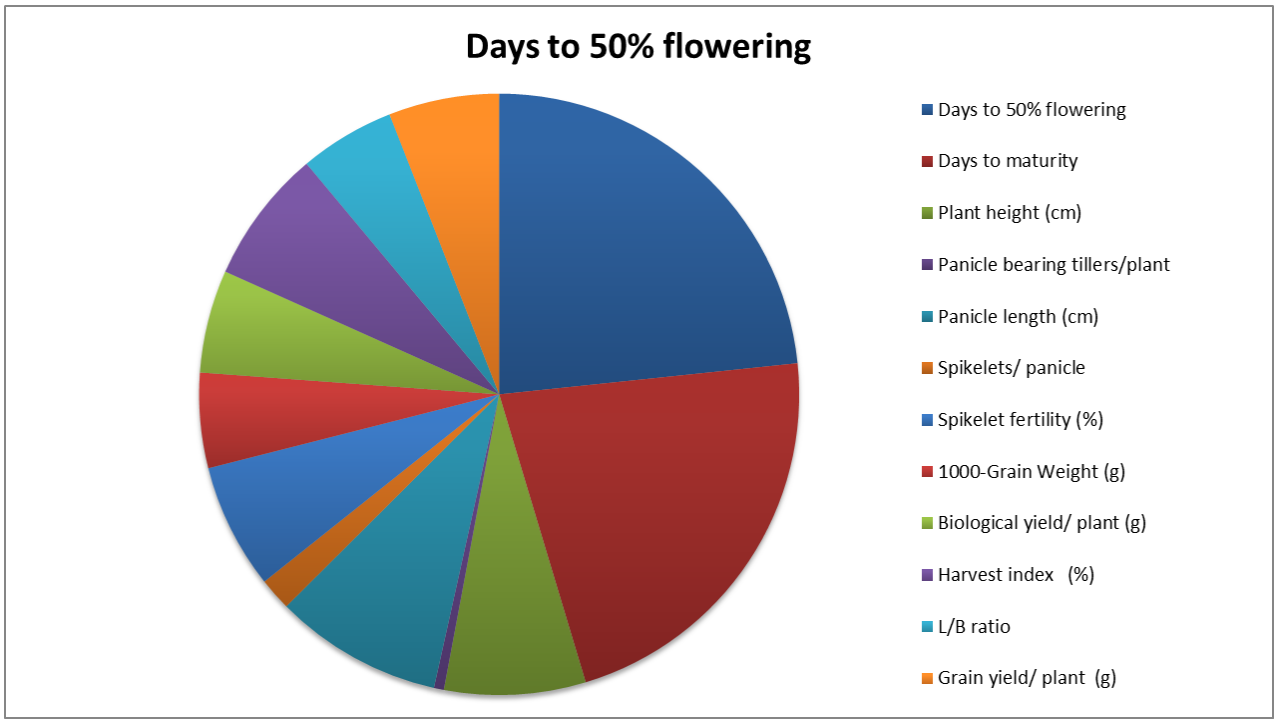

Fig 1.2: Graphical representation of genotypic correlation coefficients between 12 characters of rice (*Oryza sativa* L.).

Table 3: Direct (Bold diagonal figures) and indirect effects of different characters on grain yield per plant at phenotypic level in rice (*Oryza sativa* L.).

