Studies on Types of Gene Effects in Some Crosses of Rice (*Oryza Sativa* L.)

M. I. SHAALAN AND A. E. ALY[1]

ABSTRACT

A field investigation was conducted at the Faculty of Agriculture Experimental Farm, Alexandria University, Alexandria, Egypt, during the 1972–1974 seasons. The relative importance of types of gene effects was studied on yield and yield components in the two rice crosses, namely; Giza 159 × I.R.8 (cross I) and Giza 159 × Taichung (N.)1 (cross II). Population means of parents, F_1, BC_1, BC_2, and F_2 were used, on plant basis, in estimating the different types of gene effects on five agronomic characters, according to Gamble's method (12).

Significant additive gene effect was detected for grain yield per plant and plant height in cross I; and for plant height, 100-grain weight, and panicle length in cross I. The dominance gene effect was significant for grain yield per plant, plant height, and panicle length in cross I. On the other hand, this effect was significant for all characters except the grain yield per plant in cross II.

The characters that showed significant additive × additive type of epistasis were grain yield per plant, plant height, and panicle length in cross I. This type of epistasis was significant for all characters in cross II. The additive × dominance type of epistasis was significant for grain yield per plant and plant height in cross I; and for number of ear-bearing tillers per plant and panicle length in cross II. Significant dominance × dominance epistatic effect was detected for panicle length in cross I; and for grain yield per plant, 100-grain weight, and panicle length in cross II.

INTRODUCTION

The plant breeder is interested in the determination of various types of gene effects to establish the most advantageous breeding programs for the improvement of desired characters in different crop species. Fisher (11) partitioned the genetic variation into its components. Afterwards, a number of genetic models were proposed for the estimation of gene effects by several workers, such as Comstock and Robinson (10), Mather (15), Griffing (13), Anderson and Kempthorne (2), and Hayman and Mather (14). Most of the literature refers to the additive and dominance genetic effects as the major components of gene effects. However, additional evidence for the incorporation of epistatic gene effect in the inheritance of different quantitative characters and the relative importance of the three types of gene effects in genetic variation is highly desired (12).

The present investigation deals with the estimation of the relative importance of

[1] *Crop Science Department, Faculty of Agriculture, Alexandria University, Egypt.*

additive, dominance, and digenic epistatic gene effects for the variation of grain yield and yield components in two crosses of rice.

MATERIALS AND METHODS

A field study was carried out at the Faculty of Agriculture Experimental Farm, Alexandria University, Alexandria, Egypt, during the 1972–1974 seasons. Two crosses were made in 1972 between the local rice cultivar, Giza 159, and the two introduced rice cultivars, I.R.8 and Taichung (N.)1, from the International Rice Research Institute (I.R.R.I.) at the Philippines. The two crosses were: Cross I, Giza 159 × I.R.8, and cross II, Giza 159 × Taichung (N.)1. In 1974, the P_1, P_2, F_1, BC_1, BC_2, and F_2 populations were grown in 3 m long rows as follows: thirty rows for the F_2 plants, four rows for the two backcross plants (BC_1 and BC_2), and three rows for both parents (P_1 and P_2) and F_1 plants. The seeding rate was fifteen grains per row spaced at 20 cm.

The following agronomic characters were measured: 1) Grain yield per plant (in grams), 2) plant height (in centimeters), 3) 100-grain weight (in grams), 4) number of ear-bearing tillers per plant, and 5) panicle length (in centimeters). The types of gene effects were estimated according to the relationships given by Gamble (12) and are presented as follows:

$$a = BC_1 - BC_2.$$
$$d = -\tfrac{1}{2}P_1 - \tfrac{1}{2}P_2 + F_1 - 4F_2 + 2BC_1 + 2BC_2.$$
$$aa = -4F_2 + 2BC_1 + 2BC_2.$$
$$ad = -\tfrac{1}{2}P_1 + \tfrac{1}{2}P_2 + BC_1 - BC_2.$$
$$dd = P_1 + P_2 + 2F_1 + 4F_2 - 4BC_1 - 4BC_2.$$

Where, a = additive gene effect, d = dominance gene effect, aa = additive × additive type of epistasis, ad = additive × dominance type of epistasis, and dd = dominance × dominance type of epistasis.

The significance of these effects were tested by conducting the 't' test as follows:

$$\pm t = \frac{\text{Effect}}{\sqrt{\text{Variance of effect}}},$$

where the variance of any effect is a linear function of the variance of its mean.

RESULTS AND DISCUSSION

Means of measured characters of the parental cultivars (P_1 and P_2), F_1, BC_1, BC_2, and F_2 populations are presented in Table 1. Types of gene effects, using generation means, is illustrated in Table 2. It is obvious that all studied characters were quantitatively inherited. Generally, significant differences were obtained between the two parents for all characters but the panicle length.

