International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 24-09-2021, Accepted: 08-10-2021, Published: 25-10-2021
Volume 6, Issue 5, 2021, Page No. 1399-1404

Genetic variability and association analysis in rice (*Oryza sativa* l.)

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Abstract
Twenty eight rice genotypes including one check variety were evaluated for yield and yield contributing characters to study genetic variability, heritability, genetic advance, association and direct and indirect effects on yield during *Kharif*-2020 for 13 quantitative characters. High estimates of GCV and PCV were recorded for tillers per hill followed by panicles per hill, test weight and biological yield. Grain yield per plant was positively and significantly associated with plant height, tillers per hill, panicles per hill, panicle length, flag leaf length, flag leaf width, spikelets per panicle, biological yield, harvest index and test weight at both genotypic and phenotypic levels. Path coefficient analysis revealed positive direct effect of tillers per hill, panicles per hill, flag leaf length, spikelets per panicle, days to maturity, biological yield, harvest index and test weight with grain yield per plant at both phenotypic and genotypic level. Genetic variability, correlation, path analysis revealed that panicles per hill, test weight and biological yield are most important yield components in rice.
Thus, these traits are identified as the efficient and potential should be given for the selection of genotypes for the improvement of rice productivity.

Keywords: rice, genetic variability, GCV, PCV, correlation and path analysis

Introduction
Rice is one of the world's most important food crops, feeds more than half of the world's population. Rice (*Oryza sativa* L.) is one of the most important staple cereal food crop in the world and belongs to the genus *Oryza* of family Graminae (Poaceae). It meets the calorie requirement of 50 percent of the population and provides livelihood to 160 million of rural poor. (Santha *et al.* 2016) [18]. 'Rice is life' was the theme of International year of rice 2004 denoting its overwhelming importance as an item of food and commerce (Pandey *et al.*, 2010) [16]. As the land frontiers for many countries have been exhausted, diversification of land to other crops is taking place due to higher returns and consumer demand, and more land is being diverted for non-agricultural purposes, the growth in many countries has to come from increase in productivity of arable land. Thus, it is understood that there is an extreme need to enhance the rice productivity which will be achieved only by developing high yielding varieties. In the context, the present investigation was undertaken to elucidate information on variability, heritability, genetic advance as percent of mean, character association in rice germination traits towards formulation of successful breeding programmes for high yielding potential aimed at the development of rice varieties during germination.

Materials and Methods
Twenty eight rice genotypes and one check variety were evaluated at Department of Genetics and Plant Breeding, SHUATS during *kharif*-2020 using Randomized Block Design (RBD) with three replications. Fertilizers doses N: P: K @ 120:60:60 kg/ha were applied. The full dose of P2O5 and K2O and half dose of nitrogen were applied as basal dose at the time of transplanting. The rest of the nitrogen was top dressed in two split doses at the time of maximum tillering state i.e. 30 days after the transplanting and between panicle initiation and boot leaf stage i.e. 55 days after transplanting. Observations were recorded on plot basis for days to 50% flowering, days to physiological maturity and grain yield per plant. For rest of the characters (Plant height, Number of tillers per hill, Number of panicles per hill, Panicle length, Flag leaf length, Flag leaf width, Number of spikelets per panicle, Number of filled grains per panicle, Number of unfilled grains per panicle, Biological yield per plant, Harvest index, Test weight) the data was recorded on five randomly selected plants from each genotype in each replication leaving first two border rows from all the four sides in order to avoid sampling error. Yields were taken from whole plot crop cutting and converted it to ton per hectare. Genotypic variance (V_G or σ^2g), phenotypic variance (V_P or σ^2p), GCV and PCV by Sivasubramanian and Menon (1973), Heritability in broad sense (h^2) Burton and De Vane (1953) [4], Genetic advance Lush (1949) [14] and Johnson *et al.*(1955) [10], Genetic advance as percent of mean (GA % M) Johnson *et al.* (1955) [10].

Results and Discussion
Genotypic variance, phenotypic variance, GCV and PCV, Heritability in broad sense (h^2)**,** Genetic advance, Genetic advance as percent of mean (GA % M) are presented in Table 1. High estimates of GCV and PCV were recorded for tillers per hill followed by panicles per hill, test weight and biological yield. High phenotypic variations for these traits were noticed to be composed of high genotypic variations and less of environmental variations, indicating the presence of high genotypic variability. Hence selection on the basis of phenotypic alone can be effective for improvement of these traits. Similar results were reported earlier by Ravindra *et al.* (2012) [17].

