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Genetic parameters and character association studies in rice (*Oryza sativa* L.)

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Abstract
The genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability, genetic advance, correlation and direct and indirect effect of different yield and yield attributing traits of 36 rice genotypes were studied. Among the traits number of productive tillers and number of total tillers had high genotypic and phenotypic coefficient of variation. High positive correlation was found for the traits *viz.,* panicle weight, number of grains per panicle and number of filled grains with single plant yield. But grain length, grain breadth and seed weight had high negative correlation with single plant yield. Path coefficient analysis showed that number of productive tillers, days to maturity and grain weight had high direct effect on grain yield per plant. Among the different traits studied, maximum indirect effect on grain yield was found with total tillers per plant followed by days to maturity. Here priority should be given for all these characters during selection for the improvement of grain yield.

Keywords: GCV, PCV, heritability, genetic advance, correlation and path coefficient analysis

Introduction
Rice is the most important food crop, since more than half of the world's population depends on rice for food calorie and protein. By the year 2025, the world will need about 760 million tonnes of paddy, in order to meet the growing demand (Duwayri *et al.*, 2000) [1]. To feed the ever increasing population, yield potential of rice should be improved through evolution of new breeding lines. Grain yield is the primary targeted trait for improvement of rice at both favourable and unfavourable condition (Tiwari *et al.*, 2011) [2]. Knowledge on genetic variability existing in the population and association between the yield and its related characters is very important for the development of high yielding varieties in future.
Estimation of genetic variability in polygenic traits is the key component of breeding programmes for broadening the gene pool of rice.
Association analysis is to determine the direction of selection and number of characters to be considered in improving grain the yield. The existence of correlation may be attributed to the presence of linkage or pleiotropic effect of genes or physiological and development relationship or environmental effect or in combination of all. Path coefficient analysis provides a direct and indirect effect and also observed a critical examination of specific forces to give correlation and measures the relative importance of each factor (Kishore *et al.*, 2015) [3]. Therefore, the present study was undertaken to determine the genetic parameters, correlation coefficient and path analysis among quantitative traits for isolation of superior genotypes in mutant lines of Anna (R) 4 derived through EMS treated, gamma ray and electron beam irradiation.

Materials and Methods
The present investigation was conducted at Agricultural College and Research Institute, Madurai. The experimental material consists of 35 genotypes which includes 12 advanced breeding lines (M_7 generation) derived from Anna (R) 4 EMS induced mutant lines, 7 homozygous lines (F_5 generation) of MDU 6 x *Jaldi Dhan* 6 and one homozygous line (F_5 generation) of TKM 6 x *Jaldi Dhan* 6 and 15 mutant lines (M_4 generation) of Anna (R) 4 irradiated entries derived from gamma irradiation (8 entries) and Electron beam irradiation (7 entries). These materials were evaluated with the check variety Anna (R) 4. These breeding materials are early maturing genotypes with drought tolerance. The crop was raised in *Kharif*, 2019 with a spacing of 25 cm between row to row and 15 cm between plant to plant in Randomized Block Design (RBD) with two replications. Each genotype consists of three rows with 3m length in both the replication.

Totally seventeen quantitative characters were recorded at appropriate crop stages based on Standard Evaluation System of rice (IRRI, 2013). From each genotype five plants were randomly selected and the yield and yield attributing traits were recorded. The characters measured were plant height on 50^{th} day (cm), days to fifty per cent flowering (days), SPAD meter value, plant height (cm) at mature stage, panicle length (cm), flag leaf length (cm), flag leaf breadth (cm), total tillers, productive tillers, days to maturity (days), panicle weight (g), number of grains per panicle, number of filled grains, grain length (cm), grain breadth (cm), hundred seed weight (g) and single plant yield (g).

Analysis of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (GCV), broad sense heritability (h^2), and genetic advance as per cent of mean, genotypic and phenotypic correlation, direct and indirect effect of different characters on yield was done by using the software GENRES, version 7.01.

Result and discussion

Variability, heritability and genetic advance

Genetic variations measured as PCV, GCV, broad sense heritability (h^2) and genetic advance as per cent of mean designates a wide range of variability among 36 genotypes for 17 yield component traits (Table 1).

