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Genetic Association and Path Coefficient Analysis in rice (*Oryza sativa* L.) Genotype

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Abstract: ***The experiment was conducted in a Randomized Block Design with three replications during the Kharif season 2023 at Field experimentation centre, Department of Genetics and Plant Breeding, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Naini, Prayagraj, U.P. the plant-to-plant distance was 20 cm and row to row distance was 15 cm. The data were recorded from randomly selected five plants for each genotypes for each replications for thirteen characters viz. days to 50% flowering, days to maturity, plant height (cm), flag leaf length (cm), flag leaf width (cm), number of tillers per hill, number of panicles per hill, panicle length (cm), spikelets per panicle, biomass (g), harvest index (%), test weight (g), and grain yield per hill (g). From the present investigation, it is concluded that analysis of variance showed significant variation among different genotypes for all characters studied. Positive and significant correlation was observed for plant height, flag leaf length, flag leaf width, spikelets per panicle, biomass, test weight and harvest index with grain yield per hill at genotypic and phenotypic levels. Days to maturity, number of panicles per hill, biomass, harvest index, test weight and flag leaf width exhibited direct positive effect at phenotypic level. This indicated that grain yield was mainly a product of direct and indirect effects of the above attributing characters and priority should be given to these characters during selection for improvement in rice.***

Keywords: *Oryza sativa*, Correlation analysis, Path analysis

1. Introduction

Rice stands as the second most widely consumed and appreciated cereal globally, enjoyed by approximately 2.7 billion people. Its popularity both domestically and internationally has led to approximately 40 percent of India's food grain production being dedicated to rice cultivation. Rice is cultivated extensively across various states in India, including Bihar, Madhya Pradesh, Haryana, Uttarakhand, Odisha, Punjab, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Kerala, and West Bengal. India holds a unique position as a prolific rice producer, with its production primarily divided into two categories: Basmati Rice and Non-Basmati Rice, further comprising around 4,000 different varieties. In terms of exports, rice holds a significant position, with last fiscal year seeing it account for approximately 55 percent of India's total cereals exports. This underscores the importance of rice as a staple crop for both domestic consumption and international trade. The diversity of rice varieties and the high quality of Basmati Rice further enhance India's position as a major player in the global rice market, contributing significantly to the country's agricultural economy and trade balance.

Rice, botanically known as *Oryza sativa* (L.) is a widely consumed cereal crop renowned for its nutritional value and versatility as a staple food. Belonging to the family Poaceae, which includes other important cereals like wheat and corn, rice is a vital component of global agriculture and human diets. Rich in nutrients, rice contains various vitamins and minerals, making it an excellent source of complex carbohydrates and a prime energy provider. In India specifically, rice plays a crucial role in the diet, providing approximately 43 percent of the average caloric intake for individuals. Moreover, due to its extensive cultivation, rice contributes significantly to agricultural income, accounting for 20-25 percent of total agricultural revenue. Throughout Asia, rice holds a central position in daily meals, with many populations consuming it in every meal. In numerous countries, rice contributes to more than 70 percent of the caloric intake for individuals, highlighting its fundamental role in ensuring food security and meeting nutritional needs across the region. Overall, rice's nutritional richness, affordability, and widespread consumption underscore its importance as a key crop for global food security and human well-being. Rice, belonging to the family Poaceae (2n=24) and the genus *Oryza*, encompasses 24 species. While Oryza sativa is grown worldwide, *Oryza glaberrima* has been cultivated in West Africa for approximately 3500 years. Cultivated varieties of *Oryza sativa* are categorized into three ecotypes: *indica* (grown in tropics and subtropics), *japonica* (grown in Japan, Korea, and northern China), and *javanica* (grown in Indonesia). This diversity in rice varieties reflects its adaptability to various climates and environments, contributing to its widespread cultivation and importance as a staple food crop globally [24]. India is the second-largest producer of rice in the world, after China, with an estimated annual arear under production being 45.36 Mha and production of around 130.84 million metric tons in 2022. The highest rice producing state that contributes maximum to the overall production of rice is West Bengal. It is followed by

Uttar Pradesh, Punjab, Telangana, and Odisha. [6]. The area under production of rice in Uttar Pradesh is 5.68 Mha with production of 15.66 million tonnes and productivity of 2759 kg/ha. Understanding the nature and extent of association of different yield components with yield and inter relationship among themselves is an essential prerequisite for the formulation of breeding procedure for effective improvement of yield and its components [17]. Correlation studies offer insights into the relative contribution of individual traits to yield, while path coefficient analysis helps discern direct and indirect contributions of traits toward yield. This enables breeders to prioritize genetic attributes for breeding efforts [5].

