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Comparing Correlation Coefficients and Path Analysis in Different Populations of Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author AK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DNS and KP managed the analyses of the study. Author AP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study performed to determine the correlation, their comparison and path coefficients of yield and yield contributing characters by using F_2 (BPT-5204 /IR-64Drt1) their two parents separately and the joint parental populations. In this study, the computations for testing the significance of the difference between the 15 traits of different populations of rice determined from 324 F_2, 9 IR-64Drt1 (P_1), 9 BPT-5204 (P_2) and 18 joint parental population. Results showed that the correlation of F_2 indicated that the number of total tillers per plant, number of panicles per plant, plant height, panicle length, biomass, harvest index and yield per panicle were positive and significant association with yield per plant. Correlation of IR-64Drt1 stated that the plant height, panicle length, biomass and harvest index were positive and significant association with yield per plant. Correlation of BPT-5204 shown that the secondary branches per panicle and hundred-grain weight exhibited positive and significant association with yield per panicle. Correlation of the joint parent indicated that the plant height, panicle length, grain length, grain width, hundred-grain weight, biomass, harvest index and yield per panicle had exhibited positive and significant association with yield per plant. Path

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coefficient analysis indicated that harvest index had the highest direct positive effect (0.582) on yield per plant in the F_2 population. However, the panicles per plant had the highest direct positive effect (1.481) on yield per plant IR-64Drt1 population. The total tillers per plant had the highest direct positive effect (1.821) on yield per plant in BPT-5204 population. In the joint population of BPT-5204 and IR-64Drt1, path analysis of yield components revealed that the biomass had the highest direct positive effect (0.658) on yield per plant. Information obtained in this study revealed that traits, the harvest index, biomass and panicles per plant are suggested as selection indices for grain yield improvement at segregating populations of rice.

Keywords: Rice; correlation; association; yield; yield components.

1. INTRODUCTION

Rice is one of the pivotal main cereal crops, feeding more than half of the world population. It nourishes billions of people all over the world and further in less developed countries in Asia, Latin America and Africa. Despite of the increasing population, the main aim of the plant breeders would always be towards yield enhancement in staple food crops. Therefore, to increase the production of rice shows a very important role in food security as well as poverty mitigation. The yield of this crop is a complex object and inheritance of yield depends on a number of traits which are often polygenic in nature and are highly affected by environmental factors [1]. Development of plant breeding strategy mainly based on the association of major quantitative characters with yield or any other economic trait. Variability in segregating populations for yield and yield component traits, it is the basic factor to be considered while making a selection. Heritability besides genetic advance may deliver a clear idea to a selection of a particular trait. Selection of favourable genotypes in a breeding program depends on various criteria, most importantly final crop yield and it's quality [2]. The association between yield and yield contributing traits also play an important role in plant breeding programme. However, the simple correlation coefficient does not offer sufficient information about the contribution of each factor towards yield. Although, the method of path coefficient studies is utilized to have an idea of direct and indirect involvement of traits towards the yield [3]. Yield is a complex traits and it is controlled by numerous components that affect it directly or indirectly. Direct and indirect effects contributed by each character towards yield will be a further advantage in aiding the selection process. The correlation and path analysis provides the association between yield and yield components and also carry out the significance of their direct and indirect effects, consequently providing a real understanding of their association through grain yield. Finally, this type of analysis could help the breeder to design his selection schemes to improve grain yield. The advantage of path analysis is that it permits the partitioning of the correlation into its components, one component being the path coefficient that measures the direct effect of a predictor variable upon its response variable, the second component being the indirect effect of a predictor variable on the response variable over another predictor variable [4]. In the field of agriculture, the path coefficient analysis has been used by plant breeders to support in identifying traits that are useful as selection criteria to increase yield [4,5]. The relationship between yield and its main economic components in segregating populations of rice has been studied by several researchers [6,7,8]. The information on the relative direct and indirect contribution of each component character to yield will help breeders to formulate the actual criteria in selecting desirable genotypes in an early segregating generation. Therefore, the present study was planned to determine the correlation, their comparison and path coefficients of yield and yield contributing characters by using F_2 generations derived from BPT-5204/ IR-64Drt1 cross, their two parents separately and the joint parental populations.

2. EXPERIMENTAL DETAILS

The current investigation was carried out at the Rice Research Farm of the Department of Genetics and Plant Breeding, Birsa Agricultural University, Kanke, Ranchi during Kharif, 2019. The experimental site is located at an altitude of 651m above mean sea level and at 23.4345’ N latitude and 85.3214’ E longitude. The segregating rice populations were developed from a cross between BPT-5204 and IR-64Drt1. The selection of parents for crosses was made based on genotypes that were tolerant and susceptible to drought condition. BPT-5204 is drought susceptible and IR-64Drt1 is tolerant to drought. The seeds of F_2 sergeants were raised in the augmented block design-II in nine blocks with seven checks (F_1, IR-64, IR-20, Sahbhagidhan, Vandana, BPT-5204 and IR-64Drt1). All the progenies were sown in the raised bed nursery along with their parents and checks Thirty days old seedlings were transplanted to the main field with a spacing of 20 cm between rows and 15 cm between plants to assist tiller angle observations. The recommended agronomic practices and crop protection measures were followed during the crop growth period. Data on all the fifteen characters were subjected to statistical analysis as correlation coefficient and path coefficient analysis. The correlation coefficients analyses through two independent groups of different sample sizes, comparison between the two correlations were studied. The method to prepare this with the help of transforming the correlation coefficient values (r) into z scores. This transformation is called Fisher's r to z transformation. The computations for testing the significance of the difference between the 15 traits of different populations of rice determined from 324 F_2, 9 IR-64Drt1 (P_1), 9 BPT-5204 (P_2) and 18 joint of both IR-64Drt1 (P_1), BPT-5204 (P_2) genotypes. The observed value of correlation coefficients (r) is first transformed into z with the use of the equation $Z=1/2\{loge(1+r)-loge(1-r)\}$. The standard error of z is $1/\sqrt{N-3}$. The difference of z value was less than its standard error and hence, it may be analyzed that the two values of r were not significantly different [9].