The highest heritability was observed for biological yield followed by, days to 50% flowering, harvest index, flag leaf width, grain yield per plant, panicle length, panicles per hill, flag leaf length, days to maturity, Test weight, plant height and spikelets per panicle respectively. Knowledge of heritability of a character is important as it indicates the possibility and extent to which the improvement is possible through selection. It is a measure of relationship between parent and progeny and has been widely used to assess the degree to which a character may be transmitted from parent to progeny. Similar results are reported by Kishore *et al.* (2015) [13]. In the present study, high genetic advance (above 20%) was observed for spikelets per panicle (56.37%) and plant height (31.68%), biological yield (23.79%). Similar results are reported by Dinesh *et al.* (2014) for both characters. Highest estimates of genetic advance as per cent mean was recorded for panicles per hill followed by, tillers per hill, test weight, biological yield, flag leaf length, grain yield per plant, flag leaf width, spikelets per panicle. Similar results are reported by Kishore *et al.* (2015) [13], Dinesh *et al.* (2014), Shiva *et al.* (2018) [19] for test weight, grain yield per plant.

Character association

In the present investigation, correlation coefficient analysis measures the mutual relationship between various plant characters and to determine the component characters on which selection can be used for genetic improvement in yield while selecting the suitable plant type. Grain yield per plant was positively and significantly associated with plant height, tillers per hill, panicles per hill, panicle length, flag leaf length, flag leaf width, spikelets per panicle, biological yield, harvest index and test weight at both genotypic and phenotypic levels. Similar results are reported by Shiva *et al.* (2018) [19], Abdul *et al.* (2011) [1] for test weight, harvest index, no. of spikelet /panicle. The path coefficient analysis is the standardized partial regression coefficient, which splits the correlation coefficient in to the measures of direct and indirect effect of independent variables on the dependent variable. This approach is more important to comprehend genetic makeup of a dependent trait when the determining component characters are correlated. Path coefficient analysis revealed positive direct effect of tillers per hill, panicles per hill, flag leaf length, spikelets per panicle, days to maturity, biological yield, harvest index and test weight with grain yield per plant at both phenotypic and genotypic level. Similar results are reported by Abdul *et al.* (2011) [1] for plant height, flag leaf length, panicle length, biological yield, harvest index, test weight: Kishore *et al.* (2015) [13] no. of tillers /hill, no. of panicles/hill, panicle length respectively.

Conclusion

Number of tillers per hill character had recorded with high estimates of GCV and PCV. All the characters under study showed high heritability coupled with high values of genetic advance as percent mean (except days to maturity and number of total tillers per hill). At both genotypic and phenotypic levels, significant positive correlations were observed for grain yield per plant with biological yield per plant, number of effective tillers per hill, number of tillers per hill, flag leaf length, flag leaf width, harvest index, number of grains per panicle and panicle length. The results of the path coefficient analysis revealed that both phenotypic and genotypic levels, number of panicles per hill, number of total tillers per hill, number of grains per panicle, flag leaf length, biological yield per plant, days to maturity, test weight and harvest index had positive direct effects on grain yield per plant. Hence number of tillers per hill, panicles per hill and test weight based on these traits are best for selection for future hybridization. Selection of plants on these traits would certainly lead to improvement in grain yield.

Acknowledgement

The authors are thankful to Head of the department of Genetics and Plant Breeding, and authorities of Sam Higginbottom University of Agriculture, Technology and Sciences for providing the necessary facilities to carryout this work.

Table 1: Estimation of variability and genetic parameters for 13 quantitative characters in rice germplasm for *kharif* -2020

S. no	Character	GCV	PCV	h2 (bs) (%)	GA	GA as % mean
1.	Days to 50% flowering	8.587	8.587	99.998	17.292	17.69
2.	Plant height(cm)	11.736	11.739	99.951	31.683	24.17
3.	Number of tillers/ hill	57.753	119.511	23.353	5.994	57.493
4.	Number of panicles hill	29.075	29.078	99.978	4.918	59.888
5.	Panicle length (cm)	12.035	12.036	99.986	6.704	24.79
6.	Flag leaf length(cm)	19.16	19.169	99.907	16.309	39.452
7.	Flag leaf width(cm)	17.425	17.693	96.987	0.473	35.35
8.	No. of spikelet panicle	18.224	21.656	70.82	56.377	31.593
9.	Days to maturity	6.429	6.435	99.804	16.878	13.231
10.	Biological yield(gm)	23.093	23.093	100	23.797	47.571
11.	Harvest index (%)	9.076	9.077	99.99	8.004	18.697
12.	Test weight (g)	24.06	24.111	99.575	10.303	49.459
13.	Seed yield per hill(g)	17.528	17.529	99.986	7.656	36.105

