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Generation Mean Analysis for Yield and Its Contributing Characters in F_2 Populations of Rice (*Oryza sativa* L.)

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ABSTRACT

Gene action for yield its contributing characters and biochemical characters in rice (Oryza sativa L.,) was studied in two selected crosses, involving three parents, including their F1's, F2's, and their back cross populations. The significant scaling test (one or more scales in A, B and C) indicate the presence of digenic epistasis in all the characters studied except in grain yield per plant which showed simple additive and dominance effect. Complex genetic behavior was observed in most of the characters. Since the segregation generations did not follow a simple Mendalian inheritance, high selection pressure is expected in later generations due to probable successful exploitation of additive and dominance component.

Key words: *Generation mean analysis, Gene action, epistasis.*

INTRODUCTION

Rice is the major food crop worldwide, especially in developing countries[5]. Rice is supplying more than 40% human food requirement in the world and provides food for more than half of people living on the Earth. More than 80% daily calories and 75% required protein is obtained from Asia. At the current rate of population growth in India, estimated rice production should be around 135 to 140 million tonnes by 2020. These tasks is quit challenging and the options available are very limited in view of plateauing trend of yield in high productivity areas, decreasing and degrading land and scarcity of water and labour. So it is important to develop and use rice technologies that will result in higher yield. Hybrid rice technology is considered as one of the promising, practical, sustainable and eco-friendly options to break the yield ceiling witnessed in rice. The choice of an effective rice breeding approach to select for a particular characteristic depends substantially on the knowledge of the genetic system controlling these characters[1]. Genetic improvement also depends primarily on the effectiveness of selection among the progenies that differ in genetic value.

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The additive and dominant effect and their interactions are known as gene actions and are reported to be associated with breeding value. These states quantitative genetic methods such as diallele crosses and generation mean analysis and etc are used. Genetic analysis using generation mean analysis (GMA) has been used to estimate the gene actions controlling the quantitative characters. Determining the components contributes to a better understanding of the action of genes involved in the expression of that characters[6]. Generation Mean analysis[3] or scaling tests have been widely used for genetic analysis[2,4,7]. This approaches were used in the present research to estimate genetic parameters such as additive gene effects, dominance gene effects and narrow sense heritability. This leads to an understanding of the inheritance of traits and the nature of the epistatic gene effects.

MATERIALS AND METHODS

The Experiment was conducted at Rasi Seeds (P) Ltd., Attur, Salem in six seasons from *kharif'14* to rabi'16. Geographically, the research farm of Rasi Seeds (P) Ltd. was located at 220 57' N latitude and 720 54' E longitudes at an altitude of 11.98 m above the mean sea level. The soil of the experimental site is heavy black and fine textured with pH ranges from 7. 5 to 8.0. It receives an average annual rainfall of 760 mm. The experimental material consists of three parent's *viz*., BPT 5204, ADT 45 and JGL 1798. By using these three lines two different crosses as BPT 5204 X ADT 45 & BPT 5204 and JGL 1798 were made. Six generations *viz*., P1, P2, F1, F2, BC1 and BC2 of the above crosses were used to study the genetic analysis of quantitative and biochemical traits. The seeds of F_1 of each cross developed during *kharif'14* at Research Centre farm, Rasi Seeds (P) Ltd., Attur. F_1 ‟s along with their parents was grown during *Rabi'14*, where fresh F_1 ‟s and back crosses were developed. Parental lines and F_1 ‟s plant were selfed during the same season to obtain seeds of parental lines and F_2 ‟s. The experimental material consisting of two families, each having six generations P_1, P_2, F_1, F_2, BC_1 and BC_2 was grown during *kharif* 2015 at Research Centre farm, Rasi Seeds (P) Ltd., Attur. The experimental material consist of different generations *viz*., P_1, P_2, F_1, F_2, BC_1 and BC_2 of each family represented individual experimental unit within family was planted in compact family block design. The inter and intra row spacing was 20 cm and 15 cm, respectively. All the recommended agronomical practices and plant protection measures were followed as and when required for raising good crop. Observations were recorded for five random plants in each P_1, P_2 and F_1 and twenty plants in F_2 and 10 plants in BC_1 and BC_2 generations for different characters for days to 50 percent flowering (days), plant height (cm), number of productive tillers per plant, panicle length (cm), number of grains per panicle, spikelet fertility, L/B ratio, amylose content, Alkaline spreading value, 1000 grain weight(g) and Grain yield per plant in single plant observation. These data were subjected to statistical analysis. The mean value was computed for all the six generations for each crosses. The generation mean analysis was carried out following the methodology of Hayman (1958) using six generations and estimated the gene effects viz., m (mean), d (additive effect), h (dominant effect), I (additive X additive interaction effect), j (additive X dominance interaction effect) and l (dominance X dominance interaction effect).

