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Research Article

Genetic variability, correlation and path analysis studies for yield and yield attributes in African rice *(Oryza glaberrima)* germplasm

V. G. Ishwarya Lakshmi[1,4], M. Sreedhar[2], C. Gireesh[1*] and S. Vanisri[3]

[1]ICAR-Indian Institute of Rice Research,
[2]MFPI-Quality control Lab, Department of Genetics and Plant Breeding, College of Agriculture,
[3]Department of Molecular Biology and Biotechnology, Institute of Biotechnology,
[4]Scholar, Department of Genetics and Plant Breeding, College of Agriculture, PJTSAU, Hyderabad- 500 030, India
***E-Mail:** giri09@gmail.com

Abstract
Thirty-one accessions of *Oryza glaberrima* were evaluated to study variability, correlation and path analysis for yield and yield attributing traits. Three checks namely, BPT 5204, IR 64 and Swarna for were utilized for comparison of variability parameters. High range of variation, PCV, GCV and high heritability coupled with high genetic advance was observed for days to 50 per cent flowering and the number of spikelets per panicle. Correlation revealed that the number of productive tillers per plant, panicle length, spikelets per panicle, 1000 seed weight, kernel length, and L/B ratio showed a positive association with grain yield. However, days to 50% flowering, plant height and kernel breadth were found to be negatively correlated. Path analysis identified L/B ratio, panicle length and kernel breadth, which had the maximum direct positive effect on grain yield, while, L/B ratio *via* kernel length and days to 50% flowering *via* 1000 seed weight exhibited high positive indirect effects on grain yield per plant. Therefore, the selection of accessions with more panicle length and early maturity would be most suitable for selection in yield improvement programs.

Keywords
Correlation, Path analysis, *Oryza glaberrima*

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for more than one-third of the world's population. Of the 24 species, 21 are wild and two species are cultivated, namely, *Oryza sativa and Oryza glaberrima. Oryza sativa* is the most extensively cultivated crop species in Asia, while, *Oryza glaberrima,* is endemic to Africa, which is known to possess many beneficial traits *viz.,* resistance to biotic, abiotic stresses (Fonfana and Cloutier, 2008), early seedling vigour, early maturity, genes to enhance milling, cooking, eating qualities of *indica* rice. In India, very few systematic efforts have been undertaken to utilize the wealth of African species for broadening the genetic base of *indica* rice varieties (Sarla and Swamy, 2005). The ultimate aim of plant breeders is to develop high yielding varieties with wide adaptability. Knowledge of the relationship between yield and its attributing traits is very much necessary for the selection process which can be explained by means of correlation and path coefficient analyses. Character association derived by the correlation coefficient, aids in the evaluation of the relative effect of various component traits on seed yield, while, path analysis explains whether the association of independent characters with the dependent variable is due to their direct effect or is a result of their indirect effect *via* some other traits. Hence, the

present nvestigation was carried out with the objective of studying the character associations in African rice (*O. glaberrima*) germplasm for yield improvement.

MATERIAL AND METHODS

Thirty-one accessions of *O. glaberrima* were sown in during *Kharif* 2017 at the ICAR-Indian Institute of Rice Research, Hyderabad. After twenty-one days, seedlings of each accession were transplanted by adopting a spacing of 20 cm between rows and 15 cm between plants in a Randomized Block Design with two replications. Observations were recorded on five randomly selected plants per replication for 10 characters *viz*., days to 50% flowering, plant height (cm), panicle length (cm), the number of productive tillers, the number of spikelets per panicle, 1000 grain weight (g), grain yield per plant (g), kernel length (mm), kernel width (mm) and L/B ratio. Correlation coefficients were calculated using the formulae suggested by Falconer (1964) and path analysis by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Thirty-one accessions of *O. glaberrima* along with three checks (*O. sativa*) namely BPT 5204, IR64 and Swarna were evaluated for grain yield and yield attributing traits and the means of the entries in two replications was also analyzed for the estimation of components of genetic variance.