Vg = Genotypic variance. V p = Phenotypic variance. h^2 = Heritability, GCV = Genotypic coefficient of variation, PCV= Phenotypic coefficient of variation

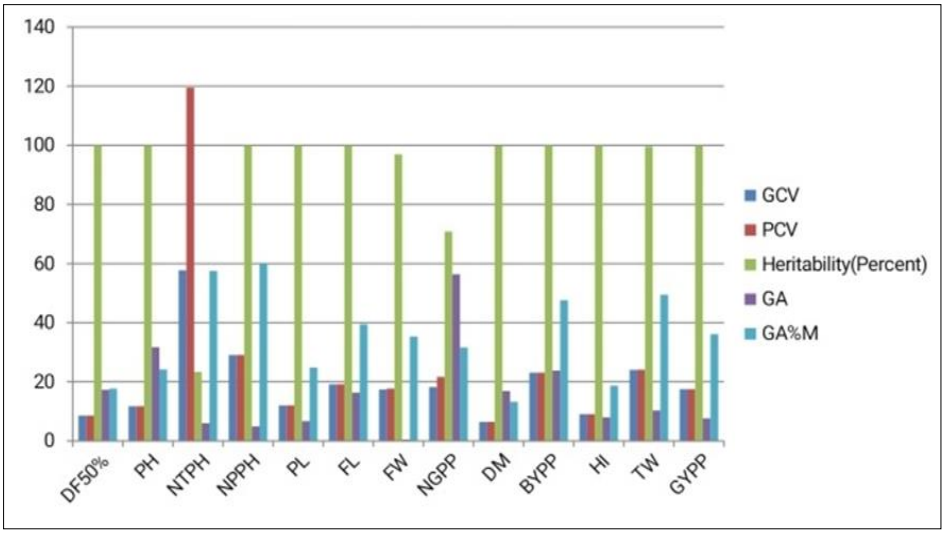

Fig 1: Histogram depicting GCV, PCV, Genetic advance and h^2 for 13 quantitative characters of rice genotype.

Table 2: Phenotypic correlation coefficient for yield and its related traits in 28 rice genotypes.

Characters	DF	PH	NTPP	NPPP	PL	FL	FW	NGPP	DM	BYPP	HI	TW	GYPP
DF	1	0.251*	-0.004^{NS}	0.037^{NS}	-0.068^{NS}	0.164^{NS}	-0.192^{NS}	0.281**	0.984**	-0.058^{NS}	-0.282**	-0.249*	-0.141^{NS}
PH		1	-0.287**	-0.504**	0.317**	0.608**	0.045^{NS}	-0.190^{NS}	0.239*	0.213^{NS}	-0.163^{NS}	-0.118^{NS}	0.166^{NS}
NTPP			1	0.596**	0.265*	-0.048^{NS}	0.340**	0.163^{NS}	0.032^{NS}	-0.059^{NS}	0.137^{NS}	0.289**	0.023**
NPPP				1	0.131^{NS}	-0.227*	0.143^{NS}	0.192^{NS}	0.061^{NS}	-0.318**	0.334**	0.453**	0.155**
PL					1	0.610**	0.360**	-0.161^{NS}	0.010^{NS}	0.191^{NS}	-0.063^{NS}	0.521**	0.287**
FL						1	0.281**	-0.157^{NS}	0.222*	0.509**	-0.348**	-0.035^{NS}	0.659**
FW							1	0.040^{NS}	-0.165^{NS}	0.384**	-0.102^{NS}	0.081^{NS}	0.387**
NGPP								1	0.301**	-0.277*	0.197^{NS}	-0.052^{NS}	0.223*
DM									1	-0.035^{NS}	-0.317**	-0.201^{NS}	-0.095^{NS}
BYPP										1	-0.684**	-0.239*	0.895**
HI											1	0.337**	0.487**
TW												1	0.098**
GYPP													1

DF: Days to 50% flowering, DM: Days to maturity, FL: Flag leaf length (cm),FW: Flag leaf width (cm), PH: Plant height (cm), TT: Number of total tillers per hill, ET: Number of effective tillers per hill, PL: Panicle length (cm), NGPP: Number of grains per panicle,, BYP: Biological yield per plant (g), TW: Test weight (g), HI: Harvest index (%), GYPP: Grain yield per plant (g). ** and * indicates significance at 1% and 5% level of significance respectively

Table 3: Genotypic correlation coefficient for yield and its related traits in 28 rice genotypes.

