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Studies on Correlation and Path Coefficient Analysis in Hybrid Rice (*Oryza sativa* L.) for Yield and Quality Traits

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Abstract

The present investigation was carried out at Regional Agricultural Research Station, Polasa, Jagtial, Telangana state, India to study the correlation and path coefficient analysis towards yield, physical and chemical quality traits in 46 genotypes including two checks in Randomized Block Design with two replications during *kharif*, october, 2019. Association of yield and yield components and among grain yield characters makes us to understand their relationship towards selecting a high yielding and good quality varieties. The result from the study revealed that all the nineteen characters studied has shown a great range of variation for correlation and path analysis. The character association studies in this experiment revealed that the trait grain yield plant^{-1} had showed significant positive correlation with plant height, spikelet fertility, 1000 grain weight, milling %, hulling %, kernel length and kernel breadth whereas it showed negative and non-significant association with days to 50% flowering. The path analysis studies revealed that kernel length was the major contributor for grain yield plant^{-1} followed by plant height, spikelet fertility, number of grains per panicle, 1000 grain weight, milling %, gel consistency, amylose content and alkali spreading value. These characters showed direct positive effects for grain yield plant^{-1}. From the study it can be concluded that the above characters can be used directly as the selection criteria in any rice yield improvement breeding programmes.

Keywords: Correlation, hybrid, path coefficient, quality, yield

1. Introduction

Rice (*Oryza sativa* L.) is one of the most vital cereal crops for human consumption as it feeds more than half of the World population (Anonymous, 2018–19). It is the third most cultivated cereal crop Worldwide and is central to the lives of billions of people around the world (Anonymous, 2020-2021). The global area under rice is 1.58bha with a production of 470.2 mt per annum (Anonymous, 2018–19). Keeping in view of increasing population, yield improvement will be the basic point that a plant breeder would always think about. Therefore, to increase production of rice plays a very important role in food security and poverty alleviation. Hybrid rice technology has evidenced to be one of the most practicable and readily adoptable approaches to disrupt the yield barrier, as they increase yield percentage about 15–20 (Ma and Yuan, 2015) which is more than the best of the improved or High Yielding Varieties. Grain yield is a complex trait which is a result of interaction between

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various genetic and environmental fluctuation (Wattoo et al., 2010). Most of the characters that a breeder chooses will be more complex as they include interaction of more characters, in order to fulfill this criterion, it is important for a breeder to understand the association among grain yield and its component characters.

Correlation is the measure of the mutual relationship between two variables. These studies among yield and its component traits give a better view towards the relationship between yield and its components. Character association derived by correlation coefficient is considered to be one of the important biometrical tools for formulating a selection index as it discloses the strength of relationship among the group of traits (Adams and Grafius, 1971). Phenotypic correlation provides the extent to which the two variables are associated and is governed by genotypic and environmental correlation whereas genotypic correlation plays a vital role in the development and execution of suitable breeding programmes. Character association of the yield attributing traits revealed significantly positive association of grain yield with many of the yield attributing traits (Sarwar et al., 2016; Rukmini Devi et al., 2017 and Gyawali et al., 2018) but in general, genotypic correlations were found to be higher than phenotypic values (Nogueira et al., 2012). Knowledge about the relationship between a trait with yield and other yield components would be helpful in selecting proper rice genotypes as parents in breeding programmes.

Path coefficient analysis helps in the separation of correlation coefficients into direct effects (path coefficient) and indirect effects i.e., other effects as influenced by other variables (Wright, 1921; Azhmadizadeh et al., 2011; Ratna et al., 2016). It is basically a standardized partial regression analysis and deals with a closed system of appropriate weighing to various yield components. According to Hasan et al. (2011) the breeding strategy in rice depends on the extent and correlation between the characters and the nature of variation. A correlation study coupled with a path analysis is more effective tool in the study of yield attributing characters (Singh, 2015). It is always necessary to have a better understanding of those characteristics that have significant association with yield because the characteristics can be used for direct selection criteria or indices to improve performances of varieties in a new plant population (Kumar et al., 2018). Present study aimed at understanding the genetic parameters which determine the relationship between rice yield and other traits.

2. Materials and Methods

2.1. Study sites

The study was conducted at Regional Agricultural Research Station, Polasa, Jagtial, Telangana state, India which is situated at an altitude of 243.4 m above mean sea level on 18°49'40'' N latitude and 78°56'45''E longitudes in Northern Zone of Telangana State. The experiment was carried out in *kharif*, october, 2019 for studying character association and their direct and indirect effects on grain yield.

2.2. Method of data collection

The experimental material comprised of 46 genotypes which includes four lines (CMS 64A, JMS 19A, JMS 13A and CMS 14A), eight testers (JGL 34984, JGL 34986, JGL 34551, JGL 34452, JGL 34985, JGL 32467, NSR 42, NSR 61) and thirty-two hybrids produced through Line X Tester mating design (Kempthorne, 1957) along with two checks *i.e*., PA 6444 and US 312. These genotypes were laid in Randomized Block Design (RBD) with two replications and a spacing of 20×15 cm^2. Twenty-eight days old seedlings were transplanted in the main field and all the necessary package of practices were followed to raise a healthy crop. Observations were recorded for yield, yield attributing characters and quality traits on five randomly selected competitive plants for each entry in each replication for 19 characters *viz.,* days to 50% flowering, plant height (cm), panicle length (cm), number of productive tillers per plant, 1000 grain weight (g), number of grains per panicle, spikelet fertility (%), grain yield plant^{-1} (g), hulling percentage, milling percentage, head rice recovery (%), kernel length (mm), kernel breadth (mm), kernel length-breadth ratio, kernel length after cooking, gel consistency (mm), amylose content (%), alkali spreading value and gelatinization temperature (°C). The mean data obtained at each location was considered for final statistical analysis. The analysis was done as per Singh and Chaudhary (1985) for correlation coefficient and Dewey and Lu (1959) for path analysis which were standard procedures used till today.

2.3. Statistical analysis

Correlation coefficients were calculated at genotypic and phenotypic level using the formula suggested by Falconer (196 4).