The rising population of country demands the supply of grains for dietary need. Not standing at par to rising population (1.48 billion in 2023), high demand makes India to depend on import of grains. And the vision to become developed nation till 2047 will be a procrastinate if we don't achieve self-reliance in grain production. Therefore, it becomes a necessity to develop high yielding varieties along with stress tolerant features for which study of variability and character for yield and yield attributing traits becomes a logistic tool in field of plant breeding to serve the need. By conducting thorough evaluations, researchers can identify superior genetic traits that can withstand local challenges such as drought, pests, and diseases. This process aids in developing improved varieties tailored to Prayagraj specific requirements, ensuring sustainable crop production and food security. Keeping this point, the present investigation was carried with objective to estimate the association among grain yield characters of rice genotypes and to study direct and indirect effects of yield component characters on grain yield

2. Materials and Methods

To better understand the correlation, and path analysis of rice genotypes, the current study was conducted. The investigation, which took place at Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, during the *Kharif* season of 2023, at Experimental Research Centre, Department of Genetics and Plant breeding. Approximately 5 kilometres from Prayagraj City, the University is located on the left side of the Prayagraj–Rewa National Highway. Field preparation, inputs, irrigation facilities, labour, and other resources required for the successful cultivation of a crop were all provided by the Department of Genetics and Plant Breeding at the Naini Agricultural Institute of Sam Higginbottom University of Agriculture, Technology, and Sciences in Prayagraj, Uttar Pradesh. Prayagraj is located in the central plain sub-zone of Agro-climatic zone V. Naini is located between latitudes 20° 33' 40" to 21".50' N and longitudes 73° 27' 58" to 73° 56' 36" E. This region has a tropical climate with warm, humid monsoons, reasonably hot summers, and mildly cold winters. This area typically experiences heavy rainfall from June to September. The majority of the precipitation falls during the south-west advancing monsoon, which is most noticeable in July and August. The experimental site consists of levelled land with a uniformly fertile sandy loam soil that has a high percentage of sand and little clay. Randomly selected soil samples were taken between 0 and 30 cm in depth. The soil was then analysed for pH (7.1); organic carbon (0.52%); available nitrogen (142.33 kg/ha); available phosphorus (4.56 kg/ha); and available potassium (206.11 kg/ha). Plant spacing was set at 15 cm between plants and 20 cm between rows. The data were recorded from randomly selected five plants for each genotypes for each replications for thirteen characters *viz*. days to 50% flowering, days to maturity, plant height (cm), flag leaf length (cm), flag leaf width (cm), number of tillers per hill, number of panicles per hill, panicle length (cm), spikelets per panicle, biomass (g), harvest index (%), test weight (g), and grain yield per hill (g). The experiment was set up using a Randomized Block Design (RBD). The method used to statistically analyse the data was Analysis of Variance [7]. Correlation was calculated using methods suggested by Al-Jibouri [1] while path coefficient analysis was worked out my method suggested by Dewey and Lu [5].

3. Results and Discussion

3.1 Analysis of Variance

Analysis of variance was performed on the mean sum squares data for 13 characters in order to design the experiment. Table 1 shows the results of the analysis of variance for the various characters that were calculated. A considerable amount of genetic variability exists among rice germplasms, as evidenced by the highly significant differences (α=0.05) among the 32 genotypes for all characters studied in the analysis of variance. It also showed the extent to which rice could be genetically improved through selection. The findings are consistent with earlier researchers [3], [8-10] and [13].

3.2 Correlation coefficient analysis

The degree and direction of the correlation can be used to determine how changes in one character will impact the other characters concurrently. For the purpose of indirect selection for grain yield, a high magnitude of positive correlation coefficient at the genotypic level between attributing characters and grain yield is crucial. Due to the lack of a suitable test of significance for the genotypic correlation coefficient, the "t-test" has been used to test the phenotypic correlation coefficient, which has received the majority of attention. Phenotypic Correlation coefficient analysis (table 2) revealed that grain yield per hill exhibited highly significant and positive correlation with plant height, flag leaf length, spikelets per panicle, biomass and harvest index. Significant and positive correlation with grain yield per plant for plant height was reported earlier [12], [14] and [20]. Grain yield per plant to be significantly and positively correlated with biomass and spikelets per panicle [15] and [21-22].