Character	DF	PH	NTPP	NPPP	PL	FL	FW	NGPP	DM	BYPP	HI	TW	GYPP
DF	1	0.251*	-0.008NS	0.037NS	-0.068NS	0.164NS	-0.195NS	0.334**	0.985**	-0.058NS	-0.282**	-0.249*	-0.141NS
PH		1	-0.596**	-0.504**	0.317**	0.608**	0.046NS	-0.225*	0.239*	0.213NS	-0.163NS	-0.118NS	0.166NS
NTPP			1	1.234**	0.549**	-0.049NS	0.704**	0.320**	0.061NS	-0.123NS	0.283**	0.603**	0.048**
NPPP				1	0.131NS	-0.227*	0.145NS	0.230*	0.061NS	-0.318**	0.334**	0.454**	0.155**
PL					1	0.610**	0.365**	-0.189NS	0.010NS	0.191NS	-0.064NS	0.522**	0.287**
FL						1	0.286**	-0.185NS	0.222*	0.509**	-0.348**	-0.035NS	0.659**
FW							1	0.054NS	-0.168NS	0.390**	-0.103NS	0.083NS	0.395**
NGPP								1	0.361**	-0.329**	0.234*	-0.065NS	0.266*
DM									1	-0.035NS	-0.317**	-0.201NS	-0.095NS
BYPP										1	-0.684**	-0.239*	0.895**
HI											1	0.338**	0.487**
TW												1	-0.098NS
GYPP													1

DF: Days to 50% flowering, DM: Days to maturity, FL: Flag leaf length (cm),FW: Flag leaf width (cm), PH: Plant height (cm), TT: Number of total tillers per hill, ET: Number of effective tillers per hill, PL: Panicle length (cm), NGPP: Number of grains per panicle,, BYP: Biological yield per plant (g), TW: Test weight (g), HI: Harvest index (%), GYPP: Grain yield per plant (g).
** and * indicates significance at 1% and 5% level of significance respectively

Table 4: Direct and indirect effects of yield related traits on grain yield in 28 rice genotypes at phenotypic level.

Characters	DF50%	PH	NTPP	NPPP	PL	FL	FW	NGPP	DM	BYPP	HI	TW
DF50%	-0.3737	-0.094	0.002	-0.0137	0.0254	-0.0615	0.0727	-0.1169	-0.368	0.0218	0.1055	0.0931
PH	-0.0413	-0.1641	0.0675	0.0827	-0.052	-0.0998	-0.0075	0.0346	-0.0392	-0.035	0.0267	0.0194
NTPP	0	-0.0021	0.0052	0.0045	0.002	-0.0002	0.0025	0.0012	0.0002	-0.0004	0.001	0.0022
NPPP	0.0033	-0.0458	0.0774	0.0908	0.0119	-0.0207	0.0131	0.0195	0.0055	-0.0289	0.0303	0.0412

PL	0.0152	-0.0708	-0.0848	-0.0294	-0.2234	-0.1363	-0.0812	0.0397	-0.0022	-0.0426	0.0142	-0.1165
FL	0.0904	0.3342	-0.0249	-0.1249	0.3353	0.5496	0.1563	-0.0954	0.1222	0.2799	-0.1912	-0.0193
FW	0.0091	-0.0021	-0.0228	-0.0068	-0.0171	-0.0134	-0.0469	-0.0023	0.0078	-0.0182	0.0048	-0.0039
NGPP	0.0044	-0.0029	0.0031	0.003	-0.0025	-0.0024	0.0007	0.0139	0.0047	-0.0043	0.0031	-0.0008
DM	0.2745	0.0666	0.0121	0.0169	0.0027	0.062	-0.0465	0.0941	0.2787	-0.0099	-0.0883	-0.0561
BYPP	-0.051	0.1863	-0.0741	-0.2778	0.1665	0.4448	0.3393	-0.2697	-0.0309	0.8735	-0.5974	-0.2089
HI	-0.0488	-0.0281	0.0338	0.0577	-0.011	-0.0602	-0.0178	0.0379	-0.0548	-0.1182	0.1729	0.0584
TW	-0.0233	-0.011	0.0388	0.0424	0.0487	-0.0033	0.0077	-0.0056	-0.0188	-0.0223	0.0315	0.0934
GYPP	-0.1411	0.1661	0.0333	-0.1546	0.2867	0.6588	0.3924	-0.2489	-0.0946	0.8954	-0.487	-0.0978
Partial R^2	0.0527	-0.0273	0.0002	-0.014	-0.064	0.3621	-0.0184	-0.0035	-0.0264	0.7821	-0.0842	-0.0091