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle bearing tillers/plant	Panicle length (cm)	Spikelet /panicle	Spikelet fertility (%)	1000-Grain Weight (g)	Biological yield/ plant (g)	Harvest index (%)	L/B ratio	Grain yield/ plant (g)
Days to 50% flowering	0.003	0.002	-0.001	0.000	-0.001	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.248
Days to maturity	0.011	0.011	-0.003	0.000	-0.004	0.001	-0.004	-0.003	-0.003	-0.004	-0.003	-0.298
Plant height (cm)	0.012	0.011	-0.037	0.008	-0.004	-0.002	-0.027	-0.023	-0.025	-0.023	-0.023	0.600
Panicle bearing tillers/plant	-0.001	-0.001	-0.007	0.031	0.003	0.003	-0.012	-0.012	-0.006	-0.011	-0.012	-0.153
Panicle length (cm)	-0.015	-0.015	0.005	0.004	0.040	0.000	0.010	0.010	0.009	0.013	0.009	0.323
Spikelets/panicle	-0.001	-0.002	-0.001	-0.002	0.000	-0.018	0.002	0.003	0.001	0.003	0.002	-0.104
Spikelet fertility (%)	0.124	0.134	-0.316	0.169	-0.104	0.056	-0.432	-0.395	-0.345	-0.412	-0.389	0.793
1000-Grain Weight(g)	-0.004	-0.005	0.012	-0.007	0.005	-0.003	0.017	0.019	0.014	0.017	0.016	0.767
Biological yield/plant (g)	-0.212	-0.247	0.618	-0.167	0.210	-0.037	0.740	0.700	0.926	0.705	0.706	0.968
Harvest index (%)	-0.176	-0.200	0.364	-0.210	0.193	-0.111	0.550	0.515	0.439	0.577	0.505	0.815
L/B ratio	0.012	0.013	-0.034	0.022	-0.013	0.008	-0.050	-0.048	-0.043	-0.049	-0.056	0.755

R SQUARE = 1.0035 RESIDUAL EFFECT =SQRT (1-1.0035).

