CORRELATION AND PATH COEFFICIENT ANALYSIS FOR YIELD, QUALITY AND THEIR COMPONENT TRAITS IN RICE (*Oryza sativa* L.)

Abstract

Investigation was carried out at the Agricultural research Institute, Hyderabad, during kharif 2018-19 with the objective of assessing the trait association and direct and indirect effects of yield and quality related traits on grain yield in fifty rice (*oryza sativa* L.) genotypes. Among eighteen characters, panicle length, 1000-grain weight, kernel L/B ratio, kernel length after cooking and kernel elongation ratio had positive and highly significant association with seed yield and positive correlation with kernel length, alkali spread value and gel consistency. Genotypic path coefficient analysis of seed yield revealed that milling, kernel length after cooking, 1000-grain weight and panicle length exerted highest positive direct effect on grain yield. The existence of strong positive correlation between grain yield and other traits helps in identifying traits that could be used for indirect selection for the improvement of grain yield, Therefore, to facilitate selection in breeding for high yield, quality and other desirable traits. Hence emphasis can be laid out on these traits and give more attention to those having the greatest influence on grain yield.

Key words: Aromatic rice, Correlation, Direct and indirect effect, Path analysis.

Introduction:

Rice is the primary carbohydrate source for more than 33% of the world's population (Thongbam et al., 2012). Aromatic rice constitutes a special group of rice genotypes well known in many countries across the world for their aroma and/or super fine grain quality (Singh *et al*., 2000). The aroma or fragrance of Basmati rice is associated with the presence and content of chemical compound, 2-acetyl-1-pyrroline and the trait is monogenic recessive. Varied aromatic genotypes originating from various sources produce different flavours or scents, and there is no consensus on the nature of rice aroma as of yet. Aromatic rice demand is increasing gradually throughout the world for its taste and flavor (Das and Baqui, 2000). It is regarded as best in quality and fetches much higher price than non-aromatic rice (Hien *et al*., 2007). Aromatic rice variants are a small but distinct group of rice that has grown in importance as the global demand for high-quality rice has grown (Sun et al., 2008). Because wild Oryza rice lacks flavour, it's possible that the aroma associated with some domesticated rice varieties resulted from a gene mutation during evolution or is the result of a separate domestication event (Bradbury et al., 2005a). Rice quality is of great importance for all people involved as it is consumed principally as a whole grain and the texture of the whole grain is a matter of great concern. Grain quality of rice is determined by several factors such as grain appearance, nutritional value, cooking and eating quality.

Correlation study provides a measure of association between characters and helps to identify important characters to be considered while making elucidates selection. correlation coefcients between grain yield, quality and its component characters is essential since grain yield in rice is a complex character and is highly infuenced by several component characters (Hossain *et al*., 2015). Likewise, correlation coefcient is another fundamental tool showing relationships among independent characteristics (Sravan *et al*., 2012). Path coefficient analysis is important for partitioning the genotypic correlation coefficient into direct and indirect effects of component characters (Dewey and Lu. 1959). Through this we can estimate the actual contribution of an attribute and its influence through other characters. Therefore, this research was conducted with the objective to determine association among traits, direct and indirect effects of traits on grain yield and quality of rice.

Materials and Methods

The study comprised 50 accessions that were provided by Agricultural research institute, Hyderabad, Telangana. Physio-chemical analysis was performed at the Indian Institute of Rice Research, Rajendranagar, and the accessions were field evaluated in a Randomised Block Design with three replications for each treatment during kharif 2018-19 at Rice Research Centre, Agricultural Research Institute, Professor Jayashankar Telangana State Agricultural University, Rajendranagar. Two checks, Shobhini and Pusa 1121 were used in the experiment. Two rows for each entry with spacing of 20 x 15 cm and each row consists of 25 plants per entry. All the necessary requirements of the crop such as irrigation and inter cultural operations were undertaken as per the package of practices. Quantitative characters were recorded on five plants that were chosen at random. The mean values over replications were subjected for analysing various parameters. The formulas proposed by Falconer were used to calculate phenotypic and genotypic correlations (1964). Path analysis is done using the approach proposed by Dewey and Lu. The genotypic and phenotypic correlation coefficients were partitioned into direct and indirect effects (1959). To assess the significance of the correlation coefficient mandated by

Fisher and Yates, the estimated values were compared to table values of the correlation coefficient (1978). Analysis is being carried out by using INDOSTAT software . The following characters were considered during the study.