3. RESULTS AND DISCUSSION

3.1 Correlations

The victory of the plant breeding program based greatly on the presence of genetic variability in crops for a particular trait. Selection based on the full knowledge of magnitude and direction of the relationship between yield and its attributes is very important to know their key characters, which can be exploited for crop improvement through a suitable breeding programme. Direct selection of yield displays low effectiveness. Henceforth, the association of selecting was undertaken to determine the direction of selection and number of characters to be considered in improving grain yield (Table 1). Correlation analysis provided reliable information on the consequences of selection for simultaneous enhancement of desirable yield component characters. Before starting the result of correlation, first of all, we should clear knowledge about the genetical basis of correlation. There are three important elements that are responsible for the correlation i.e, linkage, pleiotropy and differential gene expression (Different sets of genes expressed in different environmental condition). A negative correlation arises from the repulsion linkage of genes (s) controlling X1 and X2 traits. Although, a positive correlation occurs due to the coupling phase of linkage. An overview of correlation studies of F_2 segregants indicated that the number of total tillers per plant, number of panicles per plant, plant height, biomass, harvest index, yield per panicle were positively significant associated with yield per plant. A strong correlation of grain yield with these traits indicated that simultaneous improvement of these traits is possible, whereas only days to flowering exhibited significant negative association with it. Plant height, panicle length, biomass and harvest index had a positive and significant correlation with yield per panicle whereas days to flowering, a number of total tillers per plant and number of panicles per plant had a significant negative correlation with yield per panicle. The number of panicles per plant, plant height and panicle length had a positive and significant correlation with harvest index however only days to flowering revealed a significant negative association with it. The number of total tillers per plant, number of panicles per plant and plant height were positive and significant correlation with biomass while days to flowering and grain width exhibited significant negative association with it. The number of total tillers per plant and number of panicles per plant had a positive and significant correlation with an L/B ratio, whereas panicle length, secondary branches per panicle and grain width had a significant negative correlation with L/B ratio. However, panicle length had a positive and significant correlation with grain width. Panicle length had a positive and significant correlation with grain length, but only days to flowering exhibited a significant negative association with it. Primary branches per panicle had a positive and significant correlation with secondary branches per panicle. Panicle length had a negative and significant correlation with primary branches per panicle. The plant height had a positive and significant correlation with Panicle length while only days to flowering exhibited a significant negative association with it. The number of total tillers per plant and number of panicles per plant had a positive and significant correlation with plant height, whereas only days to flowering showed a significant negative correlation with it. The number of total tillers per plant had a positive and significant association with panicles per plant (Table 1). Correlation studied of IR-64Drt1 (P_1) stated that the plant height, panicle length, biomass and harvest index were positively and significantly associated with yield per plant. The plant height had a positive and significant association with harvest index. The secondary branches per panicle had a positive and significant association with hundred-grain weight, whereas only days to flowering revealed a significant negative correlation with it. The primary branches per panicle had a positive and significant association with secondary branches per panicle while only days to flowering shown a significant negative correlation with secondary branches per panicle. The number of total tillers per plant exhibited positive and significant association with panicles per plant (Table 1). Correlation coefficients studied of BPT-5204 (P_2) indicated that the secondary branches per panicle and hundred-grain weight exhibited positive and significant association with yield per panicle. L/B ratio exhibited a negative and significant association with harvest index. L/B ratio had exhibited a positive and significant association with biomass. The grain width had a positive and significant association with the L/B ratio. The days to flowering was indicated a negative and significant association with primary branches per panicle. The plant height had a positive and significant association with panicle length. The number of total tillers per plant showed positive and significant association with panicles per plant (Table 1). Correlation studied of the joint parent of both IR-64Drt1 and BPT-5204 indicated that the plant height, panicle length, grain length, grain width, hundred-grain weight, biomass, harvest index and yield per panicle had exhibited positive and significant association with yield per plant whereas only days to flowering exhibited a significant negative correlation with it. The plant height, panicle length, grain length, grain width, hundred-grain weight and biomass exhibited positive and significant association with yield per panicle however only days to flowering exhibited a significant negative correlation with it. The plant height had shown a positive and significant association along with harvest index. The plant height, panicle length, grain length, grain width, L/B ratio and hundred-grain weight was a positive and significant correlation with biomass, although only days to flowering exhibited a significant negative correlation with biomass. The plant height, panicle length, grain length and grain width had shown a positive and significant association with hundred-grain weight, however, days to flowering exhibited a significant negative correlation with it. The plant height, panicle length and grain length had shown a positive and significant association with grain width while days to flowering exhibited a significant negative correlation with it. The plant height and panicle length had shown positive and significant association with grain length, but days to flowering revealed a significant negative correlation with it. The plant height was revealed a positive and significant correlation with panicle length, although days to flowering revealed a significant negative correlation with it. The days to flowering revealed a significant negative correlation with plant height. The number of total tillers per plant showed positive and significant association with panicles per plant (Table 1). These above correlation results were also similar by several researchers [10,11,12,13,14, 15,16,17].