Genotypic coefficient of correlation (rg)=r(xi, xj)g=(Cov. (xi, xj) g/√Var.(xi) g.Var (xj) g

Where,

r (xi, xj)g = Genotypic correlation between ith and jth character

Cov. (xi, xj)g=Genotypic covariance between ith and jth characters

Var. (xi) g=Genotypic variance of ith character

Var (xj)g=Genotypic variance of jth character

Phenotypic coefficient of correlation (rp)=r (xi, xj) p=Cov . (xi. xj)/ √V(xi)p.v(xj)p

V (xi) p. V (xj) p

Where

r (xi, xj)p=Phenotypic correlation between ith and jth character

Cov. (xi, xj)p=Phenotypic covariance between ith and jth characters

Var. (xi) p=Phenotypic variance of ith character

Var (xj) p = phenotypic variance of jth character

The direct and indirect effects at both genotypic and phenotypic levels were estimated by taking seed yield as dependent variable, using path coefficient analysis suggested by Wright (1921) and Dewey and Lu (1959). The following equations were formed and solved simultaneously for estimating the various direct and indirect effects.

The path coefficient (direct effects) of the characters on grain yield plant^{-1}, were determined. They were obtained by solving the following simultaneous equations:

r16=P16+r12 P26+r13 P36+r14 P46+r15P56.........(1)

r26=r21 P16+P26+r23 P36+r24 P46+r25 P56........(2)

r36=r31 P16 + r32 P26 + P36 + r34P46 + r35 P56..........(3)

r46=r41 P16+r42 P26+r43p36+P46+r45 P56..........(4)

r56=r51 P16+r52 P26+r53 P36+r54 P46 + P56.........(5)

Where: r16, r26, r36,..r56 are the simple correlation coefficients of the traits involved in the model with grain yield plant^{-1}, respectively.

The residual effect was obtained by the following relation:

Pry=√1–(P1y r1y+P2y r2y+ ....+Pky rky)

Where: Pry = Residual effect. riy = The correlation coefficient between ith independent variable X (yield components) and gth dependent variable Y (yield plant^{-1}) Piy = Direct effect of X on Y.

3. Results and Discussion

Complete knowledge on interrelationship of grain yield with other characters is of paramount importance to the breeder for making improvement in complex quantitative character like grain yield for which direct selection is not much effective. Hence, association analysis was undertaken to determine the direction of selection and number of characters to be considered in improving grain yield. Genotypic correlation coefficients in general were higher than phenotypic correlation coefficients indicating strong inherent association between the traits. Phenotypic and genotypic correlations between yield and yield components were estimated in the Table 1.

Days to 50% flowering showed a positive and significant genotypic correlation with plant height (0.3779**) and kernel breadth (0.2564*) and negative significant correlation with kernel length (-0.2105*), L/B ratio (-0.3886**) and gelatinization temperature (-0.2237*). This trait registered non-significant and negative correlation with grain yield plant^{-1} at genotypic level (-0.1041). These results are in accordance with the findings of Kole et al. (2008), Yadav et al. (2010) and Nuruzzaman et al. (2017).

Plant height had negative significant association with number of grains per panicle (-0.3491**), head rice recovery (-0.2178*) and L/B ratio (-0.4346**) and was significantly and positively correlated with grain yield plant^{-1} at genotypic level (0.3122*). The results are in conformity with the findings of Rajeswari and Nadarajan (2004), Kole et al. (2008), Nuruzzaman et al. (2017) and Kampe et al. (2018).

Panicle length recorded positive and significant correlation with plant height (0.2356*), number of productive tillers per plant (0.2637*), 1000- grain weight (0.5046**), kernel length (0.3779**), kernel breadth (0.4550**), kernel length after cooking (0.3687**), gel consistency (0.2147*) and alkali spreading value (0.2645*). Panicle length was non significantly and positively correlated with grain yield per plant at genotypic level (0.1297). These results are in agreement with the findings of Kole et al. (2008), Nuruzzaman et al. (2017), and Rukmini Devi et al. (2017).

Number of productive tillers per plant exhibited positive significant genotypic correlation with plant height (0.2356*), panicle length (0.2637*), 1000 grain weight (0.4371**), kernel length (0.3501**), kernel breadth (0.3991**) and kernel length after cooking (0.2571*) and had negative significance with head rice recovery (-0.2377*). Number of productive tillers per plant was non significantly and positively correlated with grain yield per plant at genotypic level (0.1801). Rajeswari and Nadarajan (2004), Nuruzzaman et al. (2017) and Nanda et al. (2019) also reported similar results.

Number of grains per panicle recorded positive genotypic correlation with head rice recovery (0.3363*), while it had negative significant correlation with spikelet fertility (-0.4530**), 1000 grain weight (-0.6497**), milling percentage (-0.2429*), kernel length (-0.3396**) and kernel breadth (-0.5048***). Number of grains panicle^{-1} was non significantly and negatively correlated with grain yield per plant at genotypic level (-0.1391). The results are in conformity with the findings of Swapna et al. (2018).

Spikelet fertility had a significant and positive genotypic association with plant height (0.2826*), milling percentage (0.2713*), kernel length (0.2995*) and kernel breadth (0.3141*). This trait exhibited positive and significant correlation with grain yield per plant at genotypic level (0.5270**). Results are in line with the findings of Islam et al. (2019).

