Oryza Vol. 50 No.2, 2013 (115-119)

Detection of epistasis and gene effects for quality and yield traits in rice

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ABSTRACT

Scaling test and generation mean analysis were employed to detect epistatasis and gene actions in four crosses of rice for six yield and quality traits. Dominant gene effect was more important than additive in the inheritance of number of effective tillers per plant, alkali digestion value and volume expansion. Number of grains panicle^{-1} and water uptake number were mostly controlled by additive gene effect epistatic gene effects namely, additive x additive (j) and dominance x dominance (l) were more pronounced for most of the characters except number of effective tillers plant^{-1}. Heterosis for yield plant^{-1} and number of grains panicle^{-1} were considerably high. It was 71 per cent for grain in the cross MPR 71 x IT 1443. The cross Pusa Basmati 1 x NDR 359 exhibited highest heterosis (79%) for number of grains panicle^{-1} with low inbreeding depression. In general inbreeding depression in four crosses over the traits ranged from -23.58 to 14.28 per cent for number of grains panicle^{-1} and alkali digestion value, respectively.

Key words: *scaling test, generation mean analysis, rice, heterosis, inbreeding depression*

The productivity level of rice in India is very low (3.21 t/ha) as compared to the average productivity of the China (6.35 t/ha) and world (4.15 t/ha) (*Anonymous* 2008).In recent years, rice production has reached a plateau. The narrow genetic base of semi-dwarf varieties has made them vulnerable to different biotic and a biotic stresses. Therefore, to meet the increasing demand of rice for ever increasing population, emphasis should be given to genetic improvement/replacement of the existing varieties. The major thrust area for genetic improvement would lie in identifying desirable parents for hybridization programme. This would depend to a large extent on the knowledge of gene actions controlling various characters. Scaling test and generation mean analysis are efficient biometirical tools for assessing the importance of epistasis and estimating the gene(s) effects. The reliability of the estimates and genetic gains of selection in segregating population largely depend upon the genetic divergence of the parents involved and the precision of testing. In order to study the inheritance of some important quality and yield traits in terms of gene effects, four crosses representing diversity of parents for the characters under study were subjected to scaling test and generation mean analysis.

MATERIALS AND METHODS

Six generations i.e. P_1, P_2, F_1, F_2, B_1 and B_2 of four selected rice crosses *viz.,* NDR 118 x Taraori Basmati, DBS-20 x LM 1, Pusa Basmati 1 x NDR 359 and MPR 1 x IET 1443, representing contrasting performance of parents for the characters under study were grown in Completely Randomized Block Design with three replications during wet season at the Agriculture Research Farm of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Observations were recorded on ten randomly selected plants parents^{-1} and F_1s, twenty plants per back crosses and fifty plants per F_2 in each replication for characters namely, number of effective tillers plant^{-1} (NETP), number of grains panicle^{-1} (NGP), alkali digestion value (ADV), water uptake number (WUN), volume expansion (VE) and grain yield/plant (GY) in all the crosses. Detection of epistatic crosses was carried out by scaling test (Mather, 1949; Hayman and Mather, 1955). Estimation of gene actions for crosses exhibiting epistasis was carried out following six parameters model (Hayman, 1958; Jinks and Jones, 1958) whereas, for non-interacting crosses three parameter models was employed followed by method of Jinks and Jones, 1958). The heterosis over better parent and inbreeding depression were estimated according to their standard formulae.