Days to 50 percent flowering recorded a general mean value (**Table 1**) of 117.5 days ranging from 93 (EC 861816) to 148 days (EC 861791). The genotypic and phenotypic coefficients of variation estimates (**Table 2**) observed for days to 50% flowering were moderate *i.e*., 9.93% and 10.38%, respectively suggesting a moderate range of genetic variability. The observed heritability estimate for this character was high (91.49 %) with a high genetic advance (22.91) indicating the preponderance of high additive variance. So this trait can be further improved by simple selection.

Table 1. Mean performance of *O. glaberrima* accessions and checks (*O. sativa*) for yield and yield attributing traits

S.NO.	Accession No.	Days to 50% flowering	Plant height (cm)	Productive tillers	Panicle length (cm)	Spikelets/ Panicle	1000 seed weight (g)	Yield/ Plant (g)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	Grain type
1	EC 861784	126.0	127.0	12.0	26.7	110.0	15.9	8.2	7.2	2.6	2.7	MS
2	EC 861785	125.0	150.9	14.0	29.1	102.0	14.8	7.2	8.0	3.4	2.3	MS
3	EC 861786	139.0	138.8	14.0	24.2	110.0	13.7	8.1	7.8	2.7	2.8	MS
4	EC 861787	120.0	128.5	8.0	24.0	159.0	15.5	7.2	7.3	3.0	2.4	MS
5	EC 861790	137.0	122.2	14.0	27.0	119.0	16.3	9.7	8.3	3.0	2.7	MS
6	EC 861791	146.0	122.8	13.0	26.0	87.0	11.3	6.5	7.5	2.7	2.7	MS
7	EC 861792	126.0	132.9	14.0	23.4	107.0	14.6	7.1	8.7	2.8	3.0	MS
8	EC 861794	116.0	133.3	11.0	28.2	145.0	17.6	8.5	7.9	2.7	2.8	MS
9	EC 861795	119.0	144.6	9.0	23.3	120.0	18.7	9.7	9.0	3.0	3.0	MS
10	EC 861796	113.0	144.2	10.0	27.5	121.0	22.0	7.3	8.4	2.8	2.9	MS
11	EC 861797	123.0	122.7	8.0	25.4	113.0	17.6	9.0	7.4	2.9	2.5	MS
12	EC 861799	117.0	132.7	15.0	27.1	94.0	19.2	9.1	8.3	2.9	2.8	MS
13	EC 861801	121.0	136.9	7.0	27.3	98.0	16.2	9.1	8.2	3.1	2.6	MS
14	EC 861802	120.0	133.8	10.0	27.7	108.0	19.3	9.4	8.3	2.9	2.8	MS
15	EC 861803	114.0	140.6	13.0	23.8	84.0	15.8	8.3	8.2	2.7	3.0	MS
16	EC 861804	100.0	138.8	16.0	23.0	87.0	22.8	8.2	8.3	3.2	2.5	MS
17	EC 861805	140.0	140.1	9.0	24.4	80.0	12.1	6.5	8.3	3.2	2.5	MS
18	EC 861807	112.0	144.6	15.0	24.3	113.0	18.2	8.2	8.1	3.2	2.5	MS
19	EC 861808	114.0	130.7	14.0	23.3	118.0	18.4	7.9	8.5	3.0	2.8	MS
20	EC 861809	104.0	136.5	12.0	29.3	101.0	18.1	10.8	8.4	2.9	2.9	MS
21	EC 861810	116.0	118.0	12.0	24.2	138.0	19.2	8.9	8.7	3.0	2.9	MS
22	EC 861811	112.0	139.3	8.0	24.7	110.0	19.0	10.1	8.5	2.9	2.9	MS
23	EC 861812	111.0	124.3	10.0	22.6	110.0	22.1	7.1	8.0	3.0	2.6	MS
24	EC 861813	131.0	128.2	15.0	22.8	110.0	16.1	12.8	8.8	2.4	3.6	LS
25	EC 861814	109.0	138.2	7.0	24.4	102.0	20.7	7.9	8.5	2.8	2.9	MS
26	EC 861815	104.0	150.8	14.0	23.9	115.0	15.8	7.8	9.0	2.8	3.2	LS
27	EC 861816	86.0	117.3	7.0	23.0	117.0	19.8	7.8	8.5	2.8	3.0	MS
28	EC 861817	106.0	147.5	11.0	25.7	104.0	19.3	8.2	8.1	2.7	2.9	MS
29	EC 861818	109.0	155.2	7.0	23.6	126.0	17.9	8.3	8.2	2.8	2.8	MS
30	EC 861819	103.0	147.2	8.0	22.5	94.0	20.0	8.0	8.7	2.9	3.0	MS
31	EC 861820	118.0	152.0	13.0	27.2	91.0	19.8	6.8	9.2	2.9	3.1	LS
32	BPT 5204	111.0	89.0	16.0	21.5	214.0	14.2	13.5	7.43	2.1	3.3	LS
33	IR 64	106.0	99.0	18.0	23.8	197.0	22.0	10.7	9.39	2.4	3.9	LS
34	Swarna	113.0	97.7	18.0	22.5	220.0	15.0	15.8	7.52	2.42	3.1	LS