DF: Days to 50% flowering, DM: Days to maturity, FL: Flag leaf length (cm),FW: Flag leaf width (cm), PH: Plant height (cm), TT: Number of total tillers per hill, ET: Number of effective tillers per hill, PL: Panicle length (cm), NGPP: Number of grains per panicle, BYP: Biological yield per plant (g), TW: Test weight (g), HI: Harvest index (%), GYPP: Grain yield per plant (g).

Residual Effect – 0.223

Table 5: Direct and indirect effects of yield component traits on grain yield for 28 rice genotypes at Genotypic level.

Characters	DF50%	PH	NTPP	NPPP	PL	FL	FW	NGPP	DM	BYPP	HI	TW
DF50%	-0.3794	-0.0954	0.0029	-0.0139	0.0258	-0.0624	0.0742	-0.1266	-0.3738	0.0221	0.1071	0.0946
PH	-0.0408	-0.1623	0.0967	0.0818	-0.0515	-0.0987	-0.0075	0.0365	-0.0388	-0.0346	0.0264	0.0192
NTPP	-0.0001	-0.0051	0.0086	0.0106	0.0047	-0.0004	0.006	0.0027	0.0005	-0.001	0.0024	0.0052
NPPP	0.0031	-0.0432	0.1058	0.0858	0.0113	-0.0195	0.0125	0.0197	0.0052	-0.0273	0.0286	0.0389
PL	0.0154	-0.0718	-0.1243	-0.0298	-0.2264	-0.1382	-0.0827	0.0428	-0.0022	-0.0432	0.0144	-0.1182
FL	0.0905	0.3348	-0.0271	-0.1251	0.3359	0.5504	0.1574	-0.1016	0.1224	0.2803	-0.1916	-0.0194
FW	0.0096	-0.0023	-0.0347	-0.0071	-0.018	-0.0141	-0.0492	-0.0027	0.0083	-0.0192	0.0051	-0.0041
NGPP	0.0049	-0.0033	0.0047	0.0034	-0.0028	-0.0027	0.0008	0.0147	0.0053	-0.0048	0.0034	-0.0009
DM	0.2787	0.0676	0.0173	0.0172	0.0028	0.0629	-0.0475	0.1022	0.2829	-0.01	-0.0896	-0.057
BYPP	-0.051	0.1863	-0.1072	-0.2778	0.1665	0.4449	0.3411	-0.2876	-0.0309	0.8735	-0.5974	-0.209
HI	-0.0486	-0.028	0.0486	0.0575	-0.0109	-0.0599	-0.0178	0.0403	-0.0546	-0.1178	0.1722	0.0582
TW	-0.0236	-0.0112	0.0571	0.043	0.0494	-0.0033	0.0078	-0.0061	-0.0191	-0.0226	0.032	0.0946
GYPP	-0.1411	0.1661	0.0484	-0.1546	0.2867	0.6589	0.395	-0.2657	-0.0946	0.8954	-0.487	-0.0978
Partial R^2	0.0536	-0.027	0.0004	-0.0133	-0.0649	0.3626	-0.0195	-0.0039	-0.0268	0.7821	-0.0839	-0.0093

DF: Days to 50% flowering, DM: Days to maturity, FL: Flag leaf length (cm),FW: Flag leaf width (cm), PH: Plant height (cm), TT: Number of total tillers per hill, ET: Number of effective tillers per hill, PL: Panicle length (cm), NGPP: Number of grains per panicle, BYP: Biological yield per plant (g), TW: Test weight (g), HI: Harvest index (%), GYPP: Grain yield per plant (g). Residual Effect – 0.223