RESULTS AND DISCUSSION

All the four crosses for number of effective tillers plant^{-1} were non-interacting as detected by scaling test (Table 1). Among the additive and dominance types of gene effect, dominance gene effect was predominant in the inheritance of this character. Additive gene effect was significant only in the cross MPR7 1 x IET 1443. The heterobeltiosis ranged was observed from -0.7 to 22.30 per cent in the cross NDR 118 x Taraori Basmati and Pusa Basmati 1 x NDR 559) respectively. Inbreeding depression was significant in all the crosses and it ranged from 5.30 to 9.30 per cent. Two crosses namely, NDR 118 x Taraori Basmati and DBS 20 x LM 1 showed low and non-significant estimates of heterosis and exhibited considerable amount of inbreeding depression. The cross MPR7 1 x IET 1443 which showed additive gene effect for NETP exhibited significant heterosis as well as inbreeding depression. Though the dominant gene action was predominant it was reflected towards heterosis only in the cross Pusa Basmati 1 x NDR 359 exhibiting highest heterosis (Table 2). The importance of dominance gene action in the inheritance of NETP has also been reported (Verma, *et al.,* 2003) whereas; predominance of additive gene action was reported by other rice workers (Sharma and Mani, 2000).

The epistatic gene action was found important for number of grains per panicle in three of the four crosses which showed significance of either 'C' or 'A' scales. Among the additive and dominance gene effects, additive gene effect was comparatively more pronounced. Among the epistatic gene actions, dominance x dominance (l) type of epistasis was significant in two of the three crosses indicating its role in the inheritance apart from additive and dominance types of gene effects. Heterosis over better parent for this character ranged 18.56 to 78.99 per cent. The cross Pusa Basmati 1 x NDR 359 showed highest heterosis, and non-significant magnitude of inbreeding depression as well. On the other hand cross MPR7 1 x IET 1443 exhibiting next higher heterosis had negative and significant inbreeding depression. This cross was predominantly controlled by additive and dominance x dominance types of gene effects. Rest of the crosses showing non-significant inbreeding depression were

Table 1. Scaling test for six traits in four selected crosses of rice

Cross	Scale	NETP	NGP	GY	WUN	ADV	VE
NDR 118xTaraori Basmati	A	0.33	4.00	0.43	20.00	-0.26	-0.03
	B	-8.80	6.33	-0.53	35.00	-0.80	0.80*
	C	-1.06	38.33	6.83	28.33	-1.06	-0.36
	D	-0.30	14.00	3.46	-13.33	0.01	-0.57**
DBS 20xLM 1	A	-1.20	38.34	-1.80	-22.00	1.21**	0.05
	B	1.33	29.36	-0.27	-15.00	0.27	-0.10
	C	-1.73	84.33*	5.00	13.00	1.48*	1.20
	D	-0.93	8.33	3.53	25.00	0.02	0.65
Pusa Basmati 1xNDR 359	A	1.33	33.33	3.47	16.00	-1.40**	0.30
	B	0.43	42.00	2.80	30.00	0.20	0.03
	C	2.76	140.67*	7.06	140.00**	-4.00**	0.50
	D	0.50	32.67	0.40	47.00**	1.40**	0.10
MPR7 1xIET 1443	A	01.13	65.00**	-1.10	15.00	-0.10	00.77**
	B	-0.73	59.67	-3.43	-89.67	-0.09	00.01
	C	04.40	94.00	12.67**	20.00	02.10*	01.00*
	D	02.00	-15.33	08.60*	47.37	01.14*	00.11

NETP = Number of effective tillers plant^{-1}, NGP = Number of grains panicle^{-1}, GY = Grain yield plant^{-1}, WUN = Water uptake number; ADV = Alkali digestion value and VE = Volume expansion