3.1.1 Comparing correlation coefficients

The correlation value of F_2 and P_1 indicated that the two correlations were significantly different for the trait days to flowering with secondary branches per panicle, grain length and hundred-grain weight. There was also a significant difference seen in trait-like total tillers per plant with a number of panicles per plant, primary branches per panicle and yield per panicle. Similar types of the result also occurred in case of panicles per plant with primary branches per panicle and yield per panicle, plant height with panicle length, secondary branches per panicle, biomass, harvest index, and yield per plant, panicle length with L/B ratio, biomass, harvest index, and yield per plant, primary branches per panicle with secondary branches per panicle and hundred-grain weight, secondary branches per panicle with grain length and hundred-grain weight, biomass with yield per panicle and yield per plant, harvest index with yield per plant, yield per panicle with yield per plant (Table 1). The correlation of F_2 and P_2 shows that there was also significant difference occur for the trait days to flowering with primary branches per panicle, total tillers per plant with secondary branches per panicle, yield per panicle and yield per plant, panicles per plant with secondary branches per panicle, yield per panicle and yield per plant, plant height with panicle length and yield per plant, primary branches per panicle with yield per plant, secondary branches per panicle with hundred-grain weight, harvest index and yield per panicle, grain length with L/B ratio and hundred-grain weight, grain width with biomass and harvest index, L/B ratio with biomass and harvest index, hundred-grain weight with yield per panicle and yield per plant, biomass with harvest index, harvest index with yield per plant, yield per panicle with yield per plant (Table 1). There was also significant difference found on their respective correlation value of F_2 and JP for trait days to flowering with plant height, panicle length, secondary branches per panicle, grain length, grain width, hundred-grain weight, biomass, harvest index, yield per panicle and yield per plant. Likewise, the correlation difference occured in trait total tillers per plant with panicles per plant, primary branches per panicle and yield per panicle, panicles per plant with primary branches per panicle and yield per panicle, plant height with panicle length, secondary branches per panicle, grain length, grain width, hundred-grain weight, biomass, harvest index, yield per panicle and yield per plant, panicle length with grain length, grain width, hundred-grain weight, biomass, harvest index, yield per panicle and yield per plant, primary branches per panicle with secondary branches per panicle, secondary branches per panicle with grain length and grain width, grain length with grain width, hundred-grain weight, biomass, harvest index, yield per panicle and yield per plant, grain width with L/B ratio, hundred-grain weight, biomass, yield per panicle and yield per plant, L/B ratio with biomass and harvest index, hundred-grain weight with biomass, harvest index, yield per panicle and yield per plant, biomass with yield per plant, harvest index with yield per panicle and yield per plant, yield per panicle with yield per plant (Table 1). The correlation value of P_1 and P_2 shown that the two correlations were significantly different for the trait days to flowering with primary branches per panicle, total tillers per plant with panicles per plant, plant height with panicle length, secondary branches per panicle with yield per panicle (Table 1). The correlation value of P_1 and JP shows that the two correlations were significantly different for the trait days to flowering with plant height, panicle length, grain length, grain width and hundred-grain weight. However, in case of total tillers per plant with panicles per plant were also shows that the two correlations are significantly different of these populations P_1 and JP. Similar types of result also shown in case of trait plant height with panicle length, grain length, hundred-grain weight, biomass and yield per plant. Also, a significant difference occurred in the trait of panicle length with grain length, hundred-grain weight and yield per plant. Likewise, the difference of their respective correlation value found in trait grain length with grain width and hundred-grain weight. Too, grain width with hundred-grain weight, biomass and yield per plant had similar types of difference occur. Similar results were also revealed that the hundred-grain weight with biomass and yield per plant had significantly different from their correlation value. Also, the same condition as like above in case of trait biomass with yield per plant and yield per panicle with yield per plant had a significantly different correlation value of P_1 and JP populations (Table 1). The correlation of P_2 and JP shows that the two correlations were significantly different for the trait days to flowering with plant height, panicle length, primary branches per panicle, grain length, grain width, hundred-grain weight, biomass and yield per plant. However, plant height with grain length, hundred-grain weight, biomass and yield per plant were also significantly different for these two populations. Although it had shown that the populations P2 and JP were significantly different for the trait panicle length with grain length, grain width, hundred-grain weight, biomass, yield per panicle and yield per plant, Similar result were also shown in secondary branches per panicle with yield per panicle. Also, correlation difference found in trait grain length with hundred-grain weight and yield per plant, also grain width with hundred-grain weight, harvest index, yield per panicle and yield per plant revealed a difference of their correlation value. Also, a similar result occurred in trait biomass with harvest index, yield per panicle and yield per plant (Table 1).

3.2 Path Analysis

Among yield components, path coefficient analysis helps to partition the overall association of particular variables with the dependent variable into direct and indirect effects. In the F_2 population, path analysis of yield components shown that harvest index had the highest direct positive effect (0.582) on yield per plant. But, the high direct positive effect of this trait was nullified by the negative indirect effect of total tillers per plant, plant height, secondary branches per panicle, grain width, L/B ratio and biomass. The biomass indicated to be the second most important trait, it showed high direct positive effect (0.549) on yield per plant however, its indirect effect via panicles per plant was high (0.140). The panicles per plant had the third most important trait which shows the direct positive effect (0.321) on yield per plant. However, the

Table 1. Correlation coefficients of different trait of rice in different populations

