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K Palaniraja
Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu, India

Correspondence
K Palaniraja
Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu, India

Studies on generation mean analysis in rice (*Oryza sativa* L.)

K Palaniraja

Abstract
Genetic analysis using generation mean analysis is a tool for designing the most appropriate breeding approaches for developing rice varieties. An attempt was made with seeds of five generations *viz*., P_1, P_2, F_1, F_2 and F_3 for each of four cross combinations IR 75000-69-2-1-B x ADT 45, IR 75000-69-2-1-B x ADT 36, IR 63311-B-3R-B-2-4-3 x ADT 45 and IR 63311-B-3R-B-2-4-3 x ADT 36 were constituted and raised in RBD design with three replications. Observations were recorded for days to first flower, plant height, total number of tillers per plant, number of productive tillers per plant, panicle length, number of grains per panicle, grain weight per panicle, thousand grain weight and grain yield per plant. The results revealed the presence of additive, dominance and two types of interactions along with complementary and duplicate interaction were found to govern yield and all its component traits. For improvement of grain yield and its components additive, dominance and epistatic interactions *viz.*, additive x additive and dominance x dominance along with complementary and duplicate type of gene actions were important. Thus, predominance of unfixable and non-additive gene action was observed for all the traits, hence it appeared to be difficult to adopt pedigree breeding as simple pedigree breeding will not be able to fix the superior lines in the early segregating generations. Hence, selection should be postponed to later generations or one or two cycles of reciprocal recurrent selection may be followed by pedigree breeding for improvement of the economic traits.

Keywords: Generation mean analysis, grain yield, rice

Introduction
Rice is one of the important food crops of our country. The need for increased productivity of rice has become very important as the production had reached a plateau. This could be done by exploiting the variability through artificial hybridization and selection. The grain yield is a highly complex character, generally governed by genes and the interaction between them. The present study was undertaken to know the information on the nature of gene action among different traits by generation mean analysis which is a simple and successful method in self pollinated crop like rice.

Materials and Methods
The experimental material comprised of four crosses IR 75000-69-2-1-B x ADT 36, IR 75000-69-2-1-B x ADT 45, IR 63311-B-3R-B-2-4-3 x ADT 36 and IR 63311-B-3R-B-2-4-3 x ADT 45. Five generations *viz*., P_1, P_2, F_1, F_2 and F_3 were raised in RBD design with three replications at Plant Breeding Farm, Faculty of Agriculture during 2009. Recommended package of practices were followed during crop growth. Observations were recorded on ten randomly selected plants from P_1, P_2, F_1, F_2 and F_3 generation of each crosses for nine characters. The adequacy of the data for a simple additive-dominance model was tested utilizing the scales, C and D as suggested by Mather (1949). Estimation of five parameters, (m), (d), (h), (i) and (l) were analysed as given by Hayman, 1958. The test of significance of the gene effects was done by 't' test.

Results and Discussion
The estimates of genetic parameters like mean (m), additive (d), dominance (h), additive x additive (i) and dominance x dominance (l) for different characters in four crosses are presented in Table 1. Significant deviation of observed generation mean from the expected mean for most of the characters suggested that the non-allelic interactions were present in these crosses.
The data on days to first flower**,** the effect of 'd' had negative and significance in crosses 1 and 2. The 'h' effect was positive in all the crosses but significant in cross 2 and cross 4 which denoted that dominance seemed to be unidirectional. The additive x additive 'i' effect was positive and significant in cross 3 and cross 4 whereas the dominance x dominance effect 'l'

was negative and significant in cross 1 and cross 2 which indicated that selection should be postponed to later generations for improvement of this trait. This is in accordance of the results of Venkatesan (2003) [17]. The results indicated that the gene action is cross specific. However, as indicated by Sabesan (2005) [13] the 'h' and 'l' signs took opposite signs in two crosses (crosses 1 and 2) indicated the presence of duplicate epistasis and same signs in two crosses (crosses 3 and 4), thus indicated the presence of complementary epistasis.