With respect to the grain yield per plant in cross I, highly significant values were estimated for all types of gene effects except the dominance × dominance type of epistasis. Similar results were shown by Chang *et al.* (9), Ranganathan *et al.* (18), and Sivasubramaniam and Madhava Menon (19). On the other hand, in cross II, the additive × additive and dominance × dominance types of epistasis were highly significant and significant, respectively, while the other gene effects were not significant. Murayama *et al.* (17) and Bardhan Roy *et al.* (7) reported similar results on heterosis of rice grain yield.

Table 1 Means of the five characters studied in P_1, P_2, F_1, BC_1, BC_2, and F_2 populations of the two crosses of rice.

Characters	Populations					
	P_1	BC_1	F_1	F_2	BC_2	P_2
Cross I: Giza 159 × I.R.8:						
1. Grain yield/plant (g)	17.88	14.40	21.24	15.66	25.30	22.41
2. Plant height (cm)	88.07	80.78	92.90	74.24	76.30	69.87
3. 100-grain weight (g)	2.92	2.80	2.93	2.76	3.06	3.03
4. No. of ear-bearing tillers/plant	8.33	11.35	7.95	12.11	12.23	11.57
5. Panicle length (cm)	16.70	16.08	15.63	16.69	14.85	14.68
Cross II: Giza 159 × Taichung (N.)1:						
1. Grain yield/plant (g)	15.19	16.76	21.64	19.66	15.49	12.95
2. Plant height (cm)	91.50	90.22	90.32	78.55	13.33	61.67
3. 100-grain weight (g)	2.80	2.79	2.76	2.84	2.56	2.36
4. No. of ear-bearing tillers/plant	7.13	10.36	5.96	12.62	10.13	9.80
5. Panicle length (cm)	16.17	16.75	15.12	16.73	14.06	16.23

The plant height was significantly affected by the two major types of gene effects (a and d) and the additive × additive type of epistasis in the two crosses. Moreover, a highly significant additive × dominance type of epistasis for height was found in cross I only. However, the values of dominance × dominance epistatic effect on height were not significant in the two crosses. These results were in accordance with those reported by I.R.R.I. (3), Mohamed and Hanna (16), Ahmed (1), Chang (8), and Sivasubramaniam and Madhava Menon (20,21).

Concerning the 100-grain weight, the values of all types of gene effects were not significant in cross I. However, in cross II, all types of gene effects gave either highly significant (a,d,aa) or significant (dd) values except the additive × dominance type of epistasis for which no significant effect was detected. Other findings (5,18) reported significant additive and dominance gene effects on this character in other rice crosses.

Table 2 Types of gene effects using generation means of the five characters studied in the two crosses of rice.

Characters	Types of gene effects[a]				
	a	d	aa	ad	dd
Cross I: Giza 159 × I.R.8:					
1. Grain yield/plant (g)	−10.90**[b]	17.85**	16.76**	8.63**	−13.39
2. Plant height (cm)	4.48**	31.13**	17.20**	−4.62**	12.38
3. 100-grain weight (g)	− 0.26	0.64	0.68	−0.21	− 0.59
4. No. of ear-bearing tillers/plant	− 0.88	− 3.27	− 1.28	0.14	−10.08
5. Panicle length (cm)	1.23	− 4.96**	4.90**	0.22	5.68**
Cross II: Giza 159 × Taichung (N.)1:					
1. Grain yield/plant (g)	1.27	− 6.56	−14.14**	0.15	21.06*
2. Plant height (cm)	16.89**	26.64**	12.90*	1.96	− 6.19
3. 100-grain weight (g)	0.23**	− 0.48**	− 0.66**	0.01	0.64*
4. No. of ear-bearing tillers/plant	0.23	−12.00**	− 9.50**	1.57*	− 2.63
5. Panicle length (cm)	2.69**	− 6.37**	5.30**	2.72**	6.32**

[a] a = additive gene effect, d = dominance gene effect, aa = additive × additive type of epistasis, ad = additive × dominance type of epistasis, and dd = dominance × dominance type of epistasis.
[b] * Significant at $P < 0.05$, and ** = Significant at $P < 0.01$.

With regard to the number of ear-bearing tillers per plant, non-significant estimations were recorded for the types of major gene and epistatic effects in cross I. Whereas, in cross II, the dominance gene effect and the additive × additive and additive × dominance types of epistatic effect were either significant or highly significant. These results disagreed with those found by Chang *et al.* (9), Balakrishna Rao *et al.* (6), and Sivasubramaniam and Madhava Menon (20). Ranganathan *et al.* (18) believed in the importance of additive and dominance gene effects on this character.

Considering the panicle length, highly significant effect was detected for all types of gene effects in cross II. In cross I, however, the dominance effect and the additive × additive and dominance × dominance epistatic effects were highly significant, while the other effects were not significant. Ahmed (1), I.R.R.I. (4), and Chang *et al.* (9) pointed out the importance of additive gene effect on panicle length in other rice crosses. However, other workers (16,18) believed in the importance of dominance gene effect in this case.