1000- Grain weight registered positive and significant genotypic association with plant height (0.3503*), panicle length (0.5046**), number of productive tillers per plant (0.4371**), milling percentage (0.2204*), kernel length (0.5358**), kernel breadth (0.6921**) and kernel length after cooking (0.3047*). 1000 grain weight was significantly and positively correlated with grain yield per plant at genotypic level (0.2806*). The results are in akin with the findings of Rajeswari and Nadarajan (2004) and Yadav et al. (2010)

Hulling percentage recorded significant positive correlation with grain yield per plant (0.3545**), milling percentage (0.8786**), head rice recovery (0.4169**), kernel length (0.2261*) and kernel breadth (0.2087*). The results are in line with the findings of Prem Kumar et al. (2010). Hence the

Table 1: Phenotypic (P) and Genotypic (G) correlation coefficients of yield, physical and chemical quality traits in rice (*Oryza sativa* L.)												
Source		DFF	PH	PL	NPT	NG/P	SF	1000 GW	H	M	HRR	KL
DFF	P	1.0000	0.3779	-0.1151	-0.1002	0.1375	-0.0208	-0.0676	-0.0312	-0.1024	-0.0092	-0.2015
	G	1.0000	0.3779**	-0.1151	-0.1002	0.1375	-0.0208	-0.0676	-0.0312	-0.1024	-0.0092	-0.2105*
PH	P		1.0000	0.2171*	0.2256*	-0.2975*	0.2783*	0.3291*	0.1649	0.1935	-0.2039	0.1201
	G		1.0000	0.2356*	0.2498*	-0.3491**	0.2826*	0.3503**	0.1902	0.2083*	-0.2178*	0.1386
PL	P			1.0000	0.3063*	-0.1547	-0.0299	0.4218**	0.0765	0.0683	-0.0569	0.3084*
	G			1.0000	0.2637*	-0.2738*	-0.0252	0.5046**	0.0672	0.0730	-0.0776	0.3779**
NPT	P				1.0000	0.0449	-0.1764	0.3752**	0.0423	0.0107	-0.2013	0.2609*
	G				1.0000	0.0083	-0.1977	0.4371**	0.0225	-0.0161	-0.2377*	0.3501**
NG/P	P					1.0000	-0.4211**	-0.6118**	-0.0778	-0.2078*	0.3177*	-0.2993*
	G					1.0000	-0.4530**	-0.6497**	-0.0923	-0.2429*	0.3363	-0.3396**
SF	P						1.0000	0.1309	0.1800	0.2437*	-0.0661	0.2710*
	G						1.0000	0.1330	0.1971	0.2713*	-0.0696	0.2995*
1000 GW	P							1.0000	0.0975	0.1954	-0.4347**	0.4946**
	G							1.0000	0.1064	0.2204*	-0.4749**	0.5358**
H	P								1.0000	0.7674**	0.3830**	0.1720
	G								1.0000	0.8786**	0.4169**	0.2261*
M	P									1.0000	0.4665**	0.3354*
	G									1.0000	0.4913**	0.3471**
HRR	P										1.0000	0.0578
	G										1.0000	0.0619
KL	P											1.0000
	G											1.0000
KB	P											
	G											
L/B	P											
	G											
KLAC	P											
	G											
GC	P											
	G											
AC	P											
	G											
ASV	P											
	G											
GT	P											
	G											

*: Significant at (p=0.05) level; **: Significant at (*p*=0.01) level; DFF: Days to 50% flowering , PH: Plant height, PL: Panicle length, NPTP: Number of productive tillers per plant, 1000 GW: 1000-grain weight, NGPP: Number of grains per panicle, SF: Spikelet fertility, HP: Hulling %, MP: Milling %, HRR: Head rice recovery , KL: Kernel length, KB: Kernel breadth, L/B: L/B Ratio, KLAC: Kernel length after cooking , GC: Gel consistency, AC: Amylose content, ASV: Alkali spreading value, GT: Gelatinization temperature and GYP: Grain yield plant^{-1}.

Table 1: Continue...

Source		KB	L/B	KLAC	GC	AC	ASV	GT	GY/P
DFF	P	0.2029	-0.3269*	-0.1013	0.1774	-0.1769	0.1360	-0.2137*	-0.0926
	G	0.2564*	-0.3886**	-0.1353	0.1872	-0.1917	0.1587	-0.2237*	-0.1041
PH	P	0.5865**	-0.3902**	0.1125	0.1877	-0.1320	0.0674	-0.1485	0.2980
	G	0.6463**	-0.4346**	0.1470	0.1928	-0.1395	0.0706	-0.1490	0.3122*
PL	P	0.3437**	-0.0921	0.2742*	0.1794	-0.2306*	0.1841	-0.1575	0.1249
	G	0.4550**	-0.1605	0.3687**	0.2147*	-0.2769*	0.2645*	-0.1875	0.1297
NPT	P	0.3416**	-0.1220	0.1514	-0.0365	0.0148	-0.0337	-0.0890	0.1978
	G	0.3991**	-0.1185	0.2571*	-0.0390	0.0145	-0.0444	-0.1030	0.1801
NG/P	P	-0.4478**	0.1484	-0.1372	-0.1666	0.1572	-0.0464	0.0393	-0.1071
	G	-0.5048**	0.1820	-0.1454	-0.1779	0.1653	-0.0438	0.0421	-0.1391
SF	P	0.2904*	-0.0003	0.1661	-0.0795	0.0848	-0.1385	0.1835	0.5041
	G	0.3141*	0.0007	0.1826	-0.0816	0.0851	-0.1376	0.1886	0.5270**
1000 GW	P	0.6556**	-0.2183*	0.2685*	0.1270	-0.1593	-0.0195	-0.1708	0.2704
	G	0.6921**	-0.2377	0.3047*	0.1338	-0.1650	-0.0169	-0.1769	0.2806*
H	P	0.1797	-0.0195	0.1116	0.0925	-0.0206	0.0332	-0.0136	0.3502
	G	0.2087*	-0.0073	0.1384	0.1005	-0.0223	0.0370	-0.0121	0.3545**
M	P	0.2629*	0.0389	0.2254*	0.1101	-0.0329	-0.0020	0.0506	0.3648
	G	0.3103*	-0.0132	0.2326*	0.1117	-0.0421	0.0125	0.0612	0.4056**
HRR	P	-0.2694**	0.2702**	0.0344	0.1286	-0.0601	0.1476	0.1293	0.0106
	G	-0.2890*	0.2906**	0.0386	0.1317	-0.0657	0.1558	0.1330	0.0076
KL	P	0.3552*	0.4810**	0.6512**	0.0068	-0.0170	-0.0169	-0.0859	0.3144
	G	0.3760**	0.4466**	0.6983**	0.0086	-0.0205	-0.0345	-0.0976	0.3842**
KB	P	1.0000	-0.6377**	0.3075**	0.1909	-0.2225*	0.1705	-0.1725	0.4077
	G	1.0000	-0.6545**	0.3115*	0.2104*	-0.2426*	0.1887	-0.1909	0.4652**
L/B	P		1.0000	0.2493*	-0.1756	0.1984	-0.1725	0.0886	-0.1125
	G		1.0000	0.2571*	-0.1997	0.2204*	-0.2044	0.1015	-0.1162
KLAC	P			1.0000	-0.1651	0.0943	-0.1314	-0.0253	0.1159
	G			1.0000	-0.1907	0.1103	-0.1647	-0.0318	0.1545
GC	P				1.0000	-0.9549**	0.8667**	-0.6913**	0.0685
	G				1.0000	-0.9599**	0.8948**	-0.6946**	0.0729
AC	P					1.0000	-0.8958**	0.7550**	-0.0309
	G					1.0000	-0.9232**	0.7585*	-0.0295
ASV	P						1.0000	-0.6274***	-0.0153
	G						1.0000	-0.6458***	-0.0151
GT	P							1.0000	-0.0391
	G							1.0000	-0.0409