Table 1. Characters Under Study.

Quantitative Characters	Qualitative Characters
Days to 50% flowering	Milling (percent)
Plant height (cm)	Hulling (percent)
Panicle length (cm)	Kernel length after cooking (mm)
Number of effective tillers per plant	Kernel elongation ratio
Days to 50% flowering	Alkali spread value
Seed yield per plant	Head rice recovery (percent)
number of filled grains per panicle	Kernel length (mm)
1000-seed weight (g)	Amylose content
	gel consistency (mm)
	Kernel breadth (mm)
	Kernel length/breadth ratio
	Aroma

Table 2. Monthly meteorological data during the course of investigation at Agriculture Research Institute, Rajendranagar.

Month	Temperature		Relative Humidity (%)	Rainfall (mm)
	Minimum	Maximum		
June-2019	12.50	31.10	93.00	40
July-2019	14.30	30.40	94.00	80
August-2019	15.80	33.70	87.00	60
September-2019	16.60	35.60	81.00	50
October-2019	18.60	37.40	80.00	10

November-2019	20.20	38.60	80.00	5

Results and discussion

The economic product of rice, is a polygenic trait which exhibits complex genetics and is influenced by various yield contributing characters and environment. Yield component traits showed correlations among each other and also associated with yield, hence yield improvement programmes showed limited success due to direct selection for yield alone which limits the selection efficiency. As a result, the selection of its component characters may be used to improve the effective yield. Correlation studies are useful in understanding the association between grain yield and different traits (Dixet and Dubey, 1984), enabling plant breeders to select genotypes having desirable traits that are related to grain yield. Tables 1, 2, and 3 show the phenotypic and genotypic correlation coefficients of yield and quality parameters. The 1000-grain weight (0.1989*/0.1719*) and panicle length (0.2459**/0.2395**) had a positive significant relationship with single plant yield, indicating that these features were crucial for yield improvement. Kernel L/B ratio (0.2627/0.2740**), kernel length after coocking (0.2669/0.2773**), and kernel elongation ratio (0.1895/0.1943*) all showed a positive significant connection with single plant yield, indicating that selection for these traits might be used as a criterion for increased grain output. Kernel length (0.1382/0.1451), gel consistency (0.1351/0.1421), and alkali spread value (0.1254/0.1302) all had a positive but non-significant relationship with single plant yield.

Negative significant association was exhibited with days to 50% flowering (-0.3163**/-0.3402**), plant height (-0.2304**/-0.2457**), hulling (-0.3115**/-0.3364**), kernel breadth (-0.3401**/-0.3549**). Negative but non-significant correlation was reported with number of effective tillers per plant (-0.0502/-0.0447), milling (-0.1155/-0.1276), amylose content (-0.1407/-0.1707), and head rice recovery (-0.1155/-0.1275) suggesting that these characters would not be rewarding if selected for enriching yield and these would hinder yield if selected. These results were supported by Archana *et al*. (2018) for yield, panicle length and for plant height, and no. of grains per panicle were supported Reddy *et al*. (2013), Rao *et al*. (2014) and 1000 grain weight by Prakash *et al*. (2018). From the above results it can be inferred that high the time required for flowering, lower the yield .

When two traits have a negative phenotypic and genotypic connection, according to Newall and Eberhart (1961), it is challenging to use simultaneous selection for both characters in the formation of a variety. As a result, in such circumstances, a smart selection programme for simultaneous enhancement of such critical developmental and component traits may be devised.

Path analysis has evolved as a powerful and frequently used technique for assessing the relative value of multiple yield contributing characters by evaluating the direct and indirect contributions of distinct characters to economic yield in agricultural plants. The results of path coefficient analysis (Table-4, 5, 6, 7, and fig.1) revealed that milling (3.5155) had the highest positive direct effect on grain yield, followed by kernel length after cooking (1.4013), 1000 grain weight (0.5782), kernel L/B ratio (0.2244), and panicle length (0.1210). Milling (5.0209) had the biggest positive direct effect on grain yield according to genotypical effects, followed by 1000 grain weight (0.8626), panicle length (0.6139), kernel length after cooking (0.5664), and kernel L/B ratio (0.4349). As a result, in crop development programmes, selection for the above qualities should be made.