Table 2. Estimates of variability, heritability and genetic advance for yield and yield contributing traits

	Days to 50% Flowering	Plant height	No. of productive tillers/plant	Panicle length	No. of spikelets per panicle	1000 grain weight	Grain yield per plant	Kernel length	Kernel breadth	L/B ratio
MEAN	117.13	132.55	12.76	24.94	118.78	17.64	8.42	8.38	2.88	2.87
MIN	91	85.3	6.6	20.5	77.2	8.4	6.11	7.0	2.6	2.2
MAX	148	160.8	23.8	30.8	223.8	23.8	15.8	9.4	3.5	3.91
PCV	10.38	12.32	34.38	9.33	29.98	18.45	16.58	16.36	8.55	10.34
GCV	9.93	10.92	32.35	6.35	26.48	13.33	14.98	15.33	6.13	7.0
HERITABILITY	91.49	78.49	88.51	40.84	77.99	52.19	81.63	87.86	51.54	45.86
GA@5%	22.91	26.41	8.0	2.08	57.22	3.4	2.35	2.51	0.26	0.28

In the present investigation, the plant height exhibited a range from 89 cm (BPT 5204) to 155.2 cm (EC 861818) with an average of 132.56 cm. All the African rice accessions were taller than the checks. The GCV and PCV estimates observed for this trait were moderate *i.e*., 10.92% and 12.32%, respectively indicating the existence of moderate range of genetic variability. Heritability estimate for this character was also high (78.49 %) with high genetic advance (26.41), indicating a good scope for selection of plants with desirable height.

The panicle length recorded a range from 21.5 cm (BPT 5204) to 29.1 cm (EC 861785) with a general mean value of 25.1 cm. The accession EC 861785 had the highest panicle length (29.1 cm) compared to other accessions and checks, and therefore can be used as a donor parent in hybridization programs. The GCV and PCV for this trait were low i.e., 6.35% and 9.33%, respectively indicating the presence of narrow range of genetic variability. The heritability (40.84%) was moderate while the genetic advance (2.08) observed for this trait was low which indicated that selection for improvement might not be effective.

The average value for productive tillers was 10 with a range from 7 (EC 861814) to 18 (Swarna). The accession EC 861804 produced a higher number of productive tillers (16) similar to the checks, indicating its utility in yield improvement programs. The GCV and PCV for this trait were moderate (32.35% and 34.38%) suggesting moderate range of genetic variability. Though the heritability was high (88.51 %), low genetic advance (8.0) limits further improvement through direct selection.