*: Significant at (p=0.05) level; **: Significant at (*p*=0.01) level; DFF: Days to 50% flowering , PH: Plant height, PL: Panicle length, NPTP: Number of productive tillers per plant, 1000 GW: 1000-grain weight, NGPP: Number of grains per panicle, SF: Spikelet fertility, HP: Hulling %, MP: Milling %, HRR: Head rice recovery , KL: Kernel length, KB: Kernel breadth, L/B: L/B Ratio, KLAC: Kernel length after cooking , GC: Gel consistency, AC: Amylose content, ASV: Alkali spreading value, GT: Gelatinization temperature and GYP: Grain yield plant^{-1}.

selection based on hulling percentage is suitable as it brings simultaneous improvement in all other quality parameter traits.

Milling percentage exhibited significant positive genotypic correlation with grain yield per plant (0.4056**), plant height (0.2083*), spikelet fertility (0.2713*), 1000 grain weight (0.2204*), hulling percentage (0.8786**), head rice recovery (0.4913**), kernel length (0.3471**), kernel breadth (0.3103*) and kernel length after cooking (0.2326*) and negatively correlated with number of grains per panicle (-0.2429*). These results are in accordance with the findings of Prem Kumar et al. (2010), Ratna et al. (2016) and Adjah et al. (2020).

Head rice recovery has registered positive significant correlation with number of grains per panicle (0.3363*), hulling percentage (0.4169**) and L/B ratio (0.2906*), while it recorded negative significant correlation with kernel breadth (-0.2890*). Head rice recovery was non significantly and positively correlated with grain yield per plant at genotypic level (0.0076). Menaka and Ibrahim (2015), Ratna et al. (2016) and Adjah et al. (2020) also reported similar results for this trait.

Kernel length recorded a positive and significant genotypic correlation with grain yield per plant (0.3842**), panicle length (0.3779**), number of productive tillers per plant (0.3501**), spikelet fertility (0.2995*), 1000-grain weight (0.5358**), hulling percentage (0.2261*), milling percentage (0.3471**), kernel breadth (0.3760**), L/B ratio (0.4466**) and kernel length after cooking (0.6983**). Khatun et al. (2003) and Islam et al. (2019) also reported similar findings.

Kernel breadth had positive and significant genotypic association with grain yield per plant (0.4652**), days to 50% flowering (0.2564*), plant height (0.6463**), panicle length (0.4550**), number of productive tillers per plant (0.3991**), spikelet fertility (0.3141*), 1000-grain weight (0.6921**), hulling percentage (0.2087*), milling percentage (0.3103*), kernel length (0.3760**), kernel length after cooking (0.3115*) and gel consistency (0.2104*). Negative significant genotypic association is recorded with L/B ratio (-0.6545**) and amylose content (-0.2426*). Ratna et al. (2016) were reported similar results with kernel breadth.

L/B ratio had significant and positive correlation with head rice recovery (0.2906*), kernel length (0.4466**), kernel length after cooking (0.2571*), amylose content (0.2204*) and negative correlation with days to 50% flowering (-0.3886**), plant height (-0.4346**), 1000- grain weight (-0.2377*) and kernel breadth (-0.6545**) at genotypic level. While grain yield plant^{-1} (-0.1162) was negatively and non-significantly correlated with L/B ratio. Similar results were reported earlier in rice for association of L/B ratio with grain yield per plant by Khatun et al. (2003) and Ratna et al. (2016).

Kernel length after cooking had positive and significant genotypic association with panicle length (0.3687**), number of productive tillers per plant (0.2571*), 1000- grain weight (0.3047*), milling percentage (0.2326*), kernel length (0.6983**) and kernel breadth (0.3115*). This trait had positive and non-significant association with grain yield per plant at genotypic level (0.1545). The results are in line with the findings of Prem Kumar et al. (2010), Kaur et al. (2011) and Ratna et al. (2016).

Gel consistency recorded positive genotypic correlation with panicle length (0.2147*), kernel breadth (0.2104*) and alkali spreading value (0.8948**), while it had negative significant correlation with amylose content (-0.9599**) and gelatinization temperature (-0.6946**). Gel consistency was non significantly and positively correlated with grain yield per plant at genotypic level (0.0729). Khatun et al. (2003) and Menaka and Ibrahim (2015) also reported similar results.

Amylose content had significant and positive correlation with L/B ratio (0.2204*), and gelatinization temperature (0.7585**) and negative correlation with panicle length (-0.2769**), kernel breadth (-0.2426*), gel consistency (-0.9599**) and alkali spreading value (-0.9232**) at genotypic level. While grain yield plant^{-1} (-0.0295) was negatively and non-significantly correlated with amylose content. The results are in accordance with the findings of Khatun et al. (2003) and Kaur et al. (2011)

Alkali spreading value had significant and positive correlation with panicle length (0.2645*), gel consistency (0.8948**) and negative correlation with amylose content (-0.9232**) and gelatinization temperature (-0.6458**), whereas negative and non-significant association with grain yield per plant (-0.0151). The results are in conformity with the findings of Kaur et al. (2011) and Ratna et al. (2016).