Genetic correlation coefficient was higher than their corresponding phenotypic correlation coefficient for many characters was similarly reported earlier [18] and [22]. Genotypic correlation coefficient analysis revealed that grain yield per hill exhibited highly significant and positive correlation with plant height, flag leaf length, flag leaf width, spikelets per panicle, biomass, harvest index and test weight [2], [11] and [19]. The significant correlation at both the levels between above attributing characters can be used for simultaneous improvement in both the characters with selection for one character only while selection for correlated character may not be done. However, significant correlation only at genotypic level reflects the masking effects of the environment. Therefore, selection for grain yield per plant may be done by taking with plant height, flag leaf length, spikelets per panicle, biomass, harvest index and test weight into account.

3.3 Path analysis

To ascertain the contribution of various characters to the grain yield per plant, path coefficient analysis was performed using the dependent variable of grain yield per plant to divide the correlation coefficient into direct and indirect effects. There is agreement between the direction and magnitude of the direct effects of the various characters and their correlation with grain yield, according to the direct and indirect effects of the characters on grain yield. Thus, selection for the contributing traits with a high positive direct effect should result in a notable increase in grain yield. In the present investigation, at phenotypic level (table 3 and figure 1) the highest positive direct effects on grain yield were depicted by biomass, harvest index, test weight, number of tillers per hill, flag leaf width, plant height and panicle length while negative direct effects were due to days to 50% flowering, days to maturity, flag leaf length, number of panicles per hill, spikelets per panicle. The residual component of phenotypic path analysis indicated that 64.70% of variability of grain yield was accounted for by these thirteen characters. Similar results have been reported from earlier researchers. Kayastha [11] reported that harvest index had maximum positive direct effect on grain yield per plant. Number of tillers per hill and test weight had positive direct effect on grain yield [18] and [23]. Flag leaf width and biomass also had positive direct effect on grain yield [2&4]. Hence selection based on these characters would bring an improvement in grain yield in rice. Plant height and panicle also exhibited positive direct effect on grain yield [16]. In the present investigation, at genotypic level (table 4 and figure 2) the highest positive direct effects on grain yield were depicted by biomass, harvest index, test weight, flag leaf width, number of panicles per hill, plant height and days to maturity while negative direct effects were due to days to 50% flowering, number of tillers per hill, flag leaf length, panicle length, spikelets per panicle. The residual component of genotypic path analysis indicated that 73.00% of variability of grain yield was accounted for by these thirteen characters. Similar results have been reported from earlier researchers. Harvest index had maximum positive direct effect on grain yield per plant [11]. Number of tillers per hill and test weight had positive direct effect on grain yield [15], [18] and [23]. Flag leaf width and biomass also had positive direct effect on grain yield [2 & 4] and [21]. Hence selection based on these characters would bring an improvement in grain yield in rice. Plant height, flag leaf length and panicle also exhibited positive direct effect on grain yield [16], [19], [22].

Path analysis further revealed that the high positive association of other characters with grain yield per plant was also due to high indirect effect through these characters. This indicated that grain yield was mainly a product of direct and indirect effects (through each other) of harvest index and biological yield per plant. The characters having negative direct effects at genotypic level on grain yield but had positive association was due to indirect effects through biological yield per plant and harvest index. Thus, selections for these characters ought to be proved efficient for the improvement of grain yield of rice. The residual effect observed in path analysis was low indicating that the characters included in the present study were able to explain most of the effects on grain yield in rice.

4. Conclusion

Positive and significant correlation was observed for plant height, flag leaf length, flag leaf width, spikelets per panicle, biomass, test weight and harvest index with grain yield per hill at genotypic and phenotypic levels. Days to maturity, number of panicles per hill, biomass, harvest index, test weight and flag leaf width exhibited direct positive effect at phenotypic level. This indicated that grain yield was mainly a product of direct and indirect effects of the above attributing characters and priority should be given to these characters during selection for improvement in rice. The ability to measure the relationships between various plant characters is provided by correlation coefficient analysis, which also identifies the component character on which selection can be based for the genetic improvement of yield. Plant breeders' work is made easier when two desirable traits have a positive genetic correlation because simultaneous improvements in both traits are possible. By partitioning the correlation, path coefficient analysis enables separation of the direct effect and their indirect effects through other attributes. Characteristics with a high direct effect can be used directly to increase yield, whereas characteristics with high indirect effects through other characteristics can be chosen through indirect selection based on characteristics with high indirect effects.