The phenotypic coefficient of variation was higher than genotypic coefficient of variation for panicle weight and seed yield. It reveals that environmental influence on expression of that particular character (Mishra *et al.*, 2019) [4]. The environmental effect on any particular character depends on range of difference between genotypic coefficient of variation and phenotypic coefficient of variation. Other traits showed minimum difference between genotypic coefficient of variation and phenotypic coefficient of variation indicates involvement of environment effect on expression of those traits is small. These similar findings were also reported by Hossain *et al.* (2018) [5].

In this present study, number of total tillers and number of productive tillers were measured as high GCV and PCV values (Table 1 & Fig.1). It point towards the variability observed in 36 genotypes was high and so selection would be more effective for tiller numbers. The moderate genotypic coefficient of variation and phenotypic coefficient of variation values were observed for the traits number of filled grains followed by number of grains per panicle, single plant yield and grain weight. Hossain *et al.* (2018) [5] and Aditya and Bhartiya, (2013) [6] also reported moderate to high GCV and PCV values of number of grains per panicle and yield per plant. The lowest GCV and PCV values were found with days to maturity, followed by plant height, days to fifty per cent flowering and grain length. The same results also supported by Hossain *et al.* (2018) [5].

Estimation of heritability helps to select the elite genotypes, in which those characters having very high and high heritability are greater than 80% and 60-80% respectively is specifies that character is less influenced by environmental effect. Selection of genotypes based on heritability without genetic advance leads inappropriate selection because heritability includes both the effect of additive and non- additive gene action (Aditya and Bhartiya, (2013) [6]. In order to get better selection efficiency, select those traits exhibits high heritability along with high genetic advance will give effective improvement. In this experiment high heritability was observed in seed weight (96.45) followed by plant height on 50^{th} day, number of grains per panicle, flag leaf breadth and days to fifty per cent flowering (Table 1). Akinwale *et al.* (2011) [7] and Hossain *et al.* (2018) [5] also reported days to fifty per cent flowering and number of grains per panicle respectively having high heritability. High heritability combined with high genetic advance was found in total tillers followed by productive tillers, filled grains and number of grains per panicle. So it's simply conveys that these traits are controlled by additive gene action and selection remains effective. Hence during selection more importance has to be given to these traits for selecting better rice genotypes.

Correlation analysis

Association between yield and component traits

Number of filled grains had highly positive association with single plant yield both genotypic and phenotypic level which also implied the importance of characters for grain yield improvement**.** The higher genotypic correlation coefficient (r_g) than the phenotypic correlation coefficient (r_p) reveals the association between these two traits is due to genetic control and the phenotypic value is narrowed by environmental influence. These findings were earlier reported by Kalyan *et al.* (2017) [8].

Number of grains per panicle had positive correlation with single plant yield at genotypic and phenotypic level. Lalitha *et al.* (2019) [9], also observed same results of positive correlation between single plant yield and number of grains per panicle. Number of filled grains had highly positive association with number of grains per panicle, because number of filled grains is determined by product of seed setting rate and number of grains per panicle. Hence the number of grains per panicle is influenced by panicle architecture like panicle number, compactness and branching types. So it is directly contributed to higher grain yield compare with other yield contributing traits (Li *et al.*, 2019) [10].

The panicle weight exhibit positive genotypic correlation with single plant yield, but there is no significant correlation were observed between single plant yield and panicle weight at phenotypic level. Positive genotypic correlation between these traits was earlier reported by Awasthi and Lal, (2014) [11]. Grain length, grain breath and seed weight unveiled high negative association with single plant yield at genotypic and phenotypic level and also exhibit negative and significant correlation at phenotypic level for these three traits. The same negative association for single plant yield and grain weight was computed by Saha *et al.* (2019) [12]. Number of grains per panicle increased with decrease in size of the grains but yield per plant decreased with increasing small grains. The smaller grain size of majority of selected mutants may be the reason behind this (Saha *et al.*, 2019) [12].

Genotypic correlation between yield component traits

Plant height on 50^{th} day had highly positive association with plant height at maturity, panicle length, flag leaf length, grain length and also positive association with grain breadth and seed weight. Days to maturity had significant and positive correlation with days to 50% flowering and flag leaf breadth. Saha *et al.* (2019) [12] also reported for days to 50% flowering and Aditya and Bhartiya, (2013) [6] for flag leaf breadth. Significant positive correlation of SPAD value with number of grains per panicle and number of filled grains per panicle observed in present study is in accordance with the report of Nithya *et al.* (2020) [13]. Because SPAD meter value of particular genotype directionally proportional to total chlorophyll content present in the leaf. Evans and Dunstone,

(1970) [14] reported small leaves contained high concentration of chlorophyll content in diploid and tetraploid wheat.