RESULTS AND DISCUSSION

Mean performance of the six generations *viz*., P_1, P_2, F_1, F_2, BC_1 and BC_2 for all the characters studied in two crosses are presented

in table 1. The estimated mean effect (m) parameter, which reflects the contribution due to the overall mean plus the locus effects and interaction of the fixed loci, were found to be highly significant for all the characters in two crosses. The similar results were reported by Jhansi rani et al., 2015. The average performance of the six generations *viz*., P_1, P_2, F_1, F_2, BC_1 and BC_2 of both the crosses shown existence of sustainable variability in the populations for all the 11 characters studied. In these studies F_1 shows better performance than both the parents in plant height, number of productive tillers per plant, panicle length, number of grains per panicles, spikelet fertility, and grain yield per plant in both the crosses. Superiority of F_1 was observed in 1000 grain weight in BPT 5204 X JGL1798. These shows that the presence of dominant gene effects in hybrids of the two crosses. The F_1's with average performance over the two parents of that particular classes represented the presence of partial dominance. The performance of F_2 declined for the characters viz., number of productive tillers per plant, spikelet fertility (%),amylose content (%), alkaline spreading value, 1000 grains weight (g) and seed yield per plant (gm),. These characters showed the presence of dominance and epistatic interactions in both the crosses. The characters such as plant height (cm), number of grains per panicles, and L / B ratios showed presence of transgressive segregate indicating importance of additive gene action. In general, BC_2 perform better than BC_1 in both the crosses. The characters such as days to 50% flowering, number of productive tillers per plant, panicle length, number of grains per panicles, spikelet fertility, L/B ratio in the cross BPT 5204 X ADT 45 shows better performance in BC_2 when compared with BC_1. While in the cross BPT 5204 X JGL 1798, most of the characters such as days to 50 % flowering, plant height, number of productive tillers, panicle length, number of grains per panicles, spikelet fertility, amylose content, alkaline spreading value, 1000 grain weight and seed yield per plant also showed good performance in BC_2

Scaling tests *i.e.*, A, B and C results were presented in table 2. The results of scaling tests for these studies revealed that the calculated values of at least any one of the three scales A, B, C found significant for days to 50% flowering, plant height, panicle length, number of grains per panicle, spikelet fertility, amylose content, alkaline spreading and 1000 grain weight value for the cross BPT 5204 X ADT 45 and also the characters such as days to 50% flowering, plant height, number of productive tillers per plant, panicle length, number of grains per panicle, spikelet fertility, 1000 grain weight, L/B ratio, amylose content, alkaline spreading values in the cross BPT 5204 X ADT45 shows significance for scaling values, which means these characters shows the presence of non-allelic gene interactions.

The estimated value of various types of gene effects viz., m, d, h, I, j and l are presented in Table 3. Results of main effect and interaction effects governing quantitative characters are described below.