Days to 50% blooming (-0.2518/-0.1661), plant height (-0.1554/-0.5826), effective tillers per plant (-0.0486/-0.0904), grains per panicle (-0.0447/-0.0516), head rice recovery (-3.513/-5.032), kernel length (-2.1345/-1.7698) kernel breadth (-0.3723/-0.2843), and alkali spread value (-0.1051/-0.181) all had negative direct effects on grain yield. Hence selection for these traits would hinder the increase in grain yield. Hulling% had phenotypically negative direct effect (-0.1136), while it had positive effect genotypically (0.0917). Amylose content had phenotypic positive and genotypic negative direct effect on yield. Lakshmi et al. (2017), Mukesh et al. (2018), Prakash et al. (2018), Priya et al. (2017), Archana et al. (2017) all found similar findings (2018).

Conclusion

A scrutiny of the results of both correlation and path analysis revealed that most important characters accounting for cause and effect relationship on yield are 1000-grain weight, panicle length, kernel length after coocking, kernel elongation ratio, Kernel L/B ratio and milling. Thus, these traits were identified to be the major yield factors and major emphasis may be given towards selection of these traits in enhancing grain yield as well as quality in rice.

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Table 3. Correlation coefficients for yield and quality characters

Characters		Hulling	Milling	Head rice recovery	Kernel length	Kernel breadth	Kernel L/B ratio	Kernel length after cooking	Kernel elongation ratio	Amylose content	Alkali spread value	Gel consistency
Days to 50% flowering	P	0.3359**	0.0450	0.0450	-0.1210	0.2479**	-0.1569	-0.2377**	-0.2731**	0.3745**	-0.2862**	-0.2354**
	G	0.3587**	0.0555	0.0555	-0.1328	0.2743**	-0.1725*	-0.2615**	-0.3009**	0.4431**	-0.3129**	-0.2555**
Plant height	P	0.2568**	0.2431**	0.2431**	-0.1496	0.3624**	-0.2363**	-0.1803*	-0.0669	0.1687*	-0.2969**	0.0813
	G	0.2714**	0.2586**	0.2586**	-0.1535	0.3709**	-0.2402**	-0.1833*	-0.0696	0.2586**	-0.3017**	0.1695*
Effective tillers per plant	P	0.1118	-0.1459	-0.1459	-0.3460**	0.0460	-0.2642**	-0.2073*	0.1944*	0.1628*	-0.1603	0.2010*
	G	0.1552	-0.1970*	-0.1970*	-0.4531**	0.0732	-0.2536**	-0.2689**	0.2635**	-0.1970*	-0.2096*	0.2555**
Panicle length	P	-0.2131**	0.0596	0.0596	0.2760**	-0.0063	0.1834*	0.2180**	-0.1201	0.0361	0.0959	0.1190
	G	-0.2918**	0.1055	0.1055	0.3840**	0.3840**	0.2603**	0.3022**	-0.1674*	0.1055	0.1331	0.1696*
1000 grain weight	P	-0.2055*	0.1665*	0.1665*	0.8120**	0.1670*	0.4935**	0.6550**	-0.2997**	0.0607	0.4222**	0.0190
	G	-0.2244**	0.1726*	0.1726*	0.8274**	0.1710*	0.5030**	0.6671**	-0.3060**	0.1726*	0.4298**	0.0201
Grains per panicle	P	0.4052**	0.2449**	0.2448**	-0.0792	0.4771**	-0.1866*	-0.3055**	-0.4073**	0.1573	-0.1782*	-0.3412**
	G	0.4258**	0.2563**	0.2562**	-0.0849	0.5003**	-0.1990*	-0.3225**	-0.4298**	0.2563**	-0.1878*	-0.3591**
Seed yield per plant	P	-0.3115**	-0.1155	-0.1155	0.1382	-0.3401**	0.2627**	0.2669**	0.1895*	-0.1407	0.1254	0.1351
	G	-0.3364**	-0.1276	-0.1275	0.1451	-0.3549**	0.2740**	0.2773**	0.1943*	-0.1707*	0.1302	0.1421

**** Significant at 1 percent level of significance** ***Significant at 5 percent level of significance** **P - Phenotypic level;** **G - Genotypic level;**

Table 4. Correlation coefficients for yield and quality parameters.