Plant height exhibit highly positive correlation with flag leaf length and positive relationship with panicle length. The positive correlation of plant height with panicle length was earlier supported by Parimala *et al.,* (2020) [15] and for plant height with flag leaf length was given by Devi *et al.* (2017) [16] and Kishore *et al.* (2018) [17]. Panicle length had a highly positive correlation with flag leaf length, panicle weight, grain length and seed weight. Similar findings were reported by Devi *et al.* (2019) [18] for flag leaf length and Bhutta *et al.* (2019) [19], Devi *et al.* (2019) [18] for panicle weight, Idris *et al.* (2012) [20] for grain length and seed weight were earlier found Devi *et al.* (2019) [18] and Bhutta *et al.* (2019) [19]. Ashrafuzzaman *et al.* (2009) [21] reported yield and yield traits had positive correlation with flag leaf area, because flag leaf is the trait which gives the photosynthetic to the grains. It was previously studied by Asana (1968) [22]. Rafiq *et al.* (2014) [23] found that increased flag leaf length would increases panicle length with increased number of branches which directly influences the grain yield.

The trait flag leaf breadth showed high positive association between days to maturity, panicle weight, grain breadth and seed weight. Positive correlation for panicle weight with flag leaf breadth was also reported by Devi *et al.* (2019) [18]. Productive tillers and total tillers which had highest positive and significant correlation and this were previously mentioned by Kalyan *et al.* (2017) [8] and Saha *et al.* (2019) [12]. Days to maturity had positive correlation with panicle weight; and panicle weight exhibit highly positive relationship with grain length and seed weight. In the current study, number of grains per panicle had significant positive correlation with number of filled grains per panicle. Similar results were previously observed by Saha *et al.* (2019) [12] and Parimala *et al.* (2020) [15]. This indicate that spikelet fertility led to higher seed set which in turn resulted in more number of filled grains per panicle.

In this present study seed weight exhibited high positive correlation with both grain length and grain breadth. Sakamoto and Matsuoka, (2008) [24] reported higher night temperature at the time of grain filling stage leads to reduction in dry matter production, grain length and breadth, so it may reduce the grain yield of the plant.

Path coefficient analysis

The direct and indirect effects of each independent variable in the direction of single plant yield is not clearly given by correlation, and so path coefficient analysis split up the direct and indirect effect of each character on single plant yield. So selection of superior genotypes with true relationship and characters association among diverse genotypes is easiest.

Direct effect

Among the seventeen characters, number of productive tillers exhibited positive and very high (5.062) directs effect on single plant yield, followed by days to maturity (3.721), seed weight (2.004), flag leaf length (1.241), plant height on 50th day (1.180) and SPAD value (1.037) (Table 3). The trait filled grains (0.968) had positive and high direct effect towards yield. Here the association between seed weight and single plant yield is under negative relationship but direct effect of seed weight on grain yield is positive. Hence, to reduce the undesirable indirect effect, direct selection for this trait has to be followed.

The trait total tillers (4.504) had negative but very high indirect effect on single plant yield followed by flag leaf breadth (1.471), plant height (1.462) and days to fifty per cent flowering (1.393).

Indirect effect

Days to maturity had positive and very high indirect effect on single plant yield through days to maturity (3.658) followed by total tillers (1.944). Plant height showed highly positive and indirect effect through plant height on 50th day (0.684). The same rationalization was earlier reported by Srijan *et al.* (2016).The indirect effect of filled grains (0.545) with SPAD value was observed as high positive effect. Positive and very high indirect effect of total tillers (1.736) followed by days to maturity (1.221) on yield by plant height was observed in this study. Flag leaf breadth exhibited positive and very high indirect effect on single plant yield through days to maturity (2.248) followed by total tillers (1.470). Plant height on 50th day (0.698), flag leaf length (0.996), total tillers (0.994) and grain weight (0.993) contributed positively and high indirect effect on grain yield per plant by panicle length whereas it exhibited negative and high indirect effect on plant yield through plant height (0.588), number of productive tillers (0.884), days to maturity (0.566) and grain length (0.643).