For Days to 50% flowering, Genetic effect for m, d, h and l were significant in BPT 5204 X ADT 45 but in cross BPT 5204 X JGL 1798 only j and l shows significant genetic effect. The effects of dominant and dominant X dominant effects in BPT 5204 X ADT 45 were in opposite sign indicate the presence of duplicate epistasis. In cross BPT 5204 X JGL 1798, both having same sign indicates the presence of complementary epistasis. Besides duplicate epistasis in BPT 5204 X JGL 1798, additive X additive shows predominance which indicates the transgressive effects. The character Plant height showed wide range of variation in all the six generations. Accordingly the cross BPT 5204 X ADT 45 resulted as significance for the scale 1 but in another cross, scale B and C both will show significance. It resulted as inadequacy of simple additive dominance effects. The mean genetic effect was highly significant and positive in both the crosses. The component

additive effect (d) was non-significant and positive results for both the crosses. In two crosses dominant effect and dominant X dominant effects were displayed with opposite sign and then indicated the presence of duplicate epistasis. The character number of productive tillers per plant in BPT 5204 X ADT 45 indicated the non-significance for all the three scale Scale A, B and C, which means a simple additive dominant effect plays a major role. But in the cross BPT 5204 X JGL 1798 it showed non allelic gene action but providing significance for the scale B and C. In BPT 5204 X JGL 1798, except dominant X dominant interaction showed significant results. The dominant action and dominant X dominant interactions showed similar direction and this proved the presence of complementary epistasis. This type of gene action acts in favour of heterosis (Hasanuzzaman, M and F. Golam, 2011)

For the character spikelet fertility, the dominant and additive X additive gene action was highly significant in two crosses along with significance was also observed in BPT 5204 X ADT 45 for dominance X dominance gene action. In BPT 5204 X ADT 45, duplicate gene action was identified as it showed opposite sign in dominant and dominant X dominant gene action but similar sign was observed in cross II i.e. complementary gene action. In the cross BPT 5204 X ADT 45, all the three scales were non significance which implied the absence of non-allelic gene action but in next cross scale C have significant effect which depicted the presence of epistasis. The mean genetic effect was highly significant and positive in both the crosses. In cross II, the effect of [d], [h], [i] and [l] shows highly significant effect for gene action. The [d] and [l] are significant and opposite sign in cross II suggested the presence of duplicate epistasis.

For the character amylose content the scale A in cross BPT 5204 X ADT 45 had negative and significant effect and the scale C also showed similar results in both the crosses suggested the presence of epistasis effect in both the crosses. In the two crosses, the genetic effect [d], [h], [i] and [j] were highly significant and positive effect except [l], which had negative sign. In both the crosses, the genetic effect [h[and [l] are in opposite sign revealed that the presence of duplicate epistasis. The scaling test for alkaline spreading value for the cross BPT 5204 X ADT 45 had significance for all the three scales. In BPT 5204 X JGL 1798, only the scale C provided significant effect. The mean genetic effect was positive and highly significant in both the crosses and the dominant effect in cross BPT 5204 X ADT 45 was also gave similar result. Additive X additive and dominant X dominant interaction were negative and non-significant in the two crosses. Cross BPT 5204 X ADT 45 showed significance for scale B and C while in cross BPT 5204 X JGL 1798, scale A only showed the significant scaling for 1000 seed weight. The mean genetic values were positively significant in both the crosses. In cross BPT 5204 X ADT 45, other than that additive gene action showed positively significant effect. But in cross BPT 5204 X JGL 1798, gene actions [h], [i] and [j] were the positive and significant. The dominant X dominant gene actions in cross both the crosses showed significance with negative effect. In cross I, dominant effect and dominant X dominant interaction possess same sign indicated the presence of complementary gene action while in cross II, they had opposite sign showed duplicate epistasis. In both the crosses grain yield per plant showed significance for at least a single scale depicted as it plays simple additive dominant effects. F_1 in both the crosses had predominate value shows that the heterosis breeding were very effective for increasing the grain yield.