Gelatinization temperature recorded positive genotypic correlation with amylose content (0.7585**). While it had negative significant correlation with days to 50% flowering (-0.2237*), gel consistency (-0.6946**) and alkali spreading value (-0.6458**). Gelatinization temperature was non significantly and negatively correlated with grain yield per plant at genotypic level (-0.0409). Khatun et al. (2003) and Kumar (2015) found similar results with gelatinization temperature.

3.1. Path coefficient analysis

Correlation gives only the relation between two variables whereas path coefficient analysis allows the separation of direct effect and their indirect effects through other attributes by partitioning the correlations (Wright, 1921) for better interpretation of cause-and-effect relationship. Based on the data presented the genotypic and phenotypic correlations were estimated to determine direct and indirect effects of yield and yield contributing characters. If the correlation coefficient between a casual factor and the effect is almost equal to its direct effect, it explains the true relationship and a direct selection through this trait may be useful. If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects appear to be the cause of that positive correlation. In such situation the other factors are to be considered simultaneously for selection. However, if the correlation coefficient is negative but direct effect is positive and high, a restriction has to be imposed to nullify the undesirable indirect effects in order to make use of direct effect. The estimates of path coefficient analysis are provided for yield and yield component characters in Table 2 and Figure 1, 2).

Among all the characters studied kernel length (1.5366) had attributed major contribution for grain yield followed by spikelet fertility (0.6255), number of grains per panicle

Table 2: Phenotypic (P) and Genotypic (G) path coefficients of yield, physical and chemical quality traits in rice (*Oryza sativa* L.)

Source		DFF	PH	PL	NPT	NG/P	SF	1000 GW	H	M	HRR	KL
DFF	P	-0.2307	-0.0853	0.0188	0.0200	-0.0351	0.0038	0.0191	0.0062	0.0148	0.0004	0.0465
	G	-0.2892	-0.1093	0.0333	0.0290	-0.0398	0.0060	0.0195	0.0090	0.0296	0.0027	0.0609
PH	P	0.0179	0.0485	0.0105	0.0109	-0.0144	0.0135	0.0160	0.0080	0.0094	-0.0099	0.0058
	G	0.0851	0.2251	0.0530	0.0562	-0.0786	0.0636	0.0788	0.0428	0.0469	-0.0490	0.0312
PL	P	0.0010	-0.0027	-0.0123	-0.0038	0.0019	0.0004	-0.0052	-0.0009	-0.0008	0.0007	-0.0038
	G	0.0027	-0.0054	-0.0230	-0.0061	0.0063	0.0006	-0.0116	-0.0015	-0.0017	0.0018	-0.0087
NPT	P	-0.0063	0.0165	0.0224	0.0732	0.0033	-0.0129	0.0275	0.0031	0.0008	-0.0147	0.0191
	G	0.0041	-0.0102	-0.0108	-0.0408	-0.0003	0.0081	-0.0178	-0.0009	0.0007	0.0097	-0.0143
NG/P	P	0.0697	-0.1362	-0.0708	0.0205	0.4576	-0.1927	-0.2800	-0.0356	-0.0951	0.1454	-0.1370
	G	0.0823	-0.2088	-0.1638	0.0050	0.5982	-0.2710	-0.3886	-0.0552	-0.1453	0.2012	-0.2031
SF	P	-0.0094	0.1610	-0.0173	-0.1021	-0.2437	0.5787	0.0757	0.1042	0.1411	-0.0383	0.1568
	G	-0.0130	0.1768	-0.0158	-0.1237	-0.2834	0.6255	0.0832	0.1233	0.1697	-0.0435	0.1873
1000 GW	P	-0.0151	0.0601	0.0770	0.0685	-0.1116	0.0239	0.1825	0.0178	0.0357	-0.0793	0.0903
	G	-0.0051	0.0265	0.0382	0.0331	-0.0492	0.0101	0.0757	0.0081	0.0167	-0.0359	0.0405
H	P	-0.0026	0.0160	0.0074	0.0041	-0.0075	0.0174	0.0094	0.0969	0.0743	0.0371	0.0167
	G	0.0020	-0.0123	-0.0043	-0.0015	0.0060	-0.0127	-0.0069	-0.0646	-0.0568	-0.0269	-0.0146
M	P	-0.0060	0.0180	0.0064	0.0010	-0.0193	0.0227	0.0182	0.0714	0.0930	0.0434	0.0312
	G	-0.0291	0.0591	0.0207	-0.0046	-0.0690	0.0770	0.0626	0.2495	0.2840	0.1395	0.0986
HRR	P	0.0000	-0.0006	-0.0002	-0.0006	0.0010	-0.0002	-0.0013	0.0012	0.0014	0.0031	0.0002
	G	0.0014	0.0330	0.0118	0.0360	-0.0510	0.0106	0.0720	-0.0632	-0.0745	-0.1516	-0.0094
KL	P	-0.0387	0.0230	0.0592	0.0500	-0.0574	0.0520	0.0949	0.0330	0.0643	0.0111	0.1918
	G	-0.3234	0.2129	0.5807	0.5380	-0.5218	0.4602	0.8233	0.3475	0.5333	0.0951	1.5366
KB	P	0.0313	0.0906	0.0531	0.0527	-0.0692	0.0449	0.1012	0.0277	0.0406	-0.0416	0.0549
	G	-0.2958	-0.7457	-0.5250	-0.4605	0.5825	-0.3625	-0.7985	-0.2408	-0.3580	0.3334	-0.4338
L/B	P	0.0488	0.0582	0.0137	0.0182	-0.0222	0.0000	0.0326	0.0029	-0.0058	-0.0403	-0.0718
	G	0.6023	0.6736	0.2489	0.1837	-0.2820	-0.0010	0.3685	0.0113	0.0204	-0.4505	-0.6922
KLAC	P	0.0153	-0.0170	-0.0413	-0.0228	0.0207	-0.0250	-0.0404	-0.0168	-0.0340	-0.0052	-0.0981
	G	0.0404	-0.0439	-0.1102	-0.0768	0.0434	-0.0546	-0.0911	-0.0414	-0.0695	-0.0115	-0.2087
GC	P	0.0756	0.0800	0.0765	-0.0156	-0.0710	-0.0339	0.0541	0.0394	0.0469	0.0548	0.0029
	G	0.0709	0.0730	0.0813	-0.0148	-0.0674	-0.0309	0.0507	0.0381	0.0423	0.0499	0.0033
AC	P	-0.0717	-0.0535	-0.0934	0.0060	0.0637	0.0344	-0.0645	-0.0084	-0.0133	-0.0243	-0.0069
	G	-0.0885	-0.0644	-0.1279	0.0067	0.0763	0.0393	-0.0762	-0.0103	-0.0194	-0.0303	-0.0095
ASV	P	-0.0088	-0.0043	-0.0119	0.0022	0.0030	0.0089	0.0013	-0.0021	0.0001	-0.0095	0.0011
	G	0.0018	0.0008	0.0031	-0.0005	-0.0005	-0.0016	-0.0002	0.0004	0.0001	0.0018	-0.0004
GT	P	0.0369	0.0256	0.0272	0.0153	-0.0068	-0.0316	0.0295	0.0023	-0.0087	-0.0223	0.0148
	G	0.0470	0.0313	0.0394	0.0217	-0.0088	-0.0397	0.0372	0.0025	-0.0129	-0.0280	0.0205