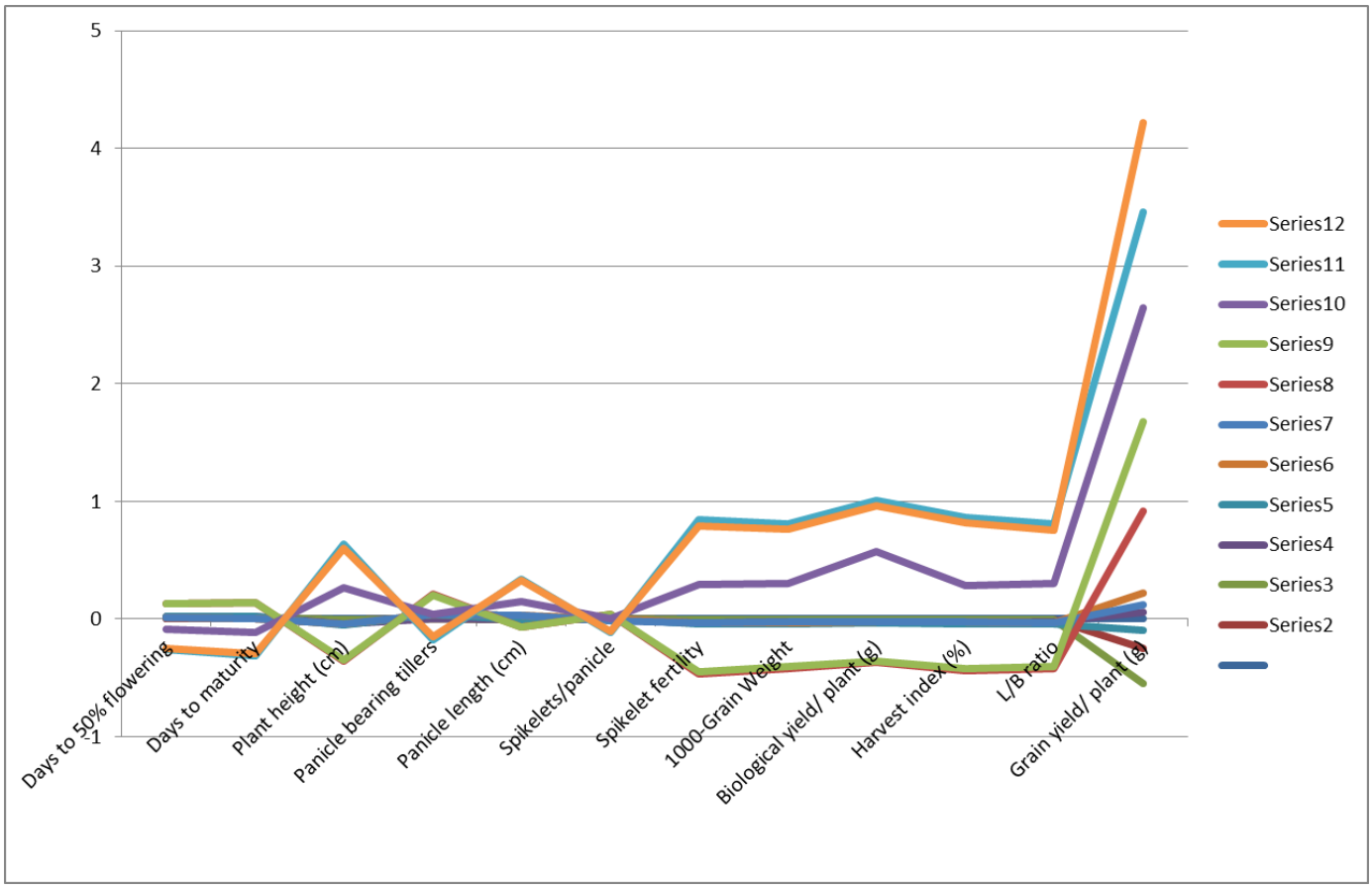

Fig 1.3: Graphical representation of Direct (Bold diagonal figures) and indirect effects of different characters on grain yield per plant at phenotypic level in rice (*Oryza sativa* L.)

Table 4: Direct (Bold diagonal figures) and indirect effects of different characters on grain yield per plant at genotypic level in rice (*Oryza sativa* L.).

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	Panicle bearing tillers /plant	Panicle length (cm)	Spikelet/ panicle	Spikelet fertility (%)	1000-Grain Weight (g)	Biological yield/ Plant (g)	Harvest index (%)	L/B ratio	Grain yield/ plant (g)
Days to 50% flowering	-0.033	-0.031	0.011	0.001	0.013	-0.002	0.009	0.007	0.008	0.010	0.007	-0.255
Days to maturity	0.046	0.049	-0.015	-0.002	-0.019	0.006	-0.015	-0.012	-0.014	-0.017	-0.011	-0.305
Plant height (cm)	0.011	0.011	-0.035	0.008	-0.005	-0.002	-0.026	-0.023	-0.024	-0.023	-0.022	0.618
Panicle bearing tillers/plant	-0.001	-0.001	-0.007	0.028	0.003	0.003	-0.011	-0.012	-0.006	-0.011	-0.011	-0.161
Panicle length (cm)	-0.010	-0.010	0.003	0.003	0.025	0.000	0.006	0.007	0.006	0.009	0.006	0.335
Spikelets/panicle	-0.001	-0.002	-0.001	-0.002	0.000	-0.017	0.002	0.003	0.001	0.003	0.002	-0.105
Spikelet fertility (%)	0.152	0.166	-0.393	0.211	-0.132	0.068	-0.527	-0.486	-0.430	-0.508	-0.479	0.805
1000-Grain Weight(g)	0.002	0.002	-0.006	0.004	-0.003	0.002	-0.009	-0.010	-0.008	-0.009	-0.008	0.880
Biological yield/plant (g)	-0.229	-0.267	0.670	-0.188	0.228	-0.040	0.790	0.752	0.968	0.766	0.759	0.980
Harvest index (%)	-0.210	-0.240	0.439	-0.256	0.243	-0.133	0.656	0.619	0.539	0.681	0.605	0.834
L/B ratio	0.017	0.017	-0.048	0.031	-0.019	0.011	-0.069	-0.066	-0.060	-0.068	-0.076	0.771

R SQUARE = 1.0035 RESIDUAL EFFECT =SQRT(1-1.0035).