Table 1: Analysis of Variance for 13 grain yield characters of rice

S. No	Characters	Mean sum of Squares		
		Replication (*df*=2)	Genotypes (*df*=31)	Error (*df*=62)
1	Days to 50% flowering	34.20	588.39**	2.50
2	Days to Maturity	10.01	563.55*	13.90
3	Plant height	19.41	440.34*	5.95
4	Flag leaf length	18.40	63.62*	4.23
5	Flag leaf width	0.01	0.12**	0.00
6	No of Tillers per hill	2.50	3.15**	0.48
7	No of panicles per hill	1.50	3.18**	0.48
8	Panicle length	2.31	19.91**	1.24
9	Spikelets per panicle	107.09	1,439.33**	154.01
10	Biomass	23.13	1,057.85**	42.36

11	Harvest Index	29.23	431.84*	42.81
12	Test weight	0.87	18.62*	2.19
13	Grain yield per hill	8.64	111.19*	10.50
	**,* Significant at 1% and 5% level of significance respectively			

Table 2: Estimates of Correlation coefficients among grain yield characters of rice genotypes

Phenotypic correlation (below diagonal) and Genotypic Correlation (above diagonal) Matrix													
Characters	Days to 50% flowering	Days to Maturity	Plant height	Flag leaf length	Flag leaf width	No of Tillers per hill	No of panicles per hill	Panicle length	Spikelets per panicle	Biomass	Harvest Index	Test weight	Grain yield per hill
Days to 50% flowering	**1.000**	0.949**	-0.369**	0.422**	-0.1018	0.283*	0.448**	-0.141	-0.0243	0.775**	-0.806**	0.246*	-0.1741
Days to Maturity	0.907**	**1.000**	-0.340**	0.353**	-0.1369	0.1548	0.316*	0.0072	0.0601	0.792**	-0.747**	0.181	-0.09
Plant height	-0.361**	-0.320*	**1.000**	-0.259*	-0.207*	0.307*	0.225*	0.419**	-0.0327	-0.0136	0.1322	0.0529	0.340**
Flag leaf length	0.383**	0.299*	-0.241*	**1.000**	0.392**	-0.1081	-0.1214	-0.0796	0.644**	0.477**	-0.1592	0.642**	0.211*
Flag leaf width	-0.0994	-0.1269	-0.1855	0.357**	**1.000**	-0.334**	-0.391**	-0.452**	0.485**	-0.0848	0.268*	0.1489	0.201*
No of Tillers per hill	0.229*	0.1478	0.257*	-0.0955	-0.270*	**1.000**	0.975**	0.0012	-0.19	0.387**	-0.360**	0.192	0.182
No of panicles per hill	0.363**	0.255*	0.1933	-0.1091	-0.310*	0.937**	**1.000**	-0.04	-0.281*	0.480**	-0.484**	0.114	0.0882
Panicle length	-0.1264	-0.0183	0.393**	-0.0189	-0.388**	-0.0257	-0.0545	**1.000**	-0.0702	-0.0221	0.0146	0.236*	0.0899
Spikelets per panicle	-0.0171	0.0385	-0.0015	0.477**	0.419**	-0.1187	-0.205*	-0.0154	**1.000**	0.206*	0.345**	0.212*	0.532**
Biomass	0.722**	0.711**	-0.0093	0.416**	-0.0793	0.305*	0.373**	0.0056	0.214*	**1.000**	-0.666**	0.472**	0.322*
Harvest Index	-0.687**	-0.623**	0.1129	-0.1414	0.252*	-0.275*	-0.362**	0.0304	0.230*	-0.600**	**1.000**	-0.356**	0.414**
Test weight	0.219*	0.1573	0.0572	0.462**	0.1176	0.1231	0.0612	0.1656	0.231*	0.367**	-0.249*	**1.000**	0.242*
Grain yield per hill	-0.1452	-0.0824	0.290*	0.167*	0.1902	0.1328	0.0497	0.1206	0.425**	0.318*	0.479**	0.1658	**1.000**