Table 2: Continue...

Source		KB	L/B	KLAC	GC	AC	ASV	GT	GY/P
DFF	P	-0.0468	0.0754	0.0234	-0.0409	0.0408	-0.0314	0.0493	-0.0926
	G	-0.0741	0.1124	0.0391	-0.0541	0.0554	-0.0459	0.0647	-0.1041
PH	P	0.0284	-0.0189	0.0055	0.0091	-0.0064	0.0033	-0.0072	0.2980*
	G	0.1455	-0.0978	0.0331	0.0434	-0.0314	0.0159	-0.0335	0.3122*
PL	P	-0.0042	0.0011	-0.0034	-0.0022	0.0028	-0.0023	0.0019	0.1249
	G	-0.0105	0.0037	-0.0085	-0.0049	0.0064	-0.0061	0.0043	0.1297
NPT	P	0.0250	-0.0089	0.0111	-0.0027	0.0011	-0.0025	-0.0065	0.1978
	G	-0.0163	0.0048	-0.0105	0.0016	-0.0006	0.0018	0.0042	0.1801
NG/P	P	-0.2049	0.0679	-0.0628	-0.0762	0.0719	-0.0212	0.0180	-0.1071
	G	-0.3020	0.1088	-0.0870	-0.1064	0.0988	-0.0262	0.0252	-0.1391
SF	P	0.1681	-0.0002	0.0961	-0.0460	0.0491	-0.0802	0.1062	0.5041**
	G	0.1965	0.0004	0.1142	-0.0511	0.0532	-0.0860	0.1180	0.5270**
1000 GW	P	0.1196	-0.0398	0.0490	0.0232	-0.0291	-0.0036	-0.0312	0.2704*
	G	0.0524	-0.0180	0.0231	0.0101	-0.0125	-0.0013	-0.0134	0.2806*
H	P	0.0174	-0.0019	0.0108	0.0090	-0.0020	0.0032	-0.0013	0.3502**
	G	-0.0135	0.0005	-0.0089	-0.0065	0.0014	-0.0024	0.0008	0.3545**
M	P	0.0245	0.0036	0.0210	0.0102	-0.0031	-0.0002	0.0047	0.3648**
	G	0.0881	-0.0037	0.0660	0.0317	-0.0120	0.0035	0.0174	0.4056**
HRR	P	-0.0008	0.0008	0.0001	0.0004	-0.0002	0.0005	0.0004	0.0106
	G	0.0438	-0.0441	-0.0058	-0.0200	0.0100	-0.0236	-0.0202	0.0076
KL	P	0.0681	0.0923	0.1249	0.0013	-0.0033	-0.0032	-0.0165	0.3144*
	G	0.5778	0.6862	1.0730	0.0133	-0.0315	-0.0531	-0.1500	0.3842**
KB	P	0.1544	-0.0985	0.0475	0.0295	-0.0344	0.0263	-0.0266	0.4077**
	G	-1.1538	0.7551	-0.3594	-0.2428	0.2799	-0.2178	0.2202	0.4652**
L/B	P	0.0952	-0.1492	-0.0372	0.0262	-0.0296	0.0257	-0.0132	-0.1125
	G	1.0144	-1.5501	-0.3985	0.3096	-0.3416	0.3168	-0.1574	-0.1162
KLAC	P	-0.0463	-0.0376	-0.1506	0.0249	-0.0142	0.0198	0.0038	0.1159
	G	-0.0931	-0.0768	-0.2989	0.0570	-0.0330	0.0492	0.0095	0.1545
GC	P	0.0813	-0.0749	-0.0704	0.4262	-0.4070	0.3694	-0.2946	0.0685
	G	0.0797	-0.0757	-0.0722	0.3788	-0.3636	0.3389	-0.2631	0.0729
AC	P	-0.0901	0.0803	0.0382	-0.3867	0.4050	-0.3628	0.3057	-0.0309
	G	-0.1120	0.1018	0.0509	-0.4432	0.4617	-0.4263	0.3502	-0.0295
ASV	P	-0.0110	0.0111	0.0085	-0.0558	0.0577	-0.0644	0.0404	-0.0153
	G	0.0022	-0.0024	-0.0019	0.0104	-0.0107	0.0116	-0.0075	-0.0151
GT	P	0.0297	-0.0153	0.0044	0.1192	-0.1302	0.1082	-0.1724	-0.0391
	G	0.0401	-0.0214	0.0067	0.1461	-0.1595	0.1358	-0.2103	-0.0409