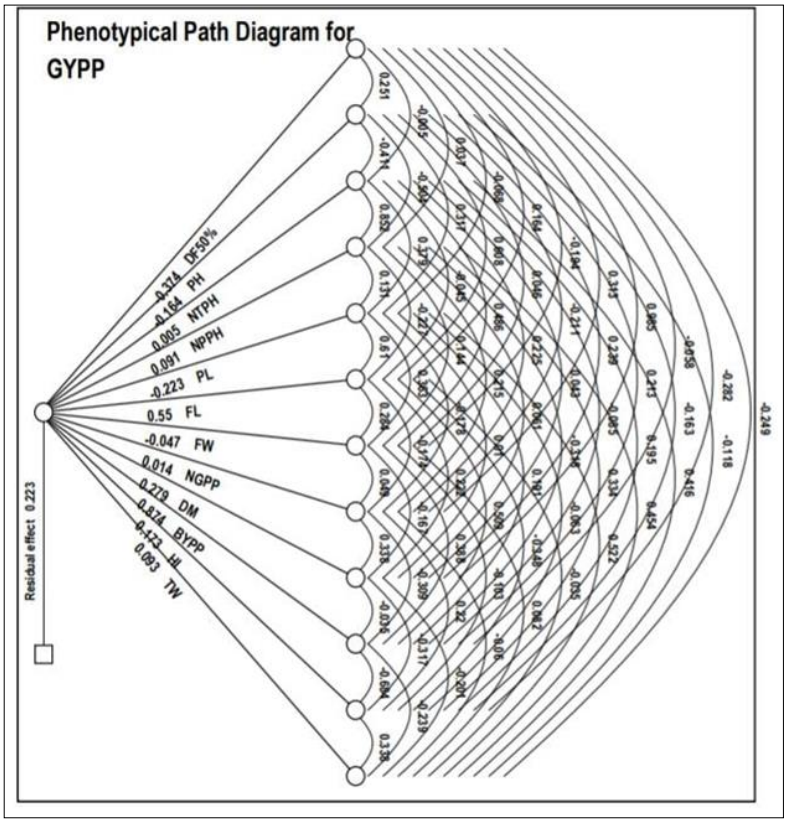

Fig 2: Phenotypic path diagram for grain yield (g)

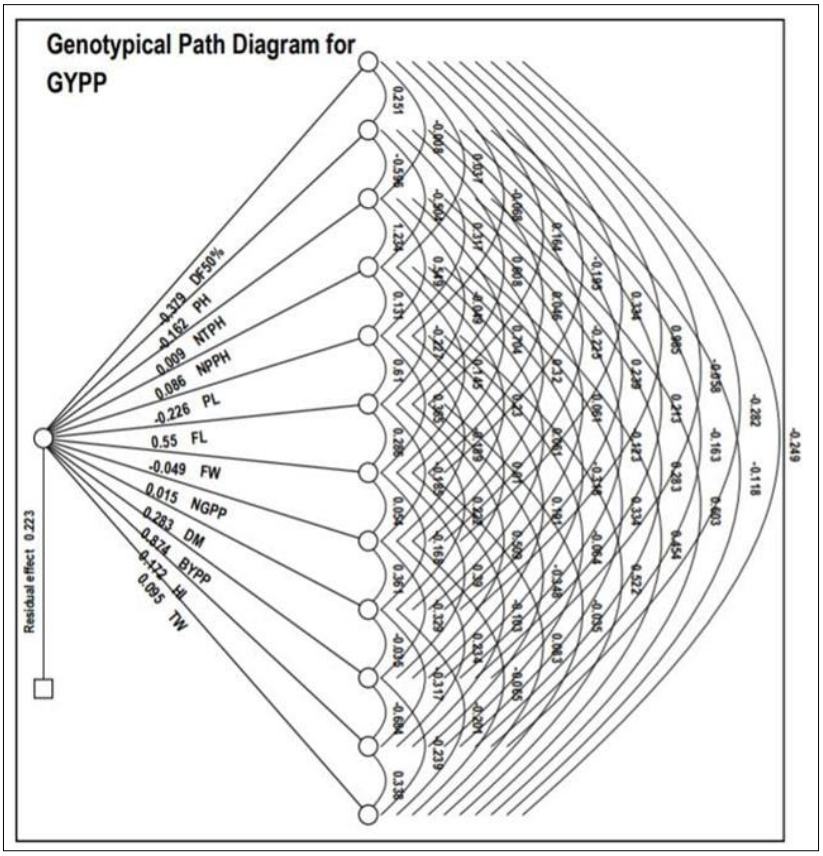

Fig 3: Genotypic path diagram for grain yield (g)

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