Characters		Days to 50% flowering	Plant height	Effective tillers per plant	Panicle length	1000 grain weight	Grains per panicle	Seed yield per plant
Days to 50% flowering	**P**	**1.0000**	0.2077**	0.1285	-0.0999	-0.0464	0.2650**	-0.3163**
	G	**1.0000**	0.2326**	0.2326**	-0.1335	-0.0482	0.2956**	-0.3402**
Plant height	**P**		**1.0000**	0.1308	0.4598**	-0.0238	0.2890**	-0.2304**
	G		**1.0000**	0.1666*	0.6229**	-0.0200	0.3123**	-0.2457**
Effective tillers per plant	**P**			**1.0000**	-0.0898	-0.2832**	-0.0670	-0.0502
	G			**1.0000**	-0.1821*	-0.3874**	-0.0690	-0.0447
Panicle length	**P**				**1.0000**	0.2297**	-0.0006	0.2959**
	G				**1.0000**	0.3371**	0.0496	0.2395**
1000 grain weight	**P**					**1.0000**	-0.0792	0.1989*
	G					**1.0000**	0.0139	0.1719*
Grains per panicle	**P**						**1.0000**	-0.3120**
	G						**1.0000**	-0.3321**
Seed yield per plant	**P**							**1.0000**
	G							**1.0000**

**** Significant at 1 percent level of significance** ***Significant at 5 percent level of significance** **P - Phenotypic level;** **G - Genotypic level;**

Table 5. Correlation coefficients for yield and quality parameters.

Characters		Hulling	Milling	Head rice recovery	Kernel length	Kernel breadth	Kernel L/B ratio	Kernel length after cooking	Kernel elongation ratio	Amylose content	Alkali spread value	Gel consistency	Seed yield per plant
Hulling	P	**10000**	0.6476**	0.6475**	-0.5473**	0.4744**	-0.5342**	-0.4598**	0.0071	0.2426**	-0.4484**	-0.1242	-0.3115*
	G	**10000**	0.6905**	0.6905**	-0.4748	0.4970**	-0.5558**	-0.4751**	0.0099	0.2670**	-0.4643**	-0.1309	-0.3364**
Milling	P		**10000**	1.0000**	-0.0762	0.3698**	-0.1894*	-0.1381	-0.0902	0.1781*	-0.1173	-0.0084	-0.1155
	G		**10000**	1.0000**	-0.0787	0.3779**	-0.1936*	-0.1401	-0.0889	0.1949*	-0.1199	-0.0084	-0.1276
Head rice recovery	P			**10000**	-0.0762	0.3698**	-0.1894*	-0.1381	-0.0902	0.1781	-0.1173	-0.0084	-0.1155
	G			**10000**	-0.0787	0.3779**	-0.1936*	-0.1421	-0.0889	0.1948*	-0.1199	-0.0084	-0.1275
Kernel length	P				**10000**	-0.2527**	0.8171**	0.8210**	-0.3200**	-0.1616*	0.4605**	-0.0044	0.1382
	G				**10000**	-0.2561**	0.8185**	0.8217**	-0.3188**	-0.1653*	0.4608**	-0.0045	0.1451
Kernel breadth	P					**10000**	-0.5563**	-0.4035**	-0.2922**	0.3731***	-0.1315	-0.0609	-0.3421**
	G					**10000**	-0.5560**	-0.4060**	-0.2917**	0.3866**	-0.1323	-0.0620	-0.3549**
Kernel L/B ratio	P						**10000**	0.7322**	-0.1691*	0.2426***	0.4241**	0.0410	0.2627**
	G						**10000**	0.7333**	-0.1693*	-0.3405**	0.4246**	0.0414	0.2740**
Kernel length after cooking	P							**10000**	0.2609**	-0.0595	0.3937**	0.1914*	0.2669**
	G							**10000**	0.2613**	-0.1920	0.3938**	-0.1920	0.2773**
Kernel elongation ratio	P								**10000**	-0.0595	-0.0917	0.3560**	0.1895*
	G								**10000**	-0.0653	-0.0921	0.3590**	0.1943*
Amylose content	P									**10000**	-0.1428	0.0443	-0.1407
	G									**10000**	-0.1475	0.0457	-0.1707*
Alkali spread value	P										**10000**	0.1383	0.1254
	G										**10000**	0.1387	0.1302
Gel consistency	P											**10000**	0.1351
	G											**10000**	0.1421