It may be concluded from the results of the present studies that the additive gene effect was significant in two and three out of the five characters studied in crosses I and II, respectively. On the other hand, the dominance gene effect was exhibited in three (cross I) and four (cross II) characters and its magnitude, generally, was relatively high for grain yield per plant, plant height, number of ear-bearing tillers per plant, and panicle length in both crosses. This may support the general belief that dominance gene effect had a major contribution in the inheritance of quantitative characters in rice. Epistatic gene effect had a significant contribution in the inheritance of the studied characters, indicating the presence of significant genetic variation in the two crosses. The additive × additive gene effect appeared to contribute more to epistasis than either the additive × dominance or dominance × dominance types of epistasis.

The magnitude of gene effect in the present investigation could not be compared since it was calculated as an average over a large number of loci. Therefore, it was expected that some loci would have positive effects, while others have negative effects. Consequently, the average gene effect would be less due to neglegence of the individual gene effects. These results showed that epistatic variation could contribute a significant effect in the inheritance of quantitative traits in the present crosses of rice.

LITERATURE CITED

1. Ahmed, I. S. 1967. Study of the inheritance of some characters in some rice crosses. M.Sc. Thesis, Cairo University, Egypt.
2. Anderson, V. L., and O. Kempthorne. 1954. A model for the study of quantitative inheritance. Genetics 39:883–898.
3. Anonymous, 1966. International Rice Research Institute (I.R.R.I.) Report. Los Banos, Laguna, Philippines. p. 302.
4. Anonymous. 1967. International Rice Research Institute (I.R.R.I.) Report. Los Banos, Laguna, Philippines. p. 308.
5. Anonymous. 1972. Central Rice Research Institute, Cuttack. Tech. Report for the year 1971. New Delhi, Indian Council of Agric. Research. p. 242.
6. Balakrishna Rao, M. J., D. Chaudhary, S. N. Ratho, and R. W. Mishra. 1973. Variability and correlation studies in upland rice. Oryza 10(1):15–21.
7. Bardhan Roy, S. K., A. K. Mitra, and D. K. Mukherji. 1975. Hybrid vigor in five cross combinations in rice (*Oryza sativa* L.). Science and Culture 41(3):118–119.

8. Chang, T. M. 1970, Studies on the genetics of semidwarf rice. J. of Taiwan Agric. Res. 19:1–10.
9. Chang, T. T., C. C. Li, and O. Tagumpay. 1973. Genotypic correlation, heterosis, inbreeding depression, and transgressive segregation of agronomic traits in a diallel cross of rice (*Oryza sativa* L.). Bot. Bull. of Academia Sinica 14(2):83–93.
10. Comstock, R. E., and H. F. Robinson. 1948. The components of genetic variance in populations of biparental progenies and their use in estimating the average degree of dominance. Biometrics 4:254–266.
11. Fisher, R. A. 1918. The correlation between relatives on the supposition of Mendelian inheritance. Trans. Royal Soc. Edinb. 52:399–433.
12. Gamble, E. E. 1962. Gene effects in corn (*Zea mays* L.). 1. Separation and relative importance of gene effects for yield. Can. J. Plant Sci. 42:339–348.
13. Griffing, B. 1953. An analysis of tomato yield components in terms of genotypic and environmental effects. Iowa Agric. Exp. Sta. Res. Bull. 397:324–380.
14. Hayman, B. I., and K. Mather. 1955. The description of genetic interaction in continuous variation. Biometrics 11:69–82.
15. Mather, K. 1949. Biometrical Genetics. Dover Publ. Inc., London.
16. Mohamed, A. H., and A. S. Hanna. 1965. Inheritance of quantitative characters in rice. II. Inheritance of panicle length. Can. J. Genet. Cyt. 7:406–417.
17. Murayama, S., T. Omura, and K. Miyazato. 1974. Basic studies on utilization of hybrid vigor in rice. IV. Heterosis under different cultural conditions. Jap. J. of Breeding 24(6):287–290. (Japanese).
18. Ranganathan, T. B., S. R. Sree Rangasamy, and P. Madhava Menon. 1973. Genetic investigations on duration of flowering and yield in semidwarf varieties of rice. Inter. Rice. Comm. Newsletter 22(4):31–43.
19. Sivasubramaniam, S., and P. Madhava Menon. 1973. Combining ability in rice. Madras Agric. J. 60(6):419–421.
20. Sivasubramaniam, S., and P. Madhava Menon. 1973. Genetic analysis of quantitative characters in rice through diallel crosses. Madras Agric. J. 60(9):1097–1102.
21. Sivasubramaniam, S., and P. Madhava Menon. 1973. Inheritance of short stature in rice. Madras Agric. J. 60(9):1129–1133.