Genotypic Residual effect = 0.584; Phenotypic Residual effect =0.667; *: Significant at (p=0.05) level; **: Significant at (p=0.01) level; DFF: Days to 50% flowering , PH: Plant height, PL: Panicle length, NPTP: Number of productive tillers plant^{-1}, 1000 GW: 1000-grain weight, NGPP: Number of grains panicle^{-1}, SF: Spikelet fertility, HP: Hulling %, MP: Milling %, HRR: Head rice recovery , KL: Kernel length, KB: Kernel breadth, L/B: L/B Ratio, KLAC: Kernel length after cooking , GC: Gel consistency, AC: Amylose content, ASV: Alkali spreading value, GT: Gelatinization temperature and GYP: Grain yield plant^{-1}

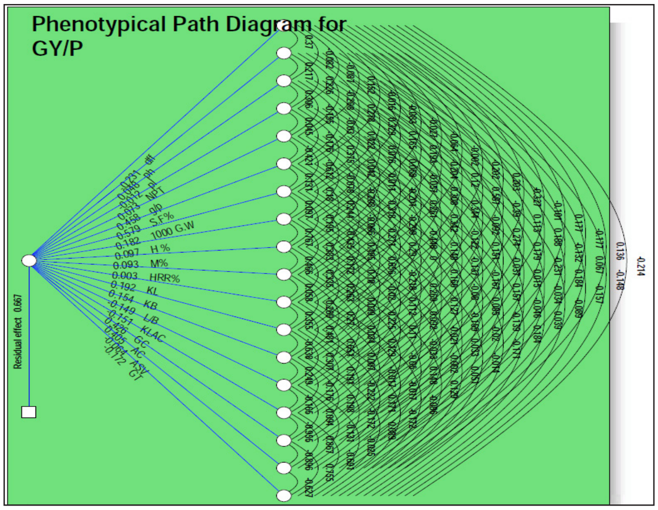

Figure 1: Phenotypical path diagram for grain yield plant^{-1} (g)

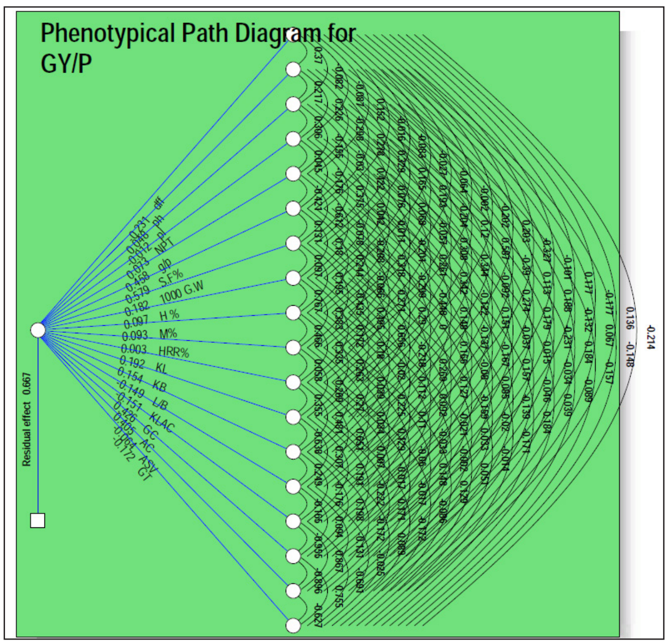

Figure 2: Genotypical path diagram for grain yield plant^{-1} (g)

(0.5982), amylose content (0.4617), gel consistency (0.3788), milling % (0.2840), plant height (0.2251), 1000 grain weight (0.0757) and alkali spreading value (0.0116). These characters showed direct positive effects for grain yield plant^{-1}. These results are in accordance with the findings of Dhurai et al. (2014), Nuruzzaman et al. (2017), Hemalatha et al. (2018) and Arulmozhi and Muthuswamy (2019).

While characters like days to 50% flowering (-0.2892), panicle length (-0.0230), number of productive tillers (-0.0408), hulling % (-0.0646), head rice recovery (-0.1516), kernel breadth (-1.1538), kernel L/B ratio (-1.5501), kernel length after cooking (-0.2989) and gelatinization temperature (-0.2103) showed direct negative effects for grain yield plant^{-1} respectively. These results are in accordance with the findings of Dhurai et al. (2014), Hemalatha et al. (2018), Swapna et al. (2018) and Islam et al. (2019).

4. Conclusion

The characters plant height, spikelet fertility, 1000 grain weight, milling %, hulling %, kernel length and kernel breadth showed significant positive genotypic correlation and would result in improvement of yield. Path analysis revealed that plant height, spikelet fertility, number of grains per panicle, 1000 grain weight, milling percentage, gel consistency, amylose content and alkali spreading value are the most important characters which could be used as selection criteria for effective improvement of grain yield.

6. References

Adams, M.W., Grafius, J.E., 1971. Yield components compensation: alternative interpretation. Crop Science. 11, 33–35.

Adjah, K.L., Abe, A., Adentimirin, V.O., 2020. Genetic variability, heritability and correlations for milling and grain appearance qualities in some accessions of rice (Oryza sativa L.). Physiology and Molecular Biology of Plants 26, 1309–1317.

Anonymous, FAO. 2018-19. World agricultural production http://faostat.fao.org/default.aspx. Accessed on 20th December, 2019.

Anonymous, Statista. 2020-21. http://www.statista.com. Accessed on 13th June, 2021.

Anonymous, Indiastat. 2018-19. Agriculture production. http://www.indiastat.com. Accessed on 20th June, 2019.

Arulmozhi, R., Muthuswamy, A., 2019. Path coefficient analysis studies in rice (*Oryza sativa* L.) for quantitative and qualitative traits. Electronic Journal of Plant Breeding 10 (4), 1576–1580.

Dewey, J.R., Lu, K.H., 1959. Correlation and path coefficient analysis of components of crested wheat grass seed production. Agronomy Journal 51, 515–518.

Dhurai, S.Y., Mohan Reddy, D., Pradeep Kumar, B., 2014. Correlation and path coefficient analysis for yield and quality traits under organic fertilizer management in rice (*Oryza sativa* L.). Electronic Journal of Plant Breeding 5(3), 581–587.

Falconer, D.S., 1964. Introduction to quantitative genetics. Longmann, 294–300.