Traits	Pop	DF	TTP	PP	PH	PL	PB	SB	GL	GW	LB	HGW	BM	HI	YN	YL
TTP	**F_2**	-0.06531	1													
	P_1	-0.29734														
	P_2	0.050736														
	JP	0.023542														
PP	**F_2**	-0.10541	0.965204**ac	1												
	P_1	-0.32308	0.996988****de**													
	P_2	0.008107	0.991617**													
	JP	-0.08983	0.987829**													
PH	**F_2**	-0.56202****c**	0.131177*	0.178268**	1											
	P_1	0.277533**e**	0.249483	0.256929												
	P_2	0.305946**f**	0.125713	0.202463												
	JP	-0.81605**	0.026305	0.146991												
PL	**F_2**	-0.28024****c**	-0.05883	-0.04145	0.514387****abc**	1										
	P_1	-0.39276**e**	0.19445	0.194581	0.602482**de**											
	P_2	0.236467**f**	0.006464	0.088185	0.832497**											
	JP	-0.67751**	-0.00331	0.117602	0.8995**											
PB	**F_2**	-0.03883**b**	-0.00182**ac**	0.005024**ac**	-0.08542	-0.18461**	1									
	P_1	-0.38533**d**	0.475824	0.46513	-0.3012	-0.13861										
	P_2	-0.71486**f**	0.291555	0.337324	0.133714	-0.12886										
	JP	-0.19528	0.363531	0.38675	-0.00088	-0.08006										
SB	**F_2**	0.100073**ac**	0.05561**b**	0.040102**b**	-0.0925**ac**	-0.06699	0.590884****ac**	1								
	P_1	-0.75444*	0.208757	0.221507	-0.50829	-0.00813	0.772469*									
	P_2	0.024102	-0.45969	-0.48618	0.279346	0.175632	0.089046									
	JP	0.341707	-0.11124	-0.1637	-0.40924	-0.27152	0.392621									
GL	**F_2**	-0.12463***ac**	0.022634	0.030851	0.067975**c**	0.121701***c**	0.015436	-0.01655**ac**	1							
	P_1	-0.47967**e**	0.064024	0.03618	-0.44341**e**	0.163749**e**	0.31081	0.571068								
	P_2	-0.3425**f**	-0.32313	-0.25344	0.420183**f**	0.437728**f**	0.323755	0.421717								
	JP	-0.9514**	-0.07086	0.040335	0.911332**	0.777185**	0.046922	-0.37842								
GW	**F_2**	-0.00014**c**	-0.0125	-0.01803	-0.01061**c**	0.203745****c**	-0.09559	-0.06215**c**	0.055016**c**	1						
	P_1	0.270402**e**	-0.15148	-0.194	-0.1435	0.096979	0.258826	0.073118	0.290582**e**							
	P_2	0.085162**f**	0.041377	0.046064	-0.17035	-0.20366**f**	-0.16384	-0.36274	0.167848							
	JP	-0.80629**	-0.05431	0.032394	0.76804**	0.619786**	0.012365	-0.45132	0.884258**							
LB	**F_2**	0.041379	0.126634*	0.111222*	-0.02813	-0.11889***a**	0.029583	-0.113*	0.060532**b**	-0.16269****c**	1					
	P_1	-0.06571	0.421582	0.427768	-0.22628	-0.49559	0.395038	0.407636	0.197638	-0.29586						
	P_2	0.044115	-0.1572	-0.09157	0.204787	0.022934	0.117128	-0.3333	0.312732	0.704296*						
	JP	-0.25313	0.003286	0.079794	0.29281	0.16493	0.199952	-0.15062	0.311144	0.404766						
HGW	**F_2**	0.046402**ac**	0.065365	0.04671	-0.0529**c**	-0.08418**c**	0.027095**a**	0.062309**ab**	-0.0441**bc**	0.002711**c**	0.100094	1				
	P_1	-0.70344***e**	0.037375	0.034739	-0.27715**e**	0.200445**e**	0.625879	0.732683*	0.397108**e**	-0.08832**e**	-0.01782					
	P_2	0.316744**f**	0.007708	-0.05369	0.085378**f**	-0.23162**f**	0.13567	0.544162	0.119185**f**	0.211157**f**	0.126022					
	JP	-0.9335**	-0.04042	0.060299	0.902666**	0.730939**	0.036165	-0.37932	0.985166**	0.87863**	0.28275					
BM	**F_2**	-0.12909***c**	0.382169**	0.436212**	0.328971****ac**	0.090073**ac**	-0.04236	-0.03365	0.027351**c**	-0.11808***bc**	0.078229**bc**	0.085821**c**	1			
	P_1	-0.30377	0.136478	0.152734	0.477321**e**	0.659308	-0.0821	0.231712	0.287694	-0.01077**e**	0.162821	0.033098**e**				
	P_2	-0.03384**f**	0.207491	0.249339	0.1884**f**	0.065747**f**	0.361276	-0.21273	0.341771	0.59699	0.738355*	0.428629				
	JP	-0.63635**	0.111293	0.204452	0.669464**	0.575186*	0.13556	-0.28832	0.673508**	0.692973**	0.585518*	0.667385**				
HI	**F_2**	-0.31565****c**	0.062931	0.11702*	0.351417****ac**	0.15741****ac**	0.092051	-0.02472**b**	-0.00337**c**	0.016925**b**	0.038854**bc**	-0.0169**c**	-0.07421**b**	1		
	P_1	0.155879	0.159031	0.136097	0.751441*	0.549342	-0.08904	-0.40273	-0.2801	-0.11484	-0.40977	0.187628	0.107131			
	P_2	0.226591	0.241712	0.203033	0.330457	0.137553	0.014243	0.462287	-0.21337	-0.64957**f**	-0.6875*	0.091733	-0.66108**f**			
	JP	-0.32845	0.178532	0.191538	0.536157*	0.431787	-0.01695	-0.08517	0.38006	0.163892	-0.4304	0.425204	-0.03307			