Table 1: Gene effects for different characters in rice

Components	Cross 1	Cross 2	Cross 3	Cross 4
1. Days to first flower				
(m)	59.50 *±0.47	61.00*±0.41	57.50*±0.60	60.50* ±0.39
(d)	-3.25*±0.41	-2.75 *±0.87	0.75 ±0.83	1.25 ±1.13
(h)	0.67 ±1.33	6.33* ±1.63	2.67 ±1.72	3.00* ±1.43
(i)	-0.58±0.90	1.58±2.94	12.42* ±2.22	9.75*±2.33
(l)	-5.33* ±2.60	-6.67* ±3.27	2.67 ±6.09	4.00* ±1.84
Type of epistasis	Duplicate	Duplicate	Complementary	Complementary
2. Plant height				
(m)	68.29*±0.62	66.03*±0.41	63.24*±0.50	63.00* ±0.49
(d)	-0.83±0.90	7.32*±1.04	5.18*±0.92	13.33*±1.06
(h)	1.50±2.15	6.29 *±2.31	-5.96 *±2.01	4.39 *±2.10
(i)	14.67*±1.51	28.41*±3.40	25.27*±8.51	48.12*±2.65
(l)	1.52±7.65	-2.21 ±7.28	36.48 *±6.42	-0.69 ±7.22
Type of epistasis	Complementary	Duplicate	Duplicate	Duplicate
3. Number of tillers per plant				
(m)	20.90*±0.36	24.01*±0.39	21.10*±0.41	21.94*±0.36
(d)	0.77±0.79	-0.75±0.65	1.23±0.92	-0.29±0.79
(h)	4.19*±1.85	-0.78±2.14	-1.23±2.01	-4.79*±1.60
(i)	2.60*±0.17	-4.49*±2.08	-1.06±4.21	-8.19*±3.99
(l)	9.63*±4.55	9.52*±4.13	18.13*±7.01	30.13*±5.40
Type of epistasis	Complementary	Duplicate	Duplicate	Duplicate
4. Number of productive tillers per plant				
(m)	20.01*±0.62	20.86*±0.60	19.34*±0.52	20.22*±0.61
(d)	0.91±0.50	0.70±0.47	0.62±0.41	0.40±0.37
(h)	2.98±1.92	0.93±2.27	-1.15±2.07	-0.88±2.04
(i)	2.32±1.76	-1.84±1.09	-2.67±1.99	-3.82±2.21
(l)	-2.00±6.60	6.29*±3.10	8.85*±4.38	9.60*±4.25
Type of epistasis	Duplicate	Complementary	Duplicate	Duplicate
5. Panicle length				
(m)	22.96*±0.30	23.02*±0.24	21.92*±0.12	22.40*±0.13
(d)	-0.58±0.57	-0.99±0.51	-1.33*±0.52	-1.74*±0.46
(h)	-0.55±1.10	-2.07*±1.00	-3.45*±0.70	-2.05*±0.71
(i)	-4.45*±1.28	-7.08*±2.71	-8.37*±2.20	-8.84*±2.52
(l)	6.61*±3.02	12.21*±3.67	11.65*±2.65	11.33*±2.71
Type of epistasis	Duplicate	Duplicate	Duplicate	Duplicate
6. Number of grains per panicle				
(m)	121.01*±0.81	123.21*±0.60	123.00*±0.71	122.00*±0.63
(d)	7.08*±1.47	-1.35±1.60	8.00*±1.54	-0.43±1.67
(h)	3.10±3.32	-0.93±3.63	-0.72±2.96	-2.59±3.52
(i)	5.36*±2.80	-8.46*±1.84	1.28±2.14	-7.54*±2.44
(l)	1.68±11.43	6.37*±3.99	13.44*±6.53	15.25*±7.37
Type of epistasis	Complementary	Duplicate	Duplicate	Duplicate
7. Grain weight per panicle				
(m)	2.55*±0.01	2.61*±0.01	2.48*±0.01	2.57*±0.02
(d)	0.13*±0.05	0.01±0.05	0.14*±0.01	0.02±0.01
(h)	0.11*±0.01	0.05*±0.01	0.01±0.01	-0.05*±0.01
(i)	0.14*±0.05	-0.09±0.10	0.14*±0.05	0.56*±0.14
(l)	-0.03*±0.01	0.05*±0.01	0.21*±0.10	0.59*±0.10
Type of epistasis	Duplicate	Complementary	Complementary	Duplicate
8. Thousand grain weight				
(m)	23.32*±0.14	23.96*±0.11	22.54*±0.08	23.21*±0.09
(d)	0.80*±0.20	0.05±0.17	0.56±0.52	-0.20±0.20
(h)	-0.19±0.63	2.19*±0.62	-0.23±0.44	-0.87±0.44
(i)	-1.29*±0.60	-0.70±1.18	-1.12*±0.51	-2.54*±1.13
(l)	3.09*±1.51	-0.05±1.62	2.53*±1.18	6.13*±1.46
Type of epistasis	Duplicate	Duplicate	Duplicate	Duplicate
9. Grain yield per plant				
(m)	41.01*±0.73	46.42*±0.68	43.00*±0.80	46.10*±0.72
(d)	4.01*±1.46	0.59±1.01	3.99*±1.49	0.57±1.05
(h)	3.41±3.37	7.44*±2.38	-0.29±2.71	-0.99±2.79
(i)	0.74±2.44	-4.55*±2.24	-7.30*±2.76	-13.16*±2.33
(l)	-2.85±9.46	-8.96*±3.79	13.71*±6.10	11.71*±5.33
Type of epistasis	Duplicate	Duplicate	Duplicate	Duplicate