Gyawali, S., Poudel, A., Poudel, S., 2018. Genetic variability and association analysis in different rice genotypes in mid-hill of western Nepal. Acta Scientific Agriculture 9(9), 69–76.

Hasan, M.J., Kulsum, M.U., Akter, A., Masuduzzaman, A.S.M., Ramesha, M.S., 2011. Genetic variability and character association for agronomic traits in hybrid rice (*Oryza Sativa* L.). Bangladesh Journal of Plant Breeding and Genetics 24(1), 45–51.

Hemalatha, M., Aananthi, N., Suresh, R., Sassikumar, D., 2018. Cause and effect analysis for yield and grain quality traits in rice (*Oryza sativa* L.). Electronic Journal of Plant Breeding 9(3), 1226–1233.

Islam, M.Z., Mian, M.A.K., Ivy, N.A., Akter, N., Rahman, M.M., 2019. Genetic variability, correlation and path analysis for yield and its component traits in restorer lines of rice. Bangladesh Journal of Agricultural Research 44(2), 291–301.

Kampe, A.K., Tassew, A.A., Gezmu, A.T., 2018. Estimation of phenotypic and genotypic correlation and path coefficients in rainfed upland rice (*Oryza sativa* L.) genotypes at Guraferda, Southwest Ethiopia. Journal of Rice Research 6(3), 1–5.

Kaur, S., Panesar, P.S., Bera, M.B., 2011. Studies on evaluation of grain quality attributes of some basmati and non-basmati rice cultivars. Journal of Food Quality 34, 435–441.

Kempthorne, O., 1957. An Introduction to Genetic Statistics. John Wiley and Sons Inc: New York

Khatun, M.M., Hazrat Ali, M., Dela Cruz, Q.D., 2003. Correlation studies on grain physicochemical characteristics of aromatic rice. Pakistan Journal of Biological Sciences 6, 511–513.

Kole, P.C., Chakarborty, N.R., Bhat, J.S., 2008. Analysis of variability, correlation and path coefficients in induced mutants of aromatic nonbasmati rice. Tropical Agricultural Research and Extension. 113, 60–64.

Kumar, S., Chauhan, M.P., Tomar, A., Kasana, R.K., Kumar, N. 2018. Correlation and path coefficient analysis in rice (*Oryza sativa* L.). The Pharma Innovation Journal. 7(6), 20-26.

Kumar, V., 2015. Variability and correlation studies for grain physicochemical characteristics of rice (*Oryza sativa* L.). The Bioscan 10(2), 917–922.

Ma, G.H., Yuan, L.P., 2015. Hybrid rice achievements, development and prospect in China. Journal of Integrative Agriculture 14(2), 197–205.

Menaka, J., Ibrahim, S.M., 2015. Correlation and path coefficient analysis for yield and grain quality parameters in rice (*Oryza sativa* L.). International Journal of Agriculture Sciences 7(14), 903–906.

Nanda, K., Bastia, D.N., Nanda, A., 2019. Character association and path coefficient analysis for yield and its component traits in slender grain rice (*Oryza sativa* L.). Electronic Journal of Plant Breeding 10(3), 963–969.

Nogueira, A.P.O., Sediyama, T., Sousa, L.B., Hamawaki, O.T., 2012. Trail analysis and correlation between characters in soybean grown in two sowing dates. Journal of Biosciences 28, 877–888.

Nuruzzaman, M., Hassan, L., Begum, S.N., Monjurul Huda, M., 2017. Correlation and path coefficient analysis of yield components in nerica mutant rice lines under rainfed conditions. International Journal of Experimental Agriculture 16(1), 1–8.

Prem Kumar, A., Sarawgi, A.K., Verulkar, S.W., Verma, R., 2010. Correlation coefficient and path analysis study among grain quality components in rice (Oryza sativa L.) Electronic Journal of Plant Breeding 1(6), 1468–1473.

Rajeswari, S., Nadarajan, N., 2004. Correlation between yield and yield components in rice (*Oryza sativa* L.). Agricultural Science Digest 24(4), 280–282.

Ratna, M., Begum, S., Kawochar, M., Ahmed, S., Ferdous, J., 2016. Estimation of grain quality components and their correlation of basmati rice (*Oryza sativa* L.). Journal of Tropical Agricultural Science. 39 (3), 381–391.

Riadi, M., Sjahril, R., Kasim, N., Diarjo, R.H., 2018. Heritability and path coefficient analysis for important characters of yield component related to grain yield in M4 red rice mutant. Earth and Environmental Science 157, 1–5.

Rukmini Devi, K., Satish Chandra, B., Lingaiah, N., Hari, Y., Venkanna, V., 2017. Analysis of variability, correlation and path coefficient studies for yield and quality traits in rice (*Oryza sativa* L.). Agricultural Science Digest 37(1), 1–9.

Sarwar, G., Harun-Ur-Rashid, M.D., Shahanaz, P., Sarowar Hossain, M.D., 2015. Correlation and path coefficient analysis for agro-morphological important traits in aman rice genotypes (*Oryza sativa* L.). Advances in Bioresearch 6(4), 40–47.

Singh, S.K., 2015. Correlation and path analysis for yield and quality characters in rice (*Oryza sativa* L.). Life Science. 8 (2), 102–105.

Singh, R.K., Chaudhary, B.D., 1985. Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi, India: 205–215.

Swapna, J., Divya, B., Shankar, G., Kavitha, B., Gowthami, C., Neelamraju, S., 2018. Correlation and path coefficient analysis using a set of diverse genotypes of Oryza spp. Journal of Rice Research 11(2), 18–26.

Wattoo, J.I., Khan, A.S., Ali, Z., Babar, M., Naeem, M., Ullah, M.A., Hussain, N., 2010. Study of correlation among yield related traits and path coefficient analysis in rice (*Oryza sativa* L.). African Journal of Biotechnology. 9(46), 7853–7856.

Wright, S., 1921. Correlation and causation. Journal of Agricultural Research 20, 57–585.

Yadav, S.K., Suresh, B.G., Pandey, P., Binod K.J., 2010. Assessment of genetic variability, correlation and path association in rice (*Oryza sativa* L.). Bioscience. 18, 1–8.