Table 1: Generation Mean (±SE) of six generations in Rice for yield, yield contributing and grain quality characters

Generation	P1	P2	F1	F2	B1	B2
Days to 50 % flowering						
BPT 5204 X ADT 45	104.90±0.23	81.80±0.30	95.7±0.335	92.92±0.474	88.3±0.650	89.2±0.573
BPT 5204 X JGL 1798	104.10±0.23	92.90±0.34	100.5±0.372	94.24±0.511	95.6±0.636	92.7±1.044
Plant height (cm)						
BPT 5204 X ADT 45	83.67±0.86	75.27±0.79	97.89±0.820	102.75±0.791	93.43±2.78	88.82±2.340
BPT 5204 X JGL 1798	82.28±0.98	79.64±0.90	93.59±0.744	94.6695±0.778	93.27±2.607	92.07±2.998
Number of productive tillers /plant						
BPT 5204 X ADT 45	13.10±0.40	13.50±0.50	18.9±0.936	15.82±0.257	16.8±0.646	17.3±0.667
BPT 5204 X JGL 1798	14.30±0.59	13.8±0.57	20±0.843	14.825±0.249	17.1±0.657	14.6±0.426
Panicle length (cm)						
BPT 5204 X ADT 45	21.59±0.22	20.17±0.36	21.65±0.297	21.85±0.172	22.57±0.397	22.66±0.312
BPT 5204 X JGL 1798	21.70±0.23	23.19±0.28	23.17±0.37	22.1965±0.14	23.11±0.379	22.87±0.262
Number of grains /panicle						
BPT 5204 X ADT 45	225.60±10.53	237.40±5.46	268±5.8405	270.82±4.434	281.7±13.546	305.5±13.419
BPT 5204 X JGL 1798	228.70±7.68	246.30±6.69	288.7±9.72	273.025±3.497	297.2±12.038	280±13.662
Spikelet fertility (%)						
BPT 5204 X ADT 45	85.57±1.22	84.49±1.33	90.6080.391	81.607±0.734	86.49±0.77	86.82±0.824
BPT 5204 X JGL 1798	87.82±0.62	88.05±0.85	88.369±0.614	80.273±0.6155	85.88±1.444	84.93±1.49
L/B Ratio						
BPT 5204 X ADT 45	3.27 ±0.04	3.49±0.05	3.366±0.036	3.4073±0.019	3.38±0.048	3.399±0.05
BPT 5204 X JGL 1798	3.12± 0.06	3.624± 0.04	3.092 ± 0.041	3.285± 0.027	2.911 ± 0.043	3.22± 0.058
Amylose content (%)						
BPT 5204 X ADT 45	25.62±0.09	23.06±0.16	25±0.086	22.799±0.164	24.77±0.158	23.69±0.184
BPT 5204 X JGL 1798	25.51± 0.15	23.37± 0.10	24.34± 0.139	23.294± 0.141	24.82± 0.238	24.16± 0.135
ASV						
BPT 5204 X ADT 45	4.44±0.037	3.80±0.03	4.04±0.0499	3.576±0.027	4.03±0.044	3.77±0.07
BPT 5204 X JGL 1798	4.39± 0.034	3.61± 0.03	3.77± 0.0473	3.669± 0.027	3.97± 0.073	3.67± 0.0597
1000 grain weight (g)						
BPT 5204 X ADT 45	14.50±0.02	17.50±0.02	16.48±0.36	15.2165±0.075	15.52±0.098	15.28±0.102
BPT 5204 X JGL 1798	14.50±0.02	15.07±0.0	15.09±0.247	15.117± 0.066	16.61±0.102	15.24±0.236
Seed yield /plant (gm)						
BPT 5204 X ADT 45	20.48±1.17	23.34±0.94	32.771.365	25.672±0.648	27.3±1.661	26.5±1.249
BPT 5204 X JGL 1798	23.31±0.68	22.31±0.93	27.2±0.864	24.734±0.587	28.51±1.903	26.09±1.732

Table 2: Scaling test for yield & its contributing characters and Biochemical characters in Rice