The number of spikelets ranged from of 80.0 to 220.0 with a general mean value of 120.0. The accessions EC 861805 (80.0) and Swarna (220.0) found to have the lowest and the highest number of spikelets per panicle respectively. All the *O. glaberrima* accessions had a lesser number of spikelets per panicle compared to the checks. High GCV and PCV were observed for this trait (26.48 and 29.98) indicating the existence of wider genetic variability. The heritability estimates for this trait were high (77.99%) coupled with high genetic advance (57.22). Hence, directional selection could be effective for desired genetic improvement for this trait.

Test weight of grains had shown a very wide distinctness among the accessions as very low (<15 g) in four (EC 861785, EC 861786, EC 861791 and EC 861805), low (15-20 g) in 24 and medium (21-25g) in three accessions (EC 861796, EC 861804, EC 861814). The grain weight of evaluated accessions varied from 11.3 g (EC 861791) to 22.8 g (EC 861804). Moderate GCV (13.33%) and PCV (18.45%) were recorded with moderate heritability estimate of 52.19 coupled with low genetic advance (3.40) showing the presence of non-additive gene action governing the trait.

In the present study, the values for grain yield per plant ranged from 6.5 g (EC 861791) to 13.8 g (Swarna) with a general mean of 8.4 g. The African rice accessions showed much lesser yield as compared to the *indica* checks due to poor adaptability, lodging susceptibility and seed shattering. The accession EC 861813 having comparable yield (12.8 g) with the checks can be used as a parent in hybridization programs. Moderate GCV (14.98%) and PCV (16.58%) were observed for this trait suggesting moderate range of genetic variability. A high heritability estimate (81.63 %) coupled with low genetic advance (2.35) indicated that selection was very ineffective through direct selection for this trait.

With respect to length of the kernel, 26 accessions were short (6.1-8.5 mm) while the remaining eight accessions were of medium (8.6-10.5 mm) kernel length. Having a mean value of 8.38, it ranged from 7.0 mm (EC 861787) to 9.39 mm (IR 64). The magnitude of GCV (15.33) and PCV (16.36) was moderate suggesting the existence of moderate range of genetic variability. High heritability (87.86 %) coupled with low genetic advance (2.51) indicated that the character is highly influenced by environmental effects and selection would be ineffective.
In the present study, four accessions (EC 861813, BPT 5204, IR 64 and Swarna) were narrow (2.1-2.5 mm), 25 accessions were medium (2.6-3.0 mm), while five accessions (EC 861785, 861801, 861804, 861805 and 861807) were broad (3.1-3.5 mm). The GCV (6.13%) and PCV (8.55%) estimates were low pointing a narrow range of genetic variability. Moderate heritability (51.54 %) and low genetic advance (0.26) were recorded indicating the presence of non-additive gene action. The moderate heritability is exhibited due to favorable

influence of environment and selection for this trait may not be rewarding.

High amount of variability was observed for this character a lowest value of 2.3 (EC 861785) to a highest value of 3.9 (IR 64) with a mean of 2.87. Out of all the accessions studied, 28 accessions had medium slender grain (2.1-3.0) while the remaining six accessions (EC 861813, 861815, 861820, BPT 5204, IR 64 and Swarna) had a long slender type of grain (>3.0). The genotypic and phenotypic coefficients of variation for this trait were low (7.0 % and 10.34% respectively) suggesting a narrow range of genetic variability. Heritability estimates were moderate (45.86 %) coupled with low genetic advance (0.28), thus selection is presumed to be ineffective.

Table 3. Correlation coefficient analysis of yield and yield attributing traits in *O. glaberrima* accessions