Table 3: Estimates of Phenotypic path matrix (direct effect in bold) for grain yield per hill in rice genotypes

Phenotypic Path Matrix													
Characters	Days to 50% flowering	Days to Maturity	Plant height	Flag leaf length	Flag leaf width	No of Tillers per hill	No of panicles per hill	Panicle length	Spikelets per panicle	Biomass	Harvest Index	Test weight	Grain yield per hill
Days to 50% flowering	**-0.0678**	-0.0615	0.0245	-0.026	0.0067	-0.0155	-0.0246	0.0086	0.0012	-0.049	0.0466	-0.0148	-0.1452
Days to Maturity	-0.0645	**-0.0711**	0.0227	-0.0213	0.009	-0.0105	-0.0182	0.0013	-0.0027	-0.0506	0.0443	-0.0112	-0.0824
Plant height	-0.0232	-0.0206	**0.0644**	-0.0155	-0.012	0.0166	0.0125	0.0253	-0.0001	-0.0006	0.0073	0.0037	0.290*
Flag leaf length	-0.0385	-0.0301	0.0242	**-0.1005**	-0.0359	0.0096	0.011	0.0019	-0.0479	-0.0418	0.0142	-0.0464	0.167*
Flag leaf width	-0.0111	-0.0142	-0.0208	0.04	**0.112**	-0.0302	-0.0348	-0.0434	0.047	-0.0089	0.0282	0.0132	0.1902
No of Tillers per hill	0.0878	0.0567	0.0986	-0.0366	-0.1035	**0.3837**	0.3594	-0.0099	-0.0456	0.117	-0.1056	0.0472	0.1328
No of panicles per hill	-0.1081	-0.0761	-0.0576	0.0325	0.0925	-0.279	**-0.2979**	0.0162	0.0611	-0.1112	0.1079	-0.0182	0.0497
Panicle length	-0.0095	-0.0014	0.0295	-0.0014	-0.0291	-0.0019	-0.0041	**0.0751**	-0.0012	0.0004	0.0023	0.0124	0.1206
Spikelets per panicle	0.0008	-0.0019	0.0001	-0.0236	-0.0208	0.0059	0.0101	0.0008	**-0.0495**	-0.0106	-0.0114	-0.0115	0.425**
Biomass	0.7539	0.7428	-0.0098	0.4339	-0.0828	0.3184	0.3897	0.0058	0.2238	**1.0442**	-0.6262	0.3827	0.318*
Harvest Index	-0.6767	-0.6135	0.1112	-0.1392	0.2477	-0.2709	-0.3566	0.03	0.2263	-0.5904	**0.9845**	-0.245	0.479**
Test weight	0.0117	0.0084	0.0031	0.0247	0.0063	0.0066	0.0033	0.0089	0.0124	0.0196	-0.0133	**0.0536**	0.1658