Cross 1 = IR 75000-69-2-1-B X ADT 36 Cross 3 = IR 63311-B-3R-B-2-4-3 X ADT 36 *Significant at 5% level
Cross 2 = IR 75000-69-2-1-B X ADT 45 Cross 4 = IR 63311-B-3R-B-2-4-3 X ADT 45

For plant height, the additive effect 'd' was positive and significant for three crosses while it was negative and non significant in cross 1. The crosses 2 and 4 showed positive and significant dominance effect 'h' and cross 3 recorded negative significance for this trait. The additive x additive 'i' effect was positive and significant in all the crosses whereas the dominance x dominance effect 'l' was positive and significant in cross 3. The results indicated that gene action is cross specific. The 'h' and 'l' signs took opposite signs in three crosses (crosses 2, 3 and 4) indicated the presence of duplicate epistasis and same signs in one cross (cross 1) thus indicated the presence of complementary epistasis. This is in accordance with the findings of Saleem *et al*. (2005) [14].

The trait, total number of tillers per plant the additive (d) effect was positive and non significant in two crosses and the dominance effect (h) was positively significant in cross 1 and negatively significant in cross 4. This indicated that gene action is cross specific. The additive x additive 'i' effect was positive and significant in cross 1 whereas, the dominance x dominance effect 'l' was positive and significant in all the crosses. This indicated the predominance of dominance and selection should be postponed to later generations for the improvement of this trait. Similar findings were done by Venkatesan (2003) [17] and Muhammad Yussouf Saleem *et al*. (2009) [11] in rice. The 'h' and 'l' effects revealed unlike sign in three crosses except cross 1 (complementary) thus indicated the presence of duplicate epistasis.

The 'h' effect was positive and more than d in two crosses but was found to be non-significant for number of productive tillers per plant The 'h' and 'l' effects revealed unlike sign in three crosses which indicated the presence of duplicate epistasis. Cross 2 observed similar signs which indicated the presence of complementary epistasis. Similar results were presented by Bui Chi Buu and Phung Ba Tao (1992) [1]. The 'i' and 'l' recorded opposite signs thereby indicated the presence of dispersed alleles in the interacting loci. This is in accordance with the results of Ram *et al*. (1994) [9] and Mahalingam (2003).