Character	Days to 50% flowering	Plant height (cm)	No. of productive tillers	Panicle length (cm)	No. of spikelets per panicle	1000 grain weight (g)	Kernel length (mm)	Kernel breadth (mm)	L/B Ratio	Grain yield per Plant (g)
Days to 50% flowering	1.00000	-0.24359	0.07454	0.20995	-0.11484	-0.75117**	-0.33566	-0.06134	-0.16740	-0.04579
Plant height (cm)		1.00000	0.07430	0.08366	-0.25107	0.07946	0.34865	0.21022	0.07782	-0.16805
No. of productive tillers			1.00000	-0.02017	-0.24025	-0.02006	0.07820	0.12747	0.00096	0.09654
Panicle length (cm)				1.00000	-0.03953	-0.11416	-0.22410	0.13684	-0.26188	0.07534
No. of spikelets per panicle					1.00000	0.09624	-0.17851	-0.09916	-0.05582	0.12332
1000 grain weight (g)						1.00000	0.33015	0.13394	0.10080	0.13907
Kernel length (mm)							1.00000	0.03806	0.64959**	0.21855
Kernel breadth (mm)								1.00000	-0.72791**	-0.28294
L/B Ratio									1.00000	0.39711
Grain yield per plant (g)										1.00000

* Significant at 5 per cent level;

Character association is driven by the correlation coefficient, aids in the evaluation of the relative influence of various yield attributing traits on grain yield. In the present study, correlation analysis among yield and its attributing traits (**Table 3**) revealed the grain yield was positively correlated with the number of productive tillers (0.096), panicle length (0.075), spikelets per panicle (0.123), thousand seed weight (0.139), kernel length (0.218) and L/B ratio (0.397) indicating that these traits could be considered as a criteria of selection for higher grain yield, since they were mutually and directly associated with grain yield. The observed positive correlation of grain yield with these traits was supported by earlier workers *viz*., Madakemohekar *et al*. (2015) in rice (*O. sativa* L.). However, days to 50% flowering (-0.045), plant height (-0.168) and kernel breadth (-0.282) were found to be negatively correlated with a yield that would hinder the expression of the plant yield as reported by

Table 4. Phenotypic (P) and Genotypic (G) Path coefficient analysis of yield and yield attributing traits in *O. glaberrima*

Character		Days to 50% flowering	Plant height (cm)	No. of productive tillers	Panicle length (cm)	No. of spikelets per panicle	1000 seed weight (g)	Kernel length (mm)	Kernel breadth (mm)	L/B Ratio
Days to 50% flowering	P	**-0.0358**	0.0084	-0.0026	-0.0062	0.0022	0.8217	0.0105	0.0022	0.0052
	G	**-0.4081**	0.3649	-0.1057	-0.4048	0.2969	0.7894	0.5827	0.0892	0.2974
Plant height (cm)	P	0.0522	**-0.2220**	-0.0156	-0.0261	0.0433	-0.0062	-0.0688	-0.0467	-0.0123
	G	0.1801	**-0.6952**	-0.0562	-0.0073	0.2615	-0.1219	-0.2968	-0.1461	-0.0846
No. of productive tillers	P	-0.0004	-0.0003	**-0.0049**	-0.0001	0.0010	0.0010	-0.0002	-0.0005	0.0000
	G	-0.0020	-0.0021	**-0.0262**	0.0023	0.0087	0.0012	-0.0034	-0.0044	-0.0005
Panicle length (cm)	P	0.0399	0.0270	0.0043	**0.2296**	0.0070	-0.0007	-0.0523	0.0211	-0.0535
	G	0.0193	0.0007	-0.0060	**0.0672**	-0.0154	-0.0253	-0.0145	0.0165	-0.0230
No. of spikelets / panicle	P	-0.0027	-0.0084	-0.0085	0.0013	**0.0432**	0.0075	-0.0049	-0.0022	-0.0020
	G	0.0313	0.0558	0.0492	0.0341	**-0.1484**	0.0122	0.0505	0.0317	0.0121
1000 seed weight (g)	P	-0.0371	0.0017	-0.0002	-0.0002	0.0106	**0.0612**	0.0139	0.0017	0.0072
	G	0.3757	-0.2446	0.0629	0.5254	0.1145	**-0.3942**	-0.7641	-0.4870	-0.0908
Kernel length (mm)	P	0.5190	-0.5467	-0.0829	0.4015	0.1986	-0.4015	**-0.7638**	-0.0479	-0.5152
	G	0.1828	-0.1885	-0.0574	0.0955	0.1503	-0.2420	**-0.4416**	-0.0272	-0.2787
Kernel breadth (mm)	P	-0.1273	0.4375	0.2142	0.1910	-0.1048	0.0579	0.0564	**0.70784**	-0.5152
	G	-0.0864	0.2867	0.2288	0.3345	-0.2917	0.4764	0.0840	**0.5640**	-0.9211
	P	-0.4458	0.1707	-0.0258	-0.7174	-0.1399	0.3600	0.9211	-0.7438	**0.9778**
L/B Ratio	G	-0.3477	0.2003	0.0283	-0.5637	-0.1345	0.1072	0.8388	-0.5974	**0.6462**
Yield per plant (g)	P	-0.0379	-0.1321	0.0781	0.0733	0.0611	0.0999	0.2121	-0.2376	0.3490
	G	-0.0549	-0.2220	0.1178	0.0832	0.2418	0.2030	0.2356	-0.3607	0.4861