**** Significant at 1 percent level of significance** ***Significant at 5 percent level of significance** **P - Phenotypic level;** **G - Genotypic level;**

Table 6. Direct and indirect effects among yield, its component characters and quality parameters

S.No	Characters		Days to 50% flowering	Plant height	Effective tillers per plant	Panicle length	1000 grain weight	Grains per panicle
1	Hulling	P	-0.0382	-0.0292	-0.0127	0.0242	0.0233	-0.0460
		G	0.0329	0.0249	0.0142	-0.0268	-0.0206	0.0391
2	Milling	P	1.5818	8.5463	-5.1278	2.0953	5.8535	8.6087
		G	2.7869	12.9854	-9.8904	5.2976	8.6649	12.8681
3	Head rice recovery	P	-1.5813	-8.5399	5.1243	-2.0953	-5.8505	-8.6019
		G	-2.7938	-13.0151	9.9124	-5.3120	-8.6865	-12.8958
4	Kernel length	P	0.2583	0.3192	0.7384	-0.5892	-1.7333	0.1691
		G	0.2351	0.2678	0.8018	-0.6797	-1.4643	0.1502
5	Kernel breadth	P	-0.0923	-0.1349	-0.0171	0.0023	-0.0622	-0.1776
		G	-0.0780	-0.1055	-0.0208	0.0051	-0.0486	-0.1422
6	Kernel L/B ratio	P	-0.0352	-0.0530	-0.0593	0.0412	0.1107	-0.0423
		G	-0.0750	-0.1044	-0.1533	0.1132	0.2188	-0.0865
7	Kernel length after cooking	P	-0.3331	-0.2526	-0.2906	0.3055	0.9171	-0.4280
		G	-0.4181	-0.1038	-0.1523	0.1711	0.3778	-0.1826
8	Kernel elongation ratio	P	0.2331	0.0571	-0.1659	0.1025	0.2558	0.3477
		G	0.0983	0.0227	-0.0860	0.0547	0.1000	0.1403
9	Amylose content	P	0.0138	0.0062	0.0060	0.0013	0.0022	0.0058
		G	-0.0346	-0.0132	-0.0179	-0.0047	-0.0049	-0.0142
10	Alkali spread value	P	0.0301	0.0328	0.0168	-0.0101	-0.0444	0.0187
		G	0.0567	0.0547	0.0380	-0.0241	-0.0779	0.0341
11	Gel consistency	P	-0.0123	0.0042	0.0105	0.0062	0.0010	-0.0178
		G	0.0027	-0.0008	-0.0027	-0.0018	-0.0002	0.0037
12	Seed yield per plant	P	-0.3163	-0.0502	-0.0502	0.2959	0.1989	-0.3120
		G	-0.3402	-0.2457	-0.0447	0.2395	0.1719	-0.3321

Table 7. **Direct and indirect effects among yield, its component characters and quality parameters**