YN	**F_2**	-0.16553** **c**	-0.21871**abc	-0.17638** **abc**	0.312149** **c**	0.128555**c**	0.051803	-0.06363**b**	0.036177**c**	-0.01752**c**	0.065707	-0.06831**bc**	0.270291** **a**	0.571853** **c**	1	
	P_1	0.224166	-0.6212	-0.60827	0.399783	0.241838	-0.3228	-0.11489**d**	-0.11215	-0.00626	-0.15193	0.044761	0.524989	0.265021		
	P_2	0.294118	-0.46802	-0.5018	0.278475	-0.02313**f**	-0.06935	0.812367** **f**	0.306396	0.036368**f**	0.066915	0.689171*	-0.07054**f**	0.352621		
	JP	-0.51066*	-0.42899	-0.37106	0.640721**	0.483407*	-0.17136	-0.13956	0.604823**	0.534063*	0.136496	0.629064**	0.542933*	0.43953		
YL	**F_2**	-0.3135** **c**	0.270286** **b**	0.358425** **b**	0.468907** **abc**	0.201909**ac**	0.081803**b**	-0.00334	0.001311**c**	-0.09196**c**	0.062053	0.027404**bc**	0.595529** **ac**	0.661069** **abc**	0.637292** **abc**	1
	P_1	-0.0522	0.167421	0.167079	0.849965** **e**	0.781738* **e**	-0.12297	-0.12719	-0.04498	-0.07892**e**	-0.15021	0.109101**e**	0.758249* **e**	0.722003*	0.583814**e**	
	P_2	0.156741**f**	0.516733	0.498461	0.482944**f**	0.037039**f**	0.48436	0.380313	0.069896**f**	-0.11662**f**	-0.07002	0.651901	0.215397**f**	0.567335	0.449542	
	JP	-0.74865**	0.152204	0.232728	0.869451**	0.695474**	0.078009	-0.3284	0.797406**	0.681783**	0.166113	0.825373**	0.736219**	0.636512**	0.74363**	

***and *shows significant at 1 and 5% level respectively, table value of F_2 segregants 0.1097 at 5% and 0.1436 at 1% level for n-2 degree of freedom, table value of IR-64Drt1 (P_1) 0.666 at 5% and 0.798 at 1% level for n-2 degree of freedom, table value of BPT-5204 (P_2) 0.666 at 5% and 0.798 at 1% level for n-2 degree of freedom and table value of joint parent BPT-5204 and IR-64Drt1 0.468 at 5% and 0.590 at 1% level for n-2 degree of freedom for correlation testing, a= shows significant correlation difference between F_2 and P_1, b =F_2 and P_2, c= F_2 and JP, d= P_1 and P_2, e= P_1 and JP, f= P_2 and JP, DF= days to flowering, TTP = total tiller per plant, PP= panicles per plant, PH= plant height, PL= panicle length, PB= primary branches per panicle, SB= secondary branches per panicle, GL= grain length, GW= grain width, LB= L/B ratio, HGW=hundred grain weight, BM= biomass, HI= harvest index, YN=yield per panicle, YL=yield per plant, Pop=population F_2= segregants of BPT-5204/IR-64Drt1, P_1= IR-64Drt1, P_2= BPT-5204, JP=joint parent P_1 and P_2.*

Table 2. Direct and indirect effects of different traits on yield in F_2 population of rice

Traits	DF	TTP	PP	PH	PL	PB	SB	GL	GW	LB	HGW	BM	HI	YN	r-values
DF	**-0.01451803**	0.015946	-0.03384	0.015894	-0.01919	-0.00148	0.001592	0.003347	5.75E-06	-0.00065	0.000242	-0.07094	-0.18389	-0.02601	-0.3135
TTP	0.000948145	**-0.24416**	0.309842	-0.00371	-0.00403	-6.9E-05	0.000885	-0.00061	0.000527	-0.002	0.000341	0.210018	0.036663	-0.03436	0.270286
PP	0.001530409	-0.23566	**0.321012**	-0.00504	-0.00284	0.000192	0.000638	-0.00083	0.00076	-0.00176	0.000244	0.239717	0.068174	-0.02771	0.358425
PH	0.008159391	-0.03203	0.057226	**-0.02828**	0.035219	-0.00327	-0.00147	-0.00183	0.000447	0.000445	-0.00028	0.180784	0.204732	0.04904	0.468907
PL	0.004068594	0.014363	-0.01331	-0.01455	**0.068468**	-0.00706	-0.00107	-0.00327	-0.00859	0.001881	-0.00044	0.049499	0.091705	0.020197	0.201909
PB	0.000563751	0.000444	0.001613	0.002416	-0.01264	**0.038232**	0.009398	-0.00041	0.004031	-0.00047	0.000141	-0.02328	0.053628	0.008138	0.081803
SB	-0.00145287	-0.01358	0.012873	0.002616	-0.00459	0.02259	**0.015906**	0.000444	0.00262	0.001788	0.000325	-0.01849	-0.0144	-0.01	-0.00334
GL	0.001809324	-0.00553	0.009904	-0.00192	0.008333	0.00059	-0.00026	**-0.02686**	-0.00232	-0.00096	-0.00023	0.015031	-0.00196	0.005684	0.001311
GW	1.97884E-06	0.003052	-0.00579	0.0003	0.01395	-0.00365	-0.00099	-0.00148	**-0.04216**	0.002575	1.41E-05	-0.06489	0.00986	-0.00275	-0.09196
LB	-0.00060075	-0.03092	0.035703	0.000796	-0.00814	0.001131	-0.0018	-0.00163	0.00686	**-0.01582**	0.000522	0.04299	0.022636	0.010323	0.062053
HGW	-0.00067366	-0.01596	0.014995	0.001496	-0.00576	0.001036	0.000991	0.001184	-0.00011	-0.00158	**0.005214**	0.047162	-0.00985	-0.01073	0.027404
BM	0.001874106	-0.09331	0.140029	-0.0093	0.006167	-0.00162	-0.00054	-0.00073	0.004979	-0.00124	0.000447	**0.549543**	-0.04323	0.042464	0.595529
HI	0.004582586	-0.01537	0.037565	-0.00994	0.010778	0.003519	-0.00039	9.04E-05	-0.00071	-0.00061	-8.8E-05	-0.04078	**0.582588**	0.089841	0.661069
YN	0.00240321	0.053399	-0.05662	-0.00883	0.008802	0.00198	-0.00101	-0.00097	0.000739	-0.00104	-0.00036	0.148537	0.333155	**0.157106**	0.637292