BOLD values are direct effects

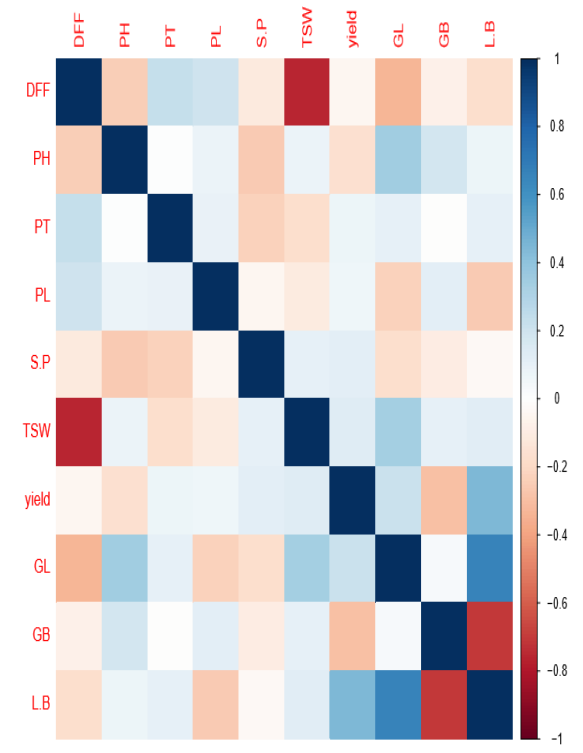

Fig. 1. Correlogram visualizing the correlation in yield and its attributing traits in O. glaberrima accessions

Anil Kumar *et al*. (2015). Hence, selecting the accessions with early maturity reduced plant height, and less kernel breadth would be rewarding. Correlogram (**Fig. 1**) depicted a strong correlation between L/B ratio and grain length, while no correlation between plant height and panicle length, grain length and grain breadth, grain breadth and productive tillers, L/B ratio and spikelets per panicle was observed. The yield per plant had a moderate correlation with L/B ratio, spikelets per panicle, kernel length and 1000 seed weight, while less correlation with kernel breadth.

Path coefficient analysis allows the separation of the correlation coefficients into direct as well as indirect effects. L/B ratio (0.977) exerted the highest direct positive effect on grain yield per plant followed by kernel breadth (0.707) and panicle length (0.229), indicating that selection for these characters is likely to bring about on overall improvement in grain yield directly (**Table 4, Fig. 2**). These findings were also corroborated by Sala *et al*. (2015) in rice (*O. sativa* L.). The direct effects of other seven characters were too low to be considered of any consequence. Although the number of productive tillers per plant (-0.004) had a negative direct effect on grain yield, its indirect effect through the number of spikelets per panicle (0.001) and 1000 seed weight was positive (0.001). The high positive indirect effects on grain yield per plant were of L/B ratio *via* kernel length (0.9211) followed by days to 50% flowering *via* 1000 seed weight (0.821). Thus, indirect selection for these traits would be beneficial in enhancing the yield potential of rice varieties.