Characters		Days to 50% flowering	Plant height	Effective tillers per plant	Panicle length	1000 grain weight	Grains per panicle	Seed yield per plant
Days to 50% flowering	P	**-0.2518**	-0.0523	-0.0324	0.0252	0.0117	-0.0667	-0.3163
	G	**-0.1661**	-0.0398	-0.0386	0.0222	0.0080	-0.0491	-0.3402
Plant height	P	-0.0323	**-0.1554**	-0.0203	-0.0715	0.0037	-0.0449	-0.2304
	G	-0.1395	**-0.5826**	-0.0971	-0.3629	0.0117	-0.1819	-0.2457
Effective tillers per plant	P	-0.0062	-0.0064	**-0.0486**	0.0044	0.0138	0.0033	-0.0502
	G	0.0210	0.0151	**0.0904**	-0.0165	-0.0350	-0.0062	-0.0447
Panicle length	P	-0.0121	0.0557	-0.0109	**0.1210**	0.0278	-0.0001	0.2959
	G	-0.0820	0.3824	-0.1118	**0.6139**	0.2070	0.0304	0.2395
1000 grain weight	P	-0.0268	-0.0137	-0.1637	0.1328	**0.5782**	0.0049	0.1989
	G	-0.0416	-0.0173	-0.3342	0.2908	**0.8626**	0.0120	0.1719
Grains per panicle	P	-0.0119	-0.0129	0.0030	0.000	-0.0004	**-0.0447**	-0.3120
	G	-0.0153	-0.0161	0.0036	-0.0026	-0.0007	**-0.0516**	-0.3321

Bold values –Direct effect, Normal values – Indirect effects **P - Phenotypic level;** **G - Genotypic level;**

Genotypic residual effect = 0.76.

**** Significant at 1 percent level of significance** ***Significant at 5 percent level of significance**

Table 8. Direct and indirect effects among yield, its component characters and quality parameters

Characters		Hulling	Milling	Head rice recovery	Kernel length	Kernel breadth	Kernel L/B ratio	Kernel length after cooking	Kernel elongation ratio	Amylose content	Alkali spread value	Gel consistency
Days to 50% flowering	P	-0.0846	-0.0113	-0.0113	0.0305	-0.0624	0.0395	0.0599	0.0688	-0.0943	0.0721	0.0593
	G	-0.0596	-0.0092	-0.0092	0.0221	-0.0456	0.0287	0.0434	0.0500	-0.0736	0.0520	0.0424
Plant height	P	-0.0399	-0.0378	-0.0378	0.0232	-0.0563	0.0367	0.0280	0.0104	-0.0262	0.0461	-0.0126
	G	-0.5181	-0.5107	-0.1507	0.0882	-0.2161	0.1399	0.1068	0.0405	-0.0987	0.1758	-0.0467
Effective tillers per plant	P	-0.0054	0.0071	0.0071	0.0168	-0.0022	0.0128	0.0101	-0.0094	-0.0079	0.0078	-0.0098
	G	0.0140	-0.0178	-0.0178	-0.0410	0.0066	-0.0319	-0.0243	0.0238	0.0207	-0.0190	0.0231
Panicle length	P	-0.0258	0.0072	0.0072	0.0334	-0.0008	0.0222	0.0264	-0.0145	0.0044	0.0116	0.0144
	G	-0.1791	0.0648	0.0648	0.2358	-0.0111	0.1598	0.1855	-0.1028	0.0369	0.0817	0.1041
1000 grain weight	P	-0.1188	0.0963	0.0963	0.4695	0.0966	-0.1188	0.3787	-0.1733	0.0351	0.2441	0.0110
	G	-0.1936	0.1489	0.1489	0.7137	0.1475	0.4339	0.5755	-0.2642	0.0543	0.3707	0.0174
Grains per panicle	P	-0.0181	-0.0110	-0.0110	0.0035	-0.0213	-0.0181	0.0137	0.0182	-0.0070	0.0080	0.0153
	G	-0.0220	-0.0132	-0.0132	0.0044	-0.0258	0.0103	0.0167	0.0222	-0.0093	0.0097	0.0187
Seed yield per plant	P	-0.3115	-0.1155	-0.1155	0.1382	-0.3401	0.2627	0.2669	0.1895	-0.1407	0.1254	0.1351
	G	-0.3364	-0.1276	-0.1275	0.1451	-0.3549	0.2740	0.2773	0.1943	-0.1707	0.1302	0.1421

Table 9. Direct and indirect effects among yield, its component characters and quality parameters.