By the way of productive tillers (5.045), total tillers gives more positive and very high indirect effect on single plant yield and days to fifty per cent flowering (0.601), plant height (0.563) and flag leaf breadth (0.480) showed its positive and indirect effect on grain yield. Days to maturity showed positive and indirect effect through grain length (0.314), however flag leaf breadth (0.888), plant height (0.480) and seed weight (0.447) had negative with high indirect effect on grain yield. High and positive indirect effect of grain length and breadth on grain yield was observed by the influence of plant height on 50th day (0.662, 0.429), productive tillers (0.799, 0.879), and very high positive indirect effect through seed weight (1.941, 1.788).

Table 1: Genetic parameters of thirty six rice genotypes for 17 quantitative traits

Characters	Genotypic coeff. of variation (%)	Phenotypic coeff. of variation (%)	Broad sense heritability (h^2)	Genetic advance as per cent of mean
Plant height on 50th day	7.24	7.53	92.39	14.34
Days to fifty per cent flowering	4.37	4.61	89.74	8.53
SPAD value	7.01	7.91	78.62	12.81
Plant height	3.52	4.13	72.56	6.18
Panicle length	7.55	8.37	81.24	14.02
Flag leaf length	10.62	11.78	81.34	19.74
Flag leaf breadth	13.29	14.02	89.79	25.94
Total tillers	26.39	27.92	89.36	51.39
Productive tillers	26.61	28.63	86.41	50.97
Days to maturity	3.62	4.05	79.97	6.68

Panicle weight	9.05	16.27	30.92	10.36
No. of grains per panicle	17.93	18.74	91.52	35.34
Filled grains	19.11	20.62	85.83	36.47
Grain length	4.88	5.33	83.64	9.19
Grain breadth	7.97	8.69	84.01	15.04
100 grain weight	16.17	16.46	96.45	32.72
Single plant yield	16.69	20.08	69.08	28.57

Table 2: Genotypic correlation coefficient among 36 rice genotypes for 17 quantitative traits