Table 2. Estimates of gene effects for six traits in four crosses of rice

Cross	Estimates	NETP	NGP	GY	WUN	ADV	VE
NDR 118 x Taraori Basmati	m	08.59**	90.67**	02.40**	313.34**	04.30**	04.10**
	d	-0.56	09.33	-0.22	80.00**	-0.80*	00.27*
	h	01.66	-2.83	-0.45	34.16	-.93	01.95*
	i		-	-	-	-	01.14**
	j		-	-	-	-	0.411**
	l		-	-	-	-	-0.19**
DBS 20 x LM 1	m	07.87**	206.33**	20.13	400.00**	05.30**	04.00**
	d	-1.73	11.00	-1.00	-75.00*	-1.20	-.50
	h	02.47*	50.17	-1.50	-23.50	-0.32	-0.90
	i	-	-16.67	-	-	00.01	-
	j	-	04.50	-	-	00.47*	-
	l	-	-51.00	-	-	1.48	-
Pusa Basmati 1 x NDR 359	m	80.00**	165.33**	17.53**	350.00**	04.20**	03.60*
	d	01.23	05.34	-1.33	-17.00	00.60**	00.70**
	h	01.31	21.00	06.06	-44.00	02.00**	00.25
	i	-	-65.34	-	-94.00	02.80**	-
	j	-	-4.34	-	-7.00	-0.80**	-
	l	-	-10.00	-	48.00	-1.60*	-
MPR7 1 x IET 1443	m	08.66**	189.34**	22.00**	290.00**	06.20**	04.65**
	d	03.46*	-62.00**	02.33	07.34	00.14	-0.71**
	h	-0.87	-11.67	-5.86	-94.67	-1.64*	00.56
	i	-	30.67	-17.20	-93.60	-2.29**	-0.32
	j	-	02.67	01.16	52.34*	-0.01	0.38*
	l	-	-155.34*	21.73*	169.33	02.48*	-0.53

NETP = Number of effective tillers plant^{-1}, NGP = Number of grains panicle^{-1}, GY = Grain yield plant^{-1}, WUN = Water uptake number; ADV = Alkali digestion value and VE = Volume expansion

either controlled by additive, dominance or additive x dominance and dominance x dominance types of epistatic gene effects. Importance of dominance x dominance (1) types of epistasis along with the additive type of gene action was also reported (Roy and Panwar, 1995).

Out of four crosses, one cross was interacting and others were non-interacting for grain yield per plant. Among non-interacting crosses additive and dominance gene effect were non-significant except dominance gene effect for the cross Pusa Basmati 1 x NDR 359. The cross MPR7 1 x IET 1443 showed presence of epistasis, it was mostly under control of dominance and dominance x dominance type of gene actions. The non-significant of additive/dominance gene effect in most of the crosses might be due to higher estimates of standard error and or less diversity for grain yield among the parents (Table 3). The heterosis for grain yield was significant in all the crosses and it ranged from 32.7 to 70.96 per cent. Inbreeding depression in most of the crosses was significant.

Two of the four crosses exhibited presence of epistasis and only two were controlled by additive and dominance types of gene action for water uptake. Additive gene action was predominant compared to dominant in the inheritance of WUN. Among the epistatic crosses Pusa Basmati 1 x NDR 359 exhibited the importance of additive x additive types of epistasis whereas, importance of additive x dominance and dominance x dominance types of epistasis was reflected in the cross MPR7 1 x IET 1443. The crosses namely, NDR 118 x Taraori Basmati and DBS 20 x LM 1 were non-interacting and included parents with large diversity for this character (Table 3). Additive gene action for water uptake number was observed in rice by earlier workers (Vivekanandan and Giridharan, 1997). The significant heterosis over better parent was revealed by the cross NDR 118 x Taraori Basmati and the

Table 3. Estimates of heterosis, inbreeding depression and significant gene effects for six traits in four crosses of rice

Crosses	Estimate	NETP	NGP	GY	WUN	ADV	VE
NDR 118xTaraori Basmati	BPH	-0.70	18.56*	53.84**	44.18**	3.53	2.90
	ID	9.30**	3.30	7.59*	-1.06	-4.65	12.19**
	GE	h	d	%	d	D	d, h, i, j
DBS 20xLM 1	BPH	2.36	38.11**	32.70**	-9.89	-29.54**	-4.87*
	ID	9.27*	5.98	7.65*	2.50	-10.0*	2.50
	GE	h	d, h, I	%	-d	d, j	D
Pusa Basmati 1xNDR 359	BPH	22.32**	78.99**	37.14**	13.03	-31.42**	-9.75**
	ID	5.87*	4.65	9.52*	-2.85	14.28**	2.77
	GE	h	h	h	i	d, h, i, j, I	D
MPR7 1xIET 1443	BPH	7.03**	42.51**	70.96**	-13.63	9.09*	-5.88**
	ID	5.30*	-23.58**	11.36*	-1.72	-3.22	3.20
	GE	d	d, I	h, I	j, I	h, i, I	d, j

BPH= Better parent heterosis, ID = Inbreeding depression, GE= Significant gene effects

NETP = Number of effective tillers plant^{-1}, NGP = Number of grains panicle^{-1}, GY = Grain yield plant^{-1}, WUN = Water uptake number; ADV = Alkali digestion value and VE = Volume expansion

inbreeding depression was low and non-significant. The cross predominantly exhibited additive gene effect.

Alkali digestion value of all the crosses except one exhibited the importance of inter- allelic gene action. The cross NDR 118 x Taraori Basmati was non-interacting and showed the importance of additive gene action. This cross was considerably diverse for ADV (Table 3). Among the interacting crosses, Pusa Basmati 1 x NDR 359 exhibited the importance of all kinds of gene effects whereas, the cross MPR7 1 x IET 1443 showed significant estimates of h, i and l types of gene actions. The ADV of the parents involved in the cross DBS 20 x LM 1 was 3.36 and 6.81, respectively. This cross showed the importance of additive and additive x dominance types of gene action. Importance of non-additive gene action for ADV was also reported in hybrid rice grain (Leng and Hong Delin, 2004). The nature of gene action varied with the diversity of the parents involved in the crosses with respect to ADV. Two crosses namely: DBS 20 x LM 1 and Pusa Basmati 1 x NDR 359 are exhibited negative and significant heterosis for ADV and showed the importance of epistatic gene action apart from the additive gene effect.

Two crosses such as DBS 20 x LM 1 and Pusa Basmati 1 x NDR 359 were non-interacting and exhibited the importance of additive gene action in the inheritance of volume expression (VE). Both the crosses involved parents with considerable diversity for volume expansion. The interacting crosses exhibited the importance of additive x dominance types of interallelic interaction along with the additive type of gene effects. The importance of dominance and additive x additive effects were reflected only in the cross NDR 118 x Taraori Basmati. Additive gene effect was predominant in all the three crosses. The cross NDR 118 x Taraori Basmati exhibited positive but non-significant heterosis and significant inbreeding depression. It showed the importance of all gene effects except dominance x dominance type of epistasis. Role of additive gene action in the inheritance of VE was observed in kernels of rice (Mohan and Ganeshan, 2003). On the other hand the importance of non-additive gene action was reported by other rice worker (Munhot *et al.,* 2000). In general, importance of additive component was observed in several cases while dominance in few cases of the crosses for the characters under study. Among the epistatic effect dominance x dominance (I) and additive x dominance (j) interactions were more frequent than the additive x additive (i) type. These results are inconformity with the earlier worker (Roy and Panwar, 1995). Contrary to the present finding other rice worker (Chauhan, 1991) observed greater frequency of additive x dominance epistasis apart from additive and dominance gene effects in the inheritance of yield traits in rice. The importance of additive gene action compared to dominance and epistatic gene action for quality traits in rice was also reported (Verma *et al.,* 2004).

Thus, the diversity of the parents with regard to specific character in detection of gene actions through generation means analysis seems to be an important criterion. Diverse the parents would mean F_1 to be heterozygous for most of the genes by which character is being controlled and ultimately F_2, B_1 and B_2 generations would be expected to exhibit true effects of segregation and recombination on the means of generations. Gene effects (d, h, i, j, l) may remain unfolded if the initial F_1 cross does not include parents of possible extreme phenotypes for the character under study.

It can be visualized from the present study that in most of the cases wherever, significant gene actions were observed, the F_1 included diverse parents. On the other hand F_1 including less diverse parents for the character under study, resulted into non-significant estimates of various gene effects or a unclear picture of gene actions for the character.

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