Generation	Scale A	Scale B	Scale C
Days to 50 % flowering			
BPT 5204 X ADT 45	-24.000 ± 1.363 **	1.300± 1.233	-6.020 ± 2.047 **
BPT 5204 X JGL 1798	-13.400 ± 1.345 **	-8.000 ± 2.149 **	-21.040 ± 2.217 **
Plant height (cm)			
BPT 5204 X ADT 45	5.300± 5.68	4.480± 4.81	52.286 ± 3.75 **
BPT 5204 X JGL 1798	10.670 ± 5.359 *	10.910± 6.111	29.578 ± 3.701 **
Number of productive tillers /plant			
BPT 5204 X ADT 45	1.600± 1.64	2.200± 1.7	-1.120± 2.23
BPT 5204 X JGL 1798	-0.100± 1.672	-4.600 ± 1.33 **	-8.800 ± 2.126 **
Panicle length (cm)			
BPT 5204 X ADT 45	1.900 *± 0.87	3.500 **± 0.78	2.374 *± 1
BPT 5204 X JGL 1798	1.350± 0.877	-0.620± 0.701	-2.444 ± 0.998 *
Number of grains /panicle			
BPT 5204 X ADT 45	69.800 ± 29.65 *	105.600 ± 28 **	84.300 ± 24.32 **
BPT 5204 X JGL 1798	77.000 ± 27.07 *	25.000± 29.76	-39.700± 26.02
Spikelet fertility (%)			
BPT 5204 X ADT 45	-3.207± 2	-1.466± 2.15	-24.862 ± 3.54 **
BPT 5204 X JGL 1798	-4.4150± 3.19	-6.5460 ± 3.15 *	-9.0258 ± 2.94 **
L/B Ratio			
BPT 5204 X ADT 45	0.123± 0.112	-0.061± 0.117	0.1334± 0.126
BPT 5204 X JGL 1798	-0.582 ± 0.1187 **	-0.276 ± 0.131 *	0.0224 **± 0.16
Amylose content (%)			
BPT 5204 X ADT 45	-1.080 ± 0.341 **	-0.680± 0.409	-7.484 ± 0.705 **
BPT 5204 X JGL 1798	-0.210± 0.521	0.610± 0.321	-4.384 ± 0.658 **
Alkaline Spreading Value			
BPT 5204 X ADT 45	-0.420 ± 0.109 **	-0.300 ± 0.151 *	-2.016 ± 0.155 **
BPT 5204 X JGL 1798	-0.2140± 0.153	-0.040± 0.133	-0.862 ± 0.151 **
1000 grain weight (g)			
BPT 5204 X ADT 45	0.060± 0.207	-3.420 ± 0.208 **	-4.094 ± 0.31 **
BPT 5204 X JGL 1798	3.630 ± 3.22 **	0.320± 0.53	0.7200± 0.56
Seed yield /plant (gm)			
BPT 5204 X ADT 45	1.3500± 3.77	-3.110± 2.99	-6.672± 4.05
BPT 5204 X JGL 1798	6.510 ± 3.96	2.610 ± 3.69	-1.1440± 3.14

Table 3: Estimation of gene effects for yield & its contributing characters and Biochemical characters using six parameter model