Residual: 0.353

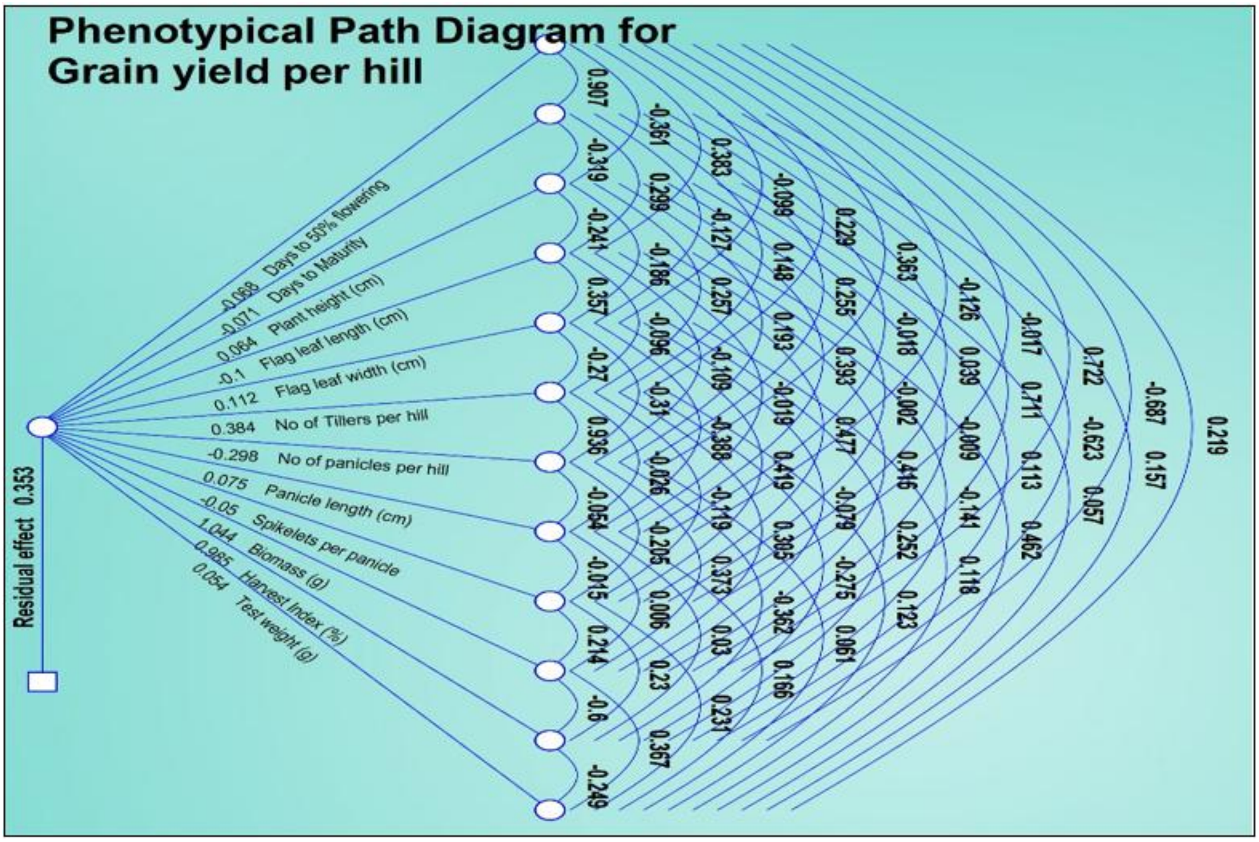

Figure 1: Phenotypic path diagram for seed yield per plant

Table 4: Estimates of Genotypic path matrix (direct effect in bold) for grain yield per hill in rice genotypes

Genotypic Path Matrix													
Characters	Days to 50% flowering	Days to Maturity	Plant height	Flag leaf length	Flag leaf width	No of Tillers per hill	No of panicles per hill	Panicle length	Spikelets per panicle	Biomass	Harvest Index	Test weight	Grain yield per hill
Days to 50% flowering	**-0.9469**	-0.8986	0.3495	-0.3998	0.0964	-0.2679	-0.424	0.1335	0.023	-0.7338	0.7636	-0.2331	-0.1741
Days to Maturity	1.0441	**1.1003**	-0.3741	0.3887	-0.1506	0.1703	0.3473	0.0079	0.0661	0.8717	-0.8213	0.1992	-0.09
Plant height	-0.0779	-0.0718	**0.2111**	-0.0547	-0.0438	0.0648	0.0474	0.0884	-0.0069	-0.0029	0.0279	0.0112	0.340**
Flag leaf length	-0.0827	-0.0692	0.0508	**-0.1958**	-0.0769	0.0212	0.0238	0.0156	-0.1261	-0.0935	0.0312	-0.1257	0.211*
Flag leaf width	-0.0067	-0.009	-0.0136	0.0258	**0.0657**	-0.0219	-0.0257	-0.0297	0.0319	-0.0056	0.0176	0.0098	0.201*
No of Tillers per hill	-0.206	-0.1127	-0.2236	0.0787	0.2432	**-0.7283**	-0.7102	-0.0009	0.1384	-0.2816	0.2622	-0.1398	0.182
No of panicles per hill	0.4818	0.3397	0.2418	-0.1307	-0.4201	1.0493	**1.0759**	-0.043	-0.3019	0.5167	-0.5209	0.1227	0.0882
Panicle length	0.0333	-0.0017	-0.0989	0.0188	0.1068	-0.0003	0.0094	**-0.2362**	0.0166	0.0052	-0.0034	-0.0557	0.0899
Spikelets per panicle	0.0004	-0.0009	0.0005	-0.0098	-0.0074	0.0029	0.0043	0.0011	**-0.0152**	-0.0031	-0.0052	-0.0032	0.532**
Biomass	0.4763	0.487	-0.0084	0.2935	-0.0521	0.2377	0.2952	-0.0136	0.1268	**0.6147**	-0.4094	0.2901	0.322*
Harvest Index	-1.0442	-0.9666	0.1712	-0.2062	0.3468	-0.4662	-0.6269	0.0189	0.4464	-0.8624	**1.2949**	-0.4612	0.414**
Test weight	0.1544	0.1136	0.0332	0.4028	0.0934	0.1205	0.0715	0.1478	0.1333	0.296	-0.2235	**0.6274**	0.242*

