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Gene action study for yield and drought related traits under irrigated and rainfed regime in rice (*Oryza sativa* L.)

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Abstract

An experiment was conducted in rice during 2017-18 using six generations of two crosses *i.e.* Azucena x BPT-5204 and Azucena x NDR-359 in two environments namely irrigated and rainfed conditions to investigate the various gene action for different yield and drought related traits through generation mean analysis. During the investigation, scaling test revealed the presence of epistasis for most of the traits under study in both the environments for both crosses. Hence, six parameter model was adopted in the presence of epistasis and three parameter model was used in the absence of epistasis for few traits under both the environments. The obtained results revealed the pre preponderance of non allelic interaction along with dominance gene effect on the expression of majority of the traits under study suggesting the postponement of the selection until fixation of higher amount of additive effect. Duplicate epistasis was reported for most of the traits suggesting that epistasis has a key role in the expression of the yield and drought related traits in present study.

Keywords: Gene action, generation mean analysis, scaling test, epistasis, yield

Introduction

Rice is a semi aquatic plant and one of the most important and staple food crops in the world upon which fifty percent of the population depends. The production of rice had attained its plateau and therefore it is the need of hour to increased productivity of rice in the scenario of ever growing population and ever changing climate. Increased productivity can be achieved by exploiting the available variability through hybridization and selection (Palaniraja, 2017) [7]. To carry out the systemic plant breeding programme, in-depth knowledge of gene action and interaction governing the traits is inevitable. Extent of trait improvement through selection can be elucidated with the help of combining ability analysis but it comes with the limit that it does not display the nature and magnitude of gene action. But generation mean analysis provides the scope to know the addititve and dominance component along with epistatsis. It is essential to investigate the non allelic interaction which can be overestimating the additive and dominance components (Gobu *et al.*, 2021) [3]. There are various biometrical techniques used but generation mean analysis is best approach to investigate gene effects and non allelic interactions to elucidate the genotypic values of the individuals. Thus, present study was undertaken to investigate the gene action and their interactions for different traits in rice for two crosses *i.e.* Azucena x BPT–5204 and Azucena x NDR-359 through generation mean analysis under irrigated as well as rainfed conditions.

Material and Methods

An experiment was conducted with two crosses In the present study two crosses comprising of three rice genotypes *i.e.* Azucena (deep rooted and drought tolerant), BPT-5204 (high yielding and Shallow rooted) and NDR-359 (high yielding and shallow rooted variety) was made. The crosses Azucena x BPT-5204 and Azucena x NDR-359 were utilized to investigate the gene actions of different traits under study. Study was conducted and crosses were made at two locations *i.e.* Institute of Agricultural Sciences, Banaras Hindu University, Varanasi and National Rice Research Institute (NRRI), Cuttack. Experimental material comprising of six generations namely P_1 (Parent 1), P_2 (parent 2), F_1 (first filial generation) F_2 (second filial generation), BC_1 (F_1 x P_1) and BC_2 (F_2 x P_2) were planted using compact family block design under two environments *i.e.* irrigated and rainfed conditions following standard package of practices. Observations for days to fifty percent flowering, plant height, panicle length number

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of panicle bearing tillers per plant, number of spikelet per panicle, 100 grain weight, total grain yield per plant, chlorophyll content, proline content and leaf rolling were recorded in both the conditions. Scaling test was carried out as suggested by Mather (1949) and Cavalli (1952) to know the presence or absence of epistasis. Scaling test indicating significant deviation from zero shows inadequacy of model suggesting the presence of non allelic interaction. In such cases, six parameter model suggested by Hayman (1958) and Jinks and Jones (1958) was used to estimate the gene effects $(\hat{m}, \hat{d}\ and\ \hat{h})$ and their interaction in the form of $(\hat{\imath}, \hat{\jmath}\ and\ \hat{l})$ whereas in case of adequacy of aditive dominance model, three parameter model suggested by Jinks and Jones (1958), was applied to estimate the gene effects *i.e.* $(\hat{m}, \hat{d}\ and\ \hat{h})$ and 't' test was carried out to test the significance of gene effect. Calculated values were compared to tabulated 't' values at respective degree of freedom at 5% and 1% level of significance.

Results and Discussion

The recorded observations were subjected to scaling test and results obtained from scaling test are presented in Table 1. All the three types of epistasis (non-allelic interaction) *viz.*,(*i*) additive × additive, (*j*) additive × dominance) and (*l*) (dominance × dominance) was indicated by significance of scale A or B. Dominance × dominance type of epistasis (*l*) was indicated by significance of only C scale and additive × additive (*i*) types of epistasis was indicated by significance of only scale D. Scaling test (A, B, C, D) showed the significant deviation from zero for both the crosses (Azucena x BPT-5204 and Azucena x NDR-359) in both the environments *i.e.* rainfed and irrigated conditions indicating the presence of epistasis for most of the traits studied and displaying the complex nature of inheritance of yield and drought tolerant traits in rice. There are plenty of reports to support the presence of epistasis for yield traits in rice (Thirumani *et al.*, 2003, Goel *et al.*, 2006, Bano *et al.*, 2017, Gobu *et al.*, 2021) [11, 4, 2, 3]. Therefore in all such cases in both the conditions, six parameter model was used in the presence of epistasis for investigating their gene action. Epistatic (Nol-allelic) interaction was reported absent in the cross Azucena x BPT-5204 (irrigated) and Azucena x NDR 359 (rainfed) for number of effective panicle bearing tillers, Azucena x NDR-359 (rainfed) for chlorophyll content, Azucena x NDR-359 (in irrigated and rainfed conditions) and Azucena x NDR-359 for stomatal conductance.

Table 1: Scaling Test for eleven traits in rice under irrigated and rainfed condition.

Characters	Environments	Cross	A	B	C	D	Non Allelic Interaction