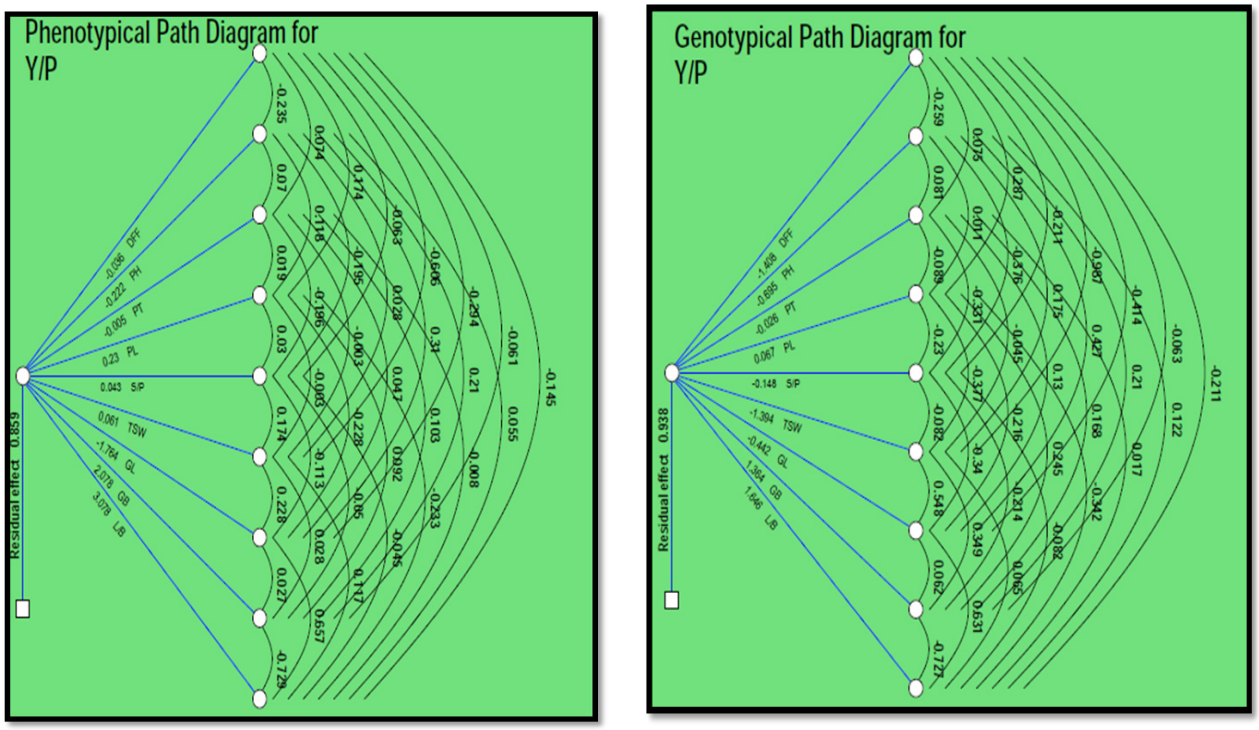

Fig. 2. Phenotypic and Genotypic path diagram for Grain yield per plant in Oryza glaberrima accessions

The present study revealed a high range of variation and high heritability coupled with high genetic advance was recorded for days to 50 per cent flowering and for the number of spikelets per panicle. The overall study reveals the presence of a broad genetic base, less environmental influence and additive gene action for the traits studied. Hence, simple and early generation selection of promising lines from present gene pool would be effective for future gene introgression programs. Direct positive associations between yield per plant and productive tillers, panicle length and L/B ratio, selection for which would be effective to enhance the yield potential. Also, L/B ratio *via* kernel length and days to 50% flowering *via* 1000 seed weight exhibited high positive indirect effects. Therefore, these characters would be most suitable for indirect selection of yield in rice improvement programs.

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