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Characters		Hulling	Milling	Head rice recovery	Kernel length	Kernel breadth	Kernel L/B ratio	Kernel length after cooking	Kernel elongation ratio	Amylose content	Alkali spread value	Gel consistency	Yield per plant
Hulling	P	**-0.1136**	-0.0736	-0.0736	0.0519	-0.0539	0.0607	0.0522	-0.0008	-0.0276	0.0509	0.0141	-0.3115
	G	**0.0917**	0.0633	0.0633	-0.0435	0.0456	-0.0510	-0.0436	0.0009	0.0245	-0.0426	-0.0120	-0.3364
Milling	P	22.7650	**3.51550**	35.1550	-2.6793	13.0002	-6.6586	-4.8551	-3.1720	6.2610	-4.1249	-0.2965	-0.1155
	G	34.6697	**5.02096**	50.2096	-3.9507	18.9732	-9.7210	-7.0356	-4.4612	9.7839	-6.0209	-0.4213	-0.1276
Head rice recovery	P	-22.7492	-35.1320	**-3.51320**	2.6766	-12.9907	6.6526	4.8507	3.1700	-6.2553	4.1217	0.2951	-0.1155
	G	-34.7491	-50.2371	**-5.03271**	3.9584	-19.0161	9.7412	7.0503	4.4721	-9.8047	6.0342	0.4205	-0.1275
Kernel length	P	0.9761	0.1627	0.1626	**-2.1345**	0.5395	-1.7442	-1.7525	0.6831	0.3449	-0.9829	0.0094	0.1382
	G	0.8403	0.1393	0.1392	**-1.7698**	0.4532	-0.4486	-1.4543	0.5642	0.2925	-0.8155	0.0080	0.1451
Kernel breadth	P	-0.1766	-0.1377	-0.1377	0.0941	**-0.3723**	0.2071	0.1502	0.1088	-0.8319	0.0489	0.0227	-0.3401
	G	-0.1413	-0.1074	-0.1074	0.0728	**-0.2843**	0.1581	0.1154	0.0829	-0.1099	0.0376	0.0176	-0.3549
Kernel L/B ratio	P	-0.1199	-0.0425	-0.0425	0.1834	-0.1248	**0.2244**	0.1643	-0.0380	-0.0740	0.0952	0.0092	0.2627
	G	-0.2417	-0.0842	-0.0842	0.3560	-0.2418	**0.4349**	0.3189	-0.0736	-0.1481	0.1847	0.0180	0.2740
Kernel length after cooking	P	-0.6443	-0.1635	-0.1935	1.1505	-0.5654	1.0260	**1.4013**	0.3656	-0.2599	0.5517	0.2682	0.2669
	G	-0.2691	-0.0794	-0.0793	0.4654	-0.2300	0.4153	**0.5664**	0.1480	-0.1087	0.2230	0.1087	0.2773
Kernel elongation ratio	P	-0.0060	0.0770	0.0770	0.2732	0.2494	0.1444	-0.2227	**-0.8535**	0.0508	0.0783	-0.3039	0.1895
	G	-0.0032	0.0290	0.0290	0.1041	0.0952	0.0553	-0.0853	**-0.3265**	0.0213	0.0301	-0.1172	0.1943
Amylose content	P	0.0090	0.0066	0.0066	-0.0060	0.0138	-0.0122	-0.0068	-0.0022	**0.0369**	-0.0053	0.0016	-0.1407
	G	-0.0208	-0.0152	-0.0152	0.0129	-0.0302	0.0266	0.0150	0.0051	**-0.0780**	0.0115	-0.0036	-0.1707
Alkali spread value	P	0.0471	0.0123	0.0123	-0.0484	0.0138	-0.0446	-0.0414	0.0096	0.0150	**-0.1051**	-0.0145	0.1254
	G	0.0842	0.0217	0.0217	-0.0836	0.0240	-0.0770	-0.0714	0.0167	0.0267	**-0.1813**	-0.0252	0.1302
Gel consistency	P	-0.0065	-0.0444	-0.0004	-0.0002	-0.0032	0.0021	0.0100	0.0186	0.0023	0.0072	**0.0521**	0.1351
	G	0.0014	0.0001	0.0001	0.0000	0.0006	-0.0004	-0.0020	-0.0037	-0.0005	-0.0014	**-0.0104**	0.1421

Bold values –Direct effect, Normal values – Indirect effects **P - Phenotypic level; G - Genotypic level;**

Genotypic residual effect = 0.76.