Residual effect, R= 0.356; DF= days to flowering, TTP = total tiller per plant, PP= panicles per plant, PH= plant height, PL= panicle length, PB= primary branches per panicle, SB= secondary branches per panicle, GL= grain length, GW= grain width, LB= L/B ratio, HGW=hundred grain weight, BM= biomass, HI= harvest index, YN=yield per panicle

Table 3. Direct and indirect effects of different traits on yield in parent IR-64 Drt1 variety

Traits	DF	TTP	PP	PH	PL	PB	SB	GL	GW	LB	HGW	BM	HI	YN	r-values
DF	**-0.34291**	0.386888	-0.47865	0.254804	0.209743	0.333555	0.014948	2.12E-05	0.196724	-0.02271	-0.54699	-0.107	0.053953	-0.00458	-0.0522
TTP	0.10196	**-1.30116**	1.47705	0.229051	-0.10384	-0.41189	-0.00414	-2.8E-06	-0.11021	0.14573	0.029062	0.048072	0.055044	0.012688	0.167421
PP	0.110787	-1.29724	**1.481513**	0.235887	-0.10391	-0.40263	-0.00439	-1.6E-06	-0.14114	0.147868	0.027013	0.053798	0.047106	0.012424	0.167079
PH	-0.09517	-0.32462	0.380644	**0.918102**	-0.32174	0.260729	0.010071	1.96E-05	-0.1044	-0.07822	-0.21551	0.168129	0.260089	-0.00817	0.849965
PL	0.134681	-0.25301	0.288274	0.55314	**-0.53402**	0.119986	0.000161	-7.3E-06	0.070555	-0.17131	0.155864	0.232232	0.190138	-0.00494	0.781738
PB	0.132133	-0.61912	0.689096	-0.27653	0.074021	**-0.86563**	-0.0153	-1.4E-05	0.188302	0.136554	0.486677	-0.02892	-0.03082	0.006593	-0.12297
SB	0.258704	-0.27163	0.328165	-0.46666	0.004342	-0.66868	**-0.01981**	-2.5E-05	0.053195	0.140909	0.569727	0.081617	-0.13939	0.002347	-0.12719
GL	0.164483	-0.08331	0.053601	-0.4071	-0.08745	-0.26905	-0.01131	**-4.4E-05**	0.211406	0.068318	0.308787	0.101336	-0.09695	0.002291	-0.04498
GW	-0.09272	0.1971	-0.28741	-0.13175	-0.05179	-0.22405	-0.00145	-1.3E-05	**0.727525**	-0.10227	-0.06868	-0.00379	-0.03975	0.000128	-0.07892
LB	0.022533	-0.54855	0.633744	-0.20775	0.264656	-0.34196	-0.00808	-8.8E-06	-0.21525	**0.345673**	-0.01386	0.057351	-0.14183	0.003103	-0.15021
HGW	0.241216	-0.04863	0.051466	-0.25445	-0.10704	-0.54178	-0.01452	-1.8E-05	-0.06426	-0.00616	**0.77759**	0.011658	0.064942	-0.00091	0.109101
BM	0.104165	-0.17758	0.226277	0.43823	-0.35209	0.071069	-0.00459	-1.3E-05	-0.00784	0.056283	0.025737	**0.352236**	0.03708	-0.01072	0.758249
HI	-0.05345	-0.20693	0.201629	0.6899	-0.29336	0.077076	0.007979	1.24E-05	-0.08355	-0.14165	0.145898	0.037735	**0.34612**	-0.00541	0.722003
YN	-0.07687	0.808282	-0.90116	0.367042	-0.12915	0.279427	0.002276	4.97E-06	-0.00455	-0.05252	0.034806	0.18492	0.091729	**-0.02042**	0.583814

Residual effect, R= 0.002; DF= days to flowering, TTP = total tiller per plant, PP= panicles per plant, PH= plant height, PL= panicle length, PB= primary branches per panicle, SB= secondary branches per panicle, GL= grain length, GW= grain width, LB= L/B ratio, HGW=hundred grain weight, BM= biomass, HI= harvest index, YN=yield per panicle

Table 4. Direct and indirect effects of different traits on yield in parent BPT- 5204 variety