Character, panicle length recorded the effect of 'd' was negative and significance in crosses 3 and 4. The 'h' effect was negative in all the crosses but significant in cross 2, cross 3 and cross 4 which denoted that dominance seemed to be unidirectional. The additive x additive 'i' effect was negative and significant in all the crosses, whereas the dominance x dominance effect 'l' was positive and significant in all the crosses, which indicated that selection should be postponed to later generations for improvement of this trait. This is in accordance of the results of Thirumeni *et al.* (2000). The results also indicated that the gene action is cross specific. However, as indicated by the 'h' and 'l' signs took opposite signs in all the crosses thus, indicated the presence of duplicate epistasis. Similar findings were reported by Kavimani (2003). The 'i' and 'l' also recorded opposite signs thereby indicated the presence of dispersed alleles in the interacting loci. This is in accordance with the results of Muhammad Yussouf Saleem *et al*. (2010) [10].

Trait like number of grains per panicle showed that the additive (d) effect was positive and significant in two crosses (Cross 1 and 3) and the dominance effect (h) was not significant in any of the crosses. This indicated that gene action is cross specific. The additive x additive 'i' effect was positive and significant in cross 1 whereas, the dominance x dominance effect 'l' was positive and significant in all the crosses except cross 1 which had positive and non-significant in cross 1. The 'h' and 'l' effects revealed unlike sign in three crosses except cross 1 (complementary) thus indicated the presence of duplicate epistasis.

The additive effect 'd' was positive and significant for two crosses, for the character grain weight per panicle. The crosses 1 and 2 showed positive and significant dominance effect ('h') and cross 4 recorded negative significance for this trait. The additive x additive 'i' effect was positive and significant in all the crosses except cross 2. The crosses 2, 3 and 4 recorded significant and positive dominance x dominance effect 'l'. The 'h' and 'l' signs took opposite signs in two crosses (crosses 1 and 4) which indicated the presence of duplicate epistasis and same signs in crosses 2 and 3 thus indicated the presence of complementary gene action. This is in accordance with the findings of Muhammad Yussouf Saleem *et al.* (2010) [10]

For thousand grain weight, additive ('d') and the dominance ('h') effect was positive and significant only in one cross (Cross 1 and cross 2 respectively). This indicated that gene action is cross specific. The additive x additive 'i' effect was negative and significant in crosses 1, 3 and 4 whereas, the dominance x dominance effect 'l' was positive and significant in all the crosses except cross 2. This is the indication of that selection should be postponed for this character to later generation. This is in agreement of the findings of Saleem *et al*. (2005) [14]. The 'h' and 'l' effects revealed unlike sign in all the four crosses thus indicated the presence of duplicate epistasis.

The most important character grain yield per plant observed that the additive effect 'd' was positive and significant for two crosses (crosses 1 and 3). The 'h' effect was positive and significant in cross 2 only. The additive x additive 'i' effect was negative and significant in all the crosses except cross 1 whereas the dominance x dominance effect 'l' was positive in two crosses *i.e*., crosses 3 and 4 and negatively significant in cross 2. This is in accordance of the findings of Dhanakodi (1990) and Kumaravelu (1992) [5]. The results also indicated that the gene action is cross specific. However, as indicated by Savery (1998) [15] the 'h' and 'l' signs took opposite signs in all the crosses thus, indicated the presence of duplicate epistasis. Similar findings were reported by Mahalingam (2003) and Venkatesan (2003) [17]. The 'i' and 'l' also recorded opposite signs in crosses 1, 3 and 4 thereby indicated the presence of dispersed alleles in the interacting loci. This is in accordance with the results of Hasib (2004) [2], Saleem *et al*. (2005) [14], Muhammad Yussouf Saleem *et al.* (2009) [11] and Muhammad Yussouf Saleem *et al.* (2010) [10].

Thus, it is understood and concluded as a whole additive, dominance and two types of interaction *i.e.,* additive x additive and dominance x dominance effects along with complementary and duplicate interactions were found to govern yield and all its component traits. However, predominance of unfixable and non-additive gene action was observed for all the traits. It is therefore, suggested that the use of biparental mating in the early segregating generations or recurrent selection which exploit both additive and dominance gene effects for the simultaneous improvement of grain yield and important component traits in rice.

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