Residual: 0.270

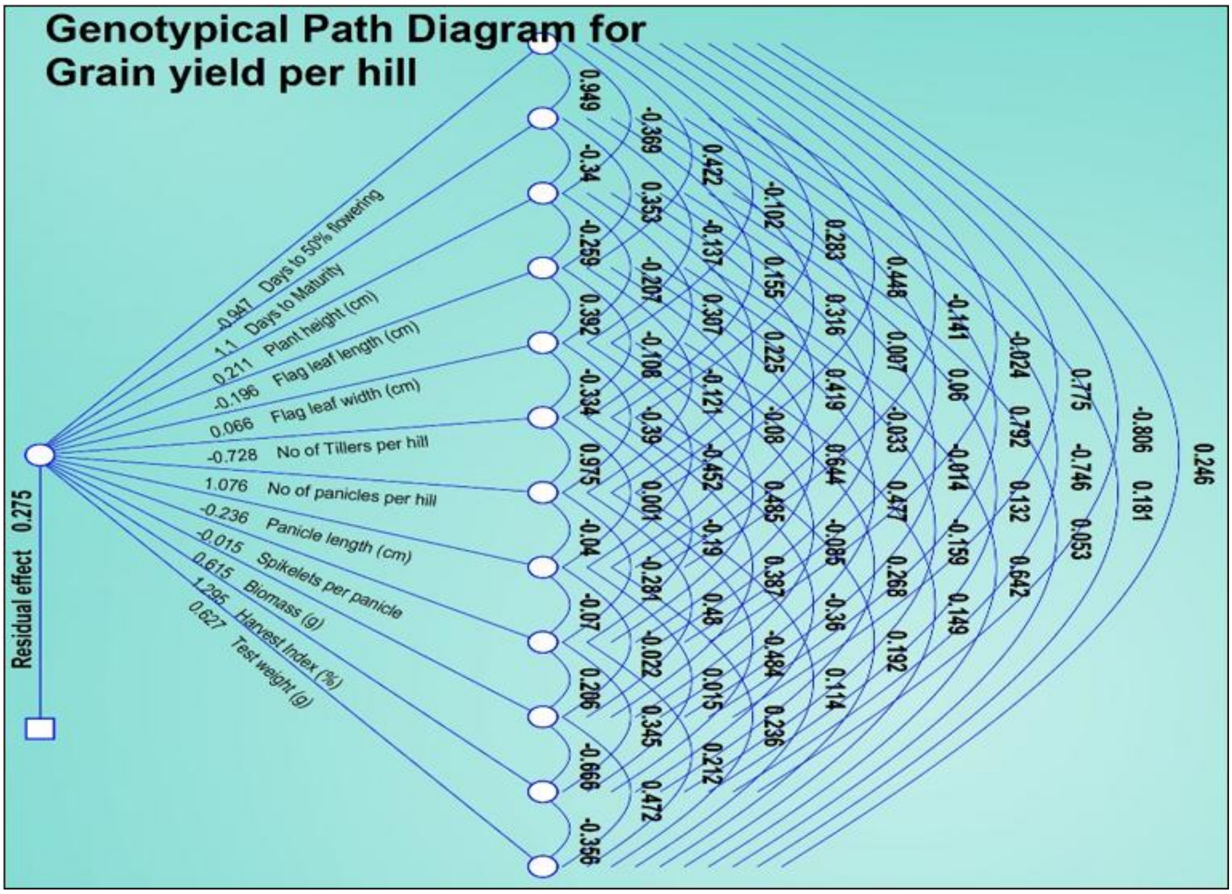

Figure 2: Genotypic path diagram for seed yield per plant

Conflicts of Interest

Authors have no conflicts of Interest.

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