Cross	Genetic effects m	(d)	(h)	(i)	(j)	(l)
Days to 50 % flowering						
BPT 5204 X ADT 45	92.92 ± 0.47 **	-0.900± 0.867	-14.130 ± 2.599 **	-16.680 ± 2.57 **	-12.650 ± 0.888 **	39.380 ± 4.028 **
BPT 5204 X JGL 1798	94.24 ± 0.51 **	2.900 ± 1.222 *	1.640± 3.216	-0.360± 3.188	-2.700 ± 1.24 *	21.760 ± 5.369 **
Plant height (cm)						
BPT 5204 X ADT 45	101.75 ± 0.79 **	4.610± 3.63	-24.086 ± 7.99 **	-42.506 ± 7.92 **	0.410± 3.68	32.726 ± 15.01 *
BPT 5204 X JGL 1798	94.66 ± 0.77 **	1.200± 3.973	4.631± 8.594	-7.998± 8.535	-0.120± 4.03	-13.581± 16.32
Number of productive tillers /plant						
BPT 5204 X ADT 45	15.82 ± 0.25 **	-0.500± 0.92	10.520 ± 2.34 **	4.920 ± 2.12 *	-0.300± 0.98	-8.720 ± 4.33 *
BPT 5204 X JGL 1798	14.82 ± 0.24 **	2.500 ± 0.783 **	10.050 ± 2.081 **	4.100 ± 1.857 *	2.250 ± 0.886 *	0.600 ± 3.788
Panicle length (cm)						
BPT 5204 X ADT 45	21.85 **± 0.02	-0.09± 0.25	3.790 **± 1.63	3.026 *± 1.49	-0.800± 0.3	-8.426 **± 5.1
BPT 5204 X JGL 1798	22.19 ± 0.14 **	0.240± 0.461	3.899 ± 1.157 **	3.174 ± 1.081 **	0.985 ± 0.496 *	-3.904± 2.099
Number of grains /panicle						
BPT 5204 X ADT 45	270.82 ± 4.43 **	-23.8± 19.06	127.600 ± 42.87 **	91.100 ± 42.06 *	-17.900± 19.97	-266.50 ± 80.06 **
BPT 5204 X JGL 1798	273.02 ± 3.49 **	17.200± 18.2	113.500 ± 40.52 *	62.300± 39.01	26.000± 18.9	-164.300± 77.35 *
Spikelet fertility (%)						
BPT 5204 X ADT 45	81.60 ± 0.73 **	-0.330± 1.12	25.758 ± 3.83 **	20.189 ± 3.7 **	-0.8705± 1.44	-15.516 ± 5.73 **
BPT 5204 X JGL 1798	31.51 ± 0.61 **	0.956± 2.07	20.9901 ± 4.89 **	20.558 ± 4.82 **	1.0655 ± 2.13	9.5977± 8.8
L/B Ratio						
BPT 5204 X ADT 45	3.40 ± 0.02 **	-0.019± 0.069	-0.0874± 0.168	-0.0714± 0.16	0.092± 0.077	0.0094± 0.306
BPT 5204 X JGL 1798	3.28 ± 0.02 **	-0.309 ± 0.073**	-1.25 ± 0.193 **	-0.88± 0.18 **	-0.153± 0.083	1.738 ± 0.334**
Amylose content (%)						
BPT 5204 X ADT 45	22.79± 0.16**	1.080 ± 0.243 **	6.38 ± 0.828 **	5.724 ± 0.819 **	-0.200± 0.259	-3.964 ± 1.201 **
BPT 5204 X JGL 1798	23.29 ± 0.14 **	0.660 ± 0.274 **	4.684 ± 0.805 **	4.784 ± 0.787 **	-0.410± 0.29	-5.184 ± 1.278 **
Alkaline Spreading Value						
BPT 5204 X ADT 45	3.57 ± 0.02 **	0.260 ± 0.083 **	1.216 ± 0.206 **	1.296 ± 0.198 **	-0.060 ± 0.086	-0.576± 0.367
BPT 5204 X JGL 1798	3.66 ± 0.02 **	0.300 ± 0.092 **	0.3780± 0.221	0.608 ± 0.214 **	-0.0870± 0.096	-0.3540± 0.401
1000 grain weight (g)						
BPT 5204 X ADT 45	15.21 ± 0.07 **	0.2400± 0.141	1.214 ± 0.415 **	0.734 ± 0.413 *	1.7400 ± 0.142 **	2.626 ± 0.647 **
BPT 5204 X JGL 1798	15.11 ± 0.06 **	1.370 ± 0.25 **	3.5350 ± 0.63 **	3.2300 ± 0.58 **	1.655 ± 25 **	-7.1800 ± 1.17 **
Seed yield /plant (gm)						
BPT 5204 X ADT 45	25.67 ± 0.64 **	0.800± 2.07	15.772 ± 5.14 **	4.912± 4.9	2.230± 2.21	-3.152± 9.25
BPT 5204 X JGL 1798	24.73 ± 0.587**	2.420± 2.573	14.6240 ± 5.75 *	10.264± 5.65	1.950± 2.63	-19.3840± 10.76

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