Traits	DF	TTP	PP	PH	PL	PB	SB	GL	GW	LB	HGW	BM	HI	YN	r-values
DF	**-1.14161**	0.092394	-0.01095	0.255887	0.016304	0.376655	-0.02603	1.35E-05	-0.04033	0.003965	0.417631	0.010511	0.020668	0.181633	0.156741
TTP	-0.05792	**1.821082**	-1.3399	0.105144	0.000446	-0.15362	0.496476	1.27E-05	-0.01959	-0.01413	0.010163	-0.06445	0.022047	-0.28903	0.516733
PP	-0.00926	1.805816	**-1.35123**	0.169336	0.00608	-0.17773	0.525086	9.97E-06	-0.02181	-0.00823	-0.07079	-0.07745	0.018519	-0.30989	0.498461
PH	-0.34927	0.228934	-0.27357	**0.836378**	0.0574	-0.07045	-0.3017	-1.7E-05	0.080672	0.018406	0.112572	-0.05852	0.030141	0.171973	0.482944
PL	-0.26995	0.011771	-0.11916	0.696282	**0.068949**	0.067896	-0.18969	-1.7E-05	0.096447	0.002061	-0.30539	-0.02042	0.012546	-0.01428	0.037039
PB	0.816089	0.530946	-0.4558	0.111835	-0.00888	**-0.52689**	-0.09617	-1.3E-05	0.077589	0.010527	0.178883	-0.11222	0.001299	-0.04283	0.48436
SB	-0.02751	-0.83713	0.656939	0.233639	0.01211	-0.04692	**-1.08002**	-1.7E-05	0.171782	-0.02996	0.717485	0.066077	0.042166	0.501679	0.380313
GL	0.391	-0.58845	0.342455	0.351432	0.030181	-0.17058	-0.45546	**-3.9E-05**	-0.07949	0.028108	0.157147	-0.10616	-0.01946	0.189216	0.069896
GW	-0.09722	0.075351	-0.06224	-0.14248	-0.01404	0.086326	0.391768	-6.6E-06	**-0.47357**	0.063301	0.278413	-0.18543	-0.05925	0.022459	-0.11662
LB	-0.05036	-0.28627	0.123732	0.171279	0.001581	-0.06171	0.359972	-1.2E-05	-0.33353	**0.089878**	0.166162	-0.22934	-0.06271	0.041324	-0.07002
HGW	-0.3616	0.014037	0.072547	0.071408	-0.01597	-0.07148	-0.58771	-4.7E-06	-0.1	0.011327	**1.318514**	-0.13314	0.008367	0.425599	0.651901
BM	0.038632	0.377858	-0.33691	0.157574	0.004533	-0.19035	0.229754	-1.3E-05	-0.28272	0.066362	0.565153	**-0.31061**	-0.0603	-0.04356	0.215397
HI	-0.25868	0.440177	-0.27434	0.276387	0.009484	-0.0075	-0.49928	8.4E-06	0.307615	-0.06179	0.120951	0.20534	**0.091211**	0.217762	0.567335
YN	-0.33577	-0.8523	0.678045	0.23291	-0.00159	0.03654	-0.87738	-1.2E-05	-0.01722	0.006014	0.908681	0.021911	0.032163	**0.617553**	0.449542

Residual effect, R= 0.001; DF= days to flowering, TTP = total tiller per plant, PP= panicles per plant, PH= plant height, PL= panicle length, PB= primary branches per panicle, SB= secondary branches per panicle, GL= grain length, GW= grain width, LB= L/B ratio, HGW=hundred grain weight, BM= biomass, HI= harvest index, YN=yield per panicle

Table 5. Direct and indirect effects of different traits on yield in joint both parents

Traits	DF	TTP	PP	PH	PL	PB	SB	GL	GW	LB	HGW	BM	HI	YN	r-values
DF	**-0.35352**	0.009537	0.038414	-0.08212	0.037787	0.004317	-0.01353	0.303249	-0.07196	-0.01234	0.055728	-0.41876	-0.21051	-0.03494	-0.74865
TTP	-0.00832	**0.405119**	-0.42241	0.002647	0.000184	-0.00804	0.004404	0.022587	-0.00485	0.00016	0.002413	0.073238	0.114424	-0.02936	0.152204
PP	0.031758	0.400188	**-0.42762**	0.014792	-0.00656	-0.00855	0.00648	-0.01286	0.002891	0.003889	-0.0036	0.134542	0.122759	-0.02539	0.232728
PH	0.288492	0.010657	-0.06286	**0.10063**	-0.05017	1.95E-05	0.0162	-0.29048	0.068547	0.01427	-0.05389	0.44055	0.343631	0.043844	0.869451
PL	0.239516	-0.00134	-0.05029	0.090516	**-0.05577**	0.00177	0.010748	-0.24772	0.055315	0.008038	-0.04364	0.378509	0.276739	0.033079	0.695474
PB	0.069036	0.147273	-0.16538	-8.9E-05	0.004465	**-0.0221**	-0.01554	-0.01496	0.001104	0.009745	-0.00216	0.089207	-0.01086	-0.01173	0.078009
SB	-0.1208	-0.04507	0.069999	-0.04118	0.015144	-0.00868	**-0.03959**	0.120617	-0.04028	-0.00734	0.022645	-0.18973	-0.05459	-0.00955	-0.3284
GL	0.336343	-0.02871	-0.01725	0.091707	-0.04335	-0.00104	0.01498	**-0.31874**	0.078919	0.015164	-0.05881	0.443211	0.243586	0.041387	0.797406
GW	0.285042	-0.022	-0.01385	0.077288	-0.03457	-0.00027	0.017866	-0.28185	**0.089249**	0.019726	-0.05245	0.45602	0.10504	0.036545	0.681783
LB	0.089489	0.001331	-0.03412	0.029465	-0.0092	-0.00442	0.005962	-0.09917	0.036125	**0.048736**	-0.01688	0.385308	-0.27585	0.00934	0.166113
HGW	0.330013	-0.01637	-0.02578	0.090835	-0.04077	-0.0008	0.015015	-0.31401	0.078417	0.01378	**-0.0597**	0.439182	0.27252	0.043046	0.825373
BM	0.224965	0.045087	-0.08743	0.067368	-0.03208	-0.003	0.011413	-0.21467	0.061847	0.028536	-0.03984	**0.658063**	-0.02119	0.037152	0.736219
HI	0.116116	0.072327	-0.0819	0.053953	-0.02408	0.000375	0.003371	-0.12114	0.014627	-0.02098	-0.02538	-0.02176	**0.640915**	0.030076	0.636512
YN	0.180528	-0.17379	0.158671	0.064476	-0.02696	0.003788	0.005525	-0.19278	0.047665	0.006652	-0.03755	0.357284	0.281701	**0.068429**	0.74363