**** Significant at 1 percent level of significance *Significant at 5 percent level of significance**

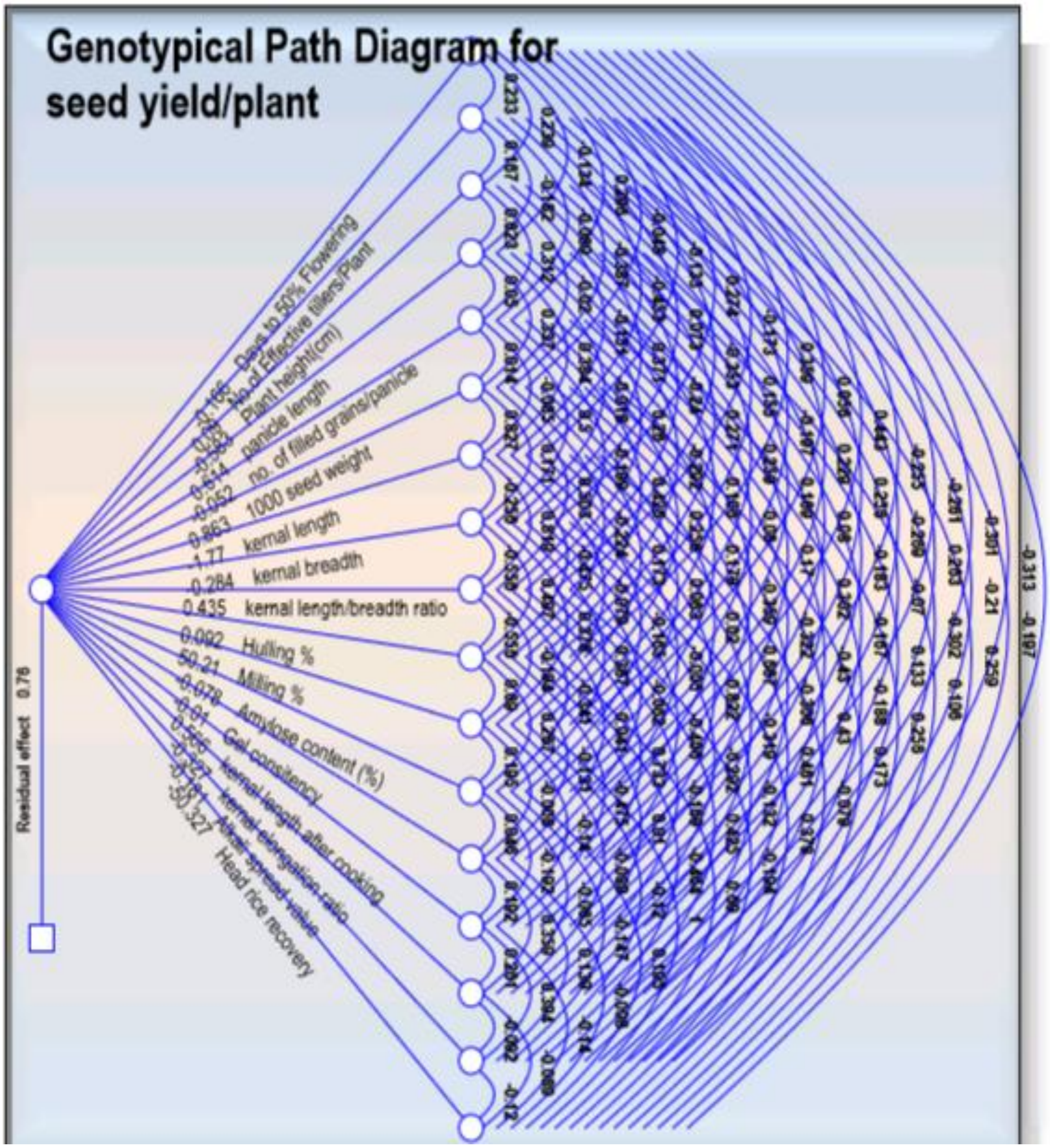

Figure 1. Simple genotypical path diagram for yield, its contributing characters and quality traits