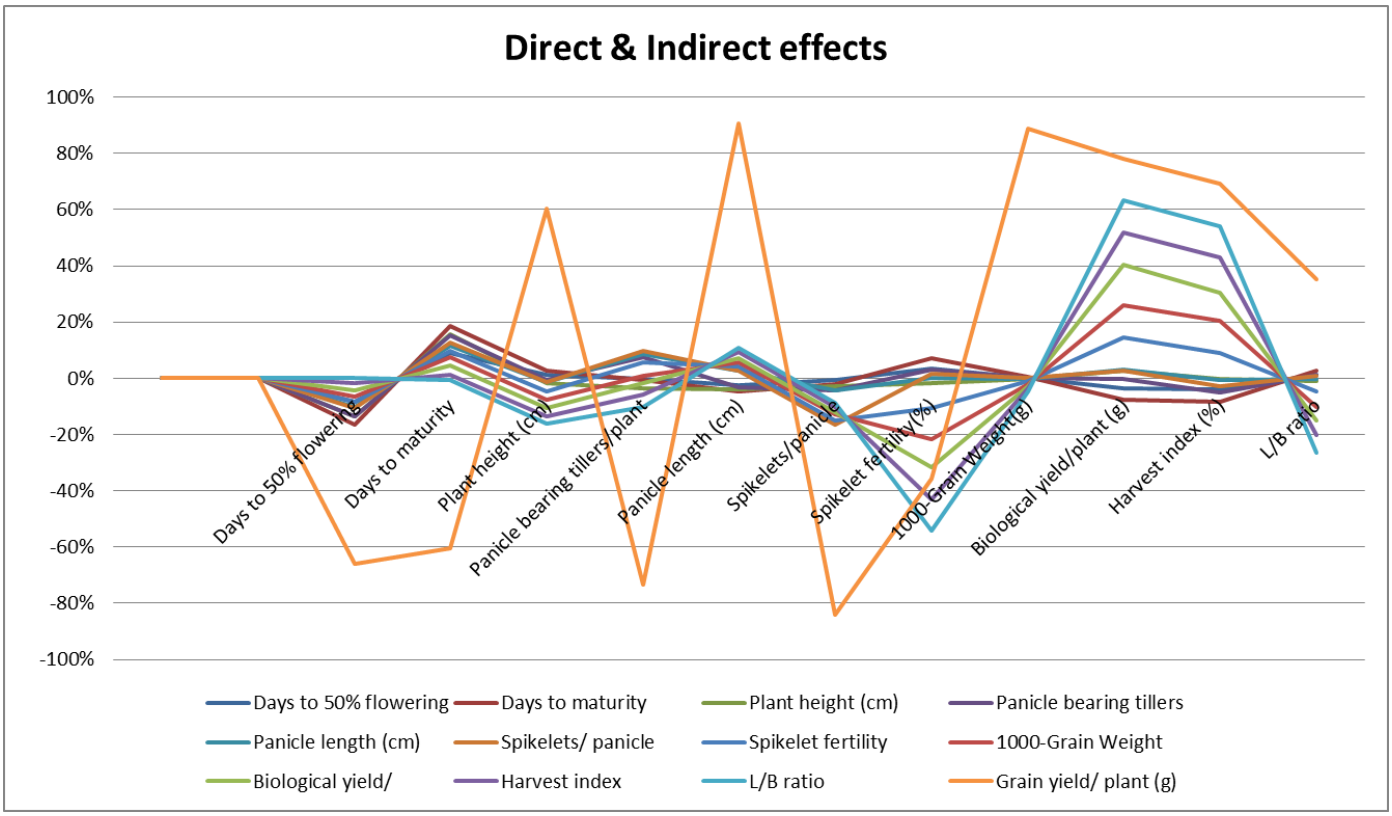

Fig 1.4: Direct (Bold diagonal figures) and indirect effects of different characters on grain yield per plant at genotypic level in rice (*Oryza sativa* L.).

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