Residual effect, R= 0.06; DF= days to flowering, TTP = total tiller per plant, PP= panicles per plant, PH= plant height, PL= panicle length, PB= primary branches per panicle, SB= secondary branches per panicle, GL= grain length, GW= grain width, LB= L/B ratio, HGW=hundred grain weight, BM= biomass, HI= harvest index, YN=yield per panicle high direct positive effect of this trait was nullified by the negative indirect effect of total tillers per plant, plant height, panicle length, grain length, L/B ratio and yield per panicle however its indirect effect via biomass was high (0.239). Results on the importance of the direct effect of panicles per plant were reported by numerous researchers [13,17,18,19,20]. The residual effect was 0.356, which shown that the contribution of component traits on yield per plant was 87.33 per cent by fourteen traits studied in path analysis (Table 2). In IR-64Drt1 population, path coefficient analysis of yield components stated that the panicles per plant had the highest direct positive effect (1.481) on yield per plant. The high direct positive effect of this trait was nullified by the negative indirect effect of total tillers per plant, panicle length, primary branches per panicle, secondary branches per panicle, grain length and grain width although, its indirect effect via plant height was high (0.235). The plant height shown to be the second most important trait, it showed high direct positive effect (0.918) on yield per plant but the high direct positive effect of this trait was nullified by the negative indirect effect of days to flowering, total tiller per plant, panicle length, grain width, L/B ratio, hundred-grain weight and yield per panicle however its indirect effect via panicles per plant was high (0.380). The direct effect of hundred-grain weight on yield per plant was positive (0.777), but the direct positive effect of this trait was nullified by the negative indirect effect of total tiller per plant, plant height, panicle length, primary branches per panicle, secondary branches per panicle, grain length, grain width, L/B ratio and yield per panicle however its indirect effect via days to flowering was high (0.241). The direct effect of grain width on yield per plant was positive (0.727), however, it showed a high indirect positive effect on it through the total tillers per plant (0.197). However, the negative indirect effect of days to flowering, panicles per plant, plant height, panicle length, primary branches per panicle, secondary branches per panicle, grain length, L/B ratio, hundred-grain weight, biomass and harvest index were also observed. The direct effect of biomass on yield per plant was positive (0.352) thus the indirect effect on it through the plant height was high (0.438). The direct effect of harvest index on yield per plant was positive (0.346) therefore the indirect effect on it through the plant height was high (0.689). The residual effect was 0.002, which indicated that the contribution of component traits on yield per plant was 99.99 per cent by fourteen traits studied in path analysis (Table 3). In BPT-5204 population, path analysis of yield components shown that the total tillers per plant had a highest direct positive effect (1.821) on yield per plant but it showed a high indirect positive effect on it through the secondary branches per panicle (0.496). The second highest direct positive effect of hundred-grain weight on yield per plant was (1.318) but it showed a high indirect positive effect on it through the yield per panicle (0.425). The direct effect of plant height on yield per plant was positive (0.836), however, it showed an indirect positive effect on it through the total tillers per plant (0.228). The direct effect of yield per panicle on yield per plant was positive (0.617) but it showed a high indirect positive effect on it through the hundred-grain weight (0.908). The residual effect was 0.001, which shown that the contribution of component traits on grain yield was 99.99 per cent by fourteen traits studied in path analysis (Table 4). In the joint population of BPT-5204 and IR-64Drt1, path analysis of yield components revealed that the biomass had a highest direct positive effect (0.658) on yield per plant, however, it showed a high indirect positive effect on it through the days to flowering (0.224). The direct effect of harvest index on yield per plant was also positive (0.640) although, days to flowering was show indirect positive effect (0.180) on it. The direct effect of total tiller per plant on yield per plant was positive (0.405), however, it showed a high indirect positive effect on it through the harvest index (0.114). The residual effect was 0.066, which indicated that the contribution of component traits on yield per plant was 99.56 per cent by fourteen traits studied in path analysis (Table 5).

4. CONCLUSION

From this experiment, it can be concluded that the traits plant height, biomass, harvest index and yield per panicle were positive and significant association with yield per plant in the F_2 and joint parental population. However, traits, plant height, biomass and harvest index were also exhibited positive and significant association with yield per plant in the F_2, IR-64Drt1 and joint parental population. An overall consideration of the results stated that the harvest index, biomass and panicles per plant are the most important characters that contribute directly to yield per plant. According to the above results, selection indices should be formulated using these traits for yield improvement at segregating populations of rice.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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