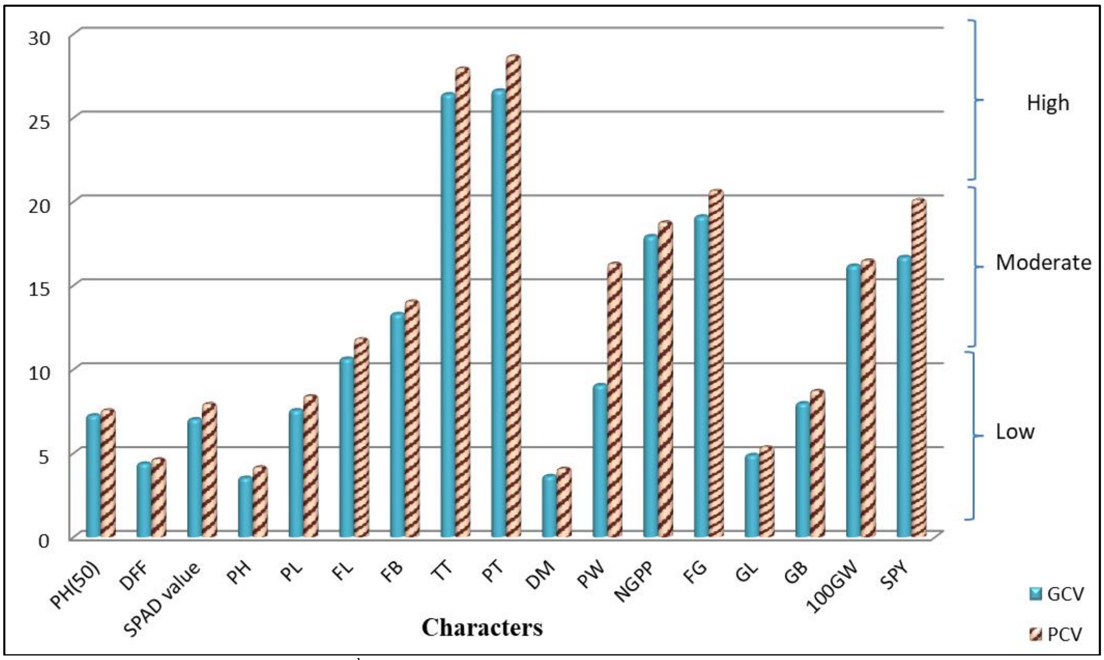
Characters	PH(50) (cm)	DFF (days)	SPAD value	PH (cm)	PL (cm)	FL (cm)	FB (cm)	TT (nos.)	PT (nos.)	DM (days)	PW (g)	NGPP (nos.)	FG (nos.)	GL (mm)	GB (mm)	100GW (g)	SPY (g)
PH(50)	1	-0.126	-0.401*	0.580**	0.592**	0.680**	0.184	-0.073	-0.058	-0.109	0.027	-0.328	-0.404*	0.561**	0.364	0.416*	-0.220
DFF		1	-0.154	0.326	-0.224	-0.079	0.595**	-0.432**	-0.420*	0.983**	0.193	-0.054	-0.196	-0.289	-0.172	-0.208	0.126
SPAD value			1	0.003	-0.182	-0.456**	-0.188	0.026	0.055	-0.204	0.024	0.504	0.563**	-0.064	-0.080	-0.177	0.279
PH				1	0.402*	0.454**	0.011	-0.385*	-0.372*	0.328	0.089	0.216	0.072	0.123	-0.201	-0.100	0.130
PL					1	0.803**	0.258	-0.221	-0.175	-0.152	0.478	-0.008	-0.204	0.572**	0.270	0.495**	0.124
FL						1	0.126	-0.214	-0.208	-0.107	-0.025	-0.133	-0.246	0.229	0.037	0.234	0.116
FB							1	-0.326	-0.253	0.604**	0.733**	-0.139	-0.450**	0.329*	0.495**	0.430**	-0.063
TT								1	0.997**	-0.497**	-0.423*	-0.391	-0.300	0.113	0.106	0.114	-0.144
PT									1	-0.477**	-0.333*	-0.414*	-0.354*	0.158	0.174	0.172	-0.170
DM										1	0.393*	0.093	-0.073	-0.279	-0.218	-0.223	0.198
PW											1	0.370*	0.087	0.424**	0.314	0.460**	0.381*
NGPP												1	0.915**	-0.448**	-0.484**	-0.545**	0.500**
FG													1	-0.602**	-0.672**	-0.707**	0.569**
GL														1	0.748**	0.969**	-0.472**
GB															1	0.893**	-0.514**
100GW																1	-0.479**
SPY																	1

Note: * indicates significance at 5%,** indicates significance at 1%, PH (50)= Plant height on 50th day, DFF= Days to fifty per cent flowering, SPAD value= SPAD meter value, PH= Plant height, PL= Panicle length, FL= Flag leaf length, FB= Flag leaf breadth, TT= Total tillers, PT= Productive tillers, DM= Days to maturity, PW= Panicle weight, NGPP= Number of grains per panicle, FG= Number of filled grains, GL= Grain length , GB= Grain breadth, HGW=Hundred grain weight, SPY= Single plant yield

Table 3: Direct and indirect effects of the trait on yield in 36 rice genotypes for 17 quantitative traits

Characters	PH(50) (cm)	DFF (days)	SPAD value	PH (cm)	PL (cm)	FL (cm)	FB (cm)	TT (nos.)	PT (nos.)	DM (days)	PW (g)	NGPP (nos.)	FG (nos.)	GL (mm)	GB (mm)	100GW (g)	SPY (g)
PH(50)	1.180	0.175	-0.416	-0.848	-0.131	0.844	-0.271	0.330	-0.292	-0.407	-0.005	-0.037	-0.391	-0.630	-0.156	0.833	-0.220
DFF	-0.148	-1.393	-0.160	-0.476	0.049	-0.098	-0.876	1.944	-2.125	3.658	-0.035	-0.006	-0.190	0.324	0.074	-0.417	0.126
SPAD value	-0.473	0.215	1.037	-0.004	0.040	-0.566	0.277	-0.115	0.276	-0.758	-0.004	0.057	0.545	0.072	0.034	-0.355	0.279
PH	0.684	-0.453	0.003	-1.462	-0.089	0.564	-0.016	1.736	-1.883	1.221	-0.016	0.024	0.069	-0.138	0.086	-0.201	0.130
PL	0.698	0.312	-0.189	-0.588	-0.221	0.996	-0.380	0.994	-0.884	-0.566	-0.086	-0.001	-0.197	-0.643	-0.116	0.993	0.124
FL	0.803	0.110	-0.473	-0.664	-0.177	1.241	-0.185	0.964	-1.053	-0.396	0.005	-0.015	-0.238	-0.258	-0.016	0.468	0.116
FB	0.217	-0.829	-0.195	-0.016	-0.057	0.156	-1.471	1.470	-1.282	2.248	-0.132	-0.016	-0.435	-0.370	-0.211	0.862	-0.063
TT	-0.087	0.601	0.026	0.563	0.049	-0.266	0.480	-4.504	5.045	-1.851	0.076	-0.044	-0.291	-0.127	-0.045	0.229	-0.144
PT	-0.068	0.585	0.057	0.544	0.039	-0.258	0.373	-4.488	5.062	-1.777	0.060	-0.047	-0.343	-0.177	-0.074	0.344	-0.170
DM	-0.129	-1.369	-0.211	-0.480	0.034	-0.132	-0.888	2.240	-2.417	3.721	-0.070	0.011	-0.070	0.314	0.093	-0.447	0.198
PW	0.032	-0.269	0.025	-0.130	-0.106	-0.032	-1.078	1.905	-1.686	1.461	-0.180	0.042	0.085	-0.477	-0.134	0.922	0.381
NGPP	-0.387	0.075	0.523	-0.316	0.002	-0.165	0.205	1.759	-2.093	0.348	-0.066	0.113	0.885	0.503	0.207	-1.092	0.500
FG	-0.476	0.273	0.584	-0.105	0.045	-0.306	0.661	1.352	-1.793	-0.270	-0.016	0.103	0.968	0.677	0.287	-1.417	0.569
GL	0.662	0.402	-0.067	-0.179	-0.126	0.285	-0.484	-0.510	0.799	-1.040	-0.076	-0.051	-0.583	-1.124	-0.32	1.941	-0.472
GB	0.429	0.240	-0.083	0.294	-0.060	0.045	-0.727	-0.479	0.879	-0.811	-0.056	-0.055	-0.650	-0.840	-0.428	1.788	-0.514
100GW	0.490	0.289	-0.184	0.147	-0.109	0.290	-0.633	-0.516	0.870	-0.830	-0.083	-0.062	-0.684	-1.089	-0.382	2.004	-0.479

Note: * indicates significance at 5%,** indicates significance at 1%, PH (50)= Plant height at 50th day, DFF= Days to fifty per cent flowering, SPAD value= SPAD meter value, PH= Plant height, PL= Panicle length, FL= Flag leaf length, FB= Flag leaf breadth, TT= Total tillers, PT= Productive tillers, DM= Days to maturity, PW= Panicle weight, NGPP= Number of grains per panicle, FG= Number of filled grains, GL= Grain length , GB= Grain breadth, 100GW=Hundred grain weight, SPY= Single plant yield



Note: PH (50)= Plant height at 50th day, DFF= Days to fifty per cent flowering, SPAD value= SPAD meter value, PH= Plant height, PL= Panicle length, FL= Flag leaf length, FB= Flag leaf breadth, TT= Total tillers, PT= Productive tillers, DM= Days to maturity, PW= Panicle weight, NGPP= Number of grains per panicle, FG= Number of filled grains, GL= Grain length , GB= Grain breadth, 100GW=Hundred grain weight, SPY= Single plant yield.

Fig 1: Phenotypic and genotypic coefficient of variation for 17 characters of 36 rice genotypes

Conclusion

In this study, wide range of variation has been observed among the 36 rice genotypes. Among the quantitative characters studied, number of grains per panicle had highly significant and positive correlation with grain yield per plant but direct effect of this trait on single plant yield is comparatively low (0.113). In the case of correlation, number of filled grains and single plant yield had highly significant and its direct effect towards grain yield is high. The heritability (85.53%) and genetic advance (36.47%) of this trait is also very high. So selection of traits such as total tillers, productive tillers, number of grains per panicle and number of filled grains per panicle for further improvement in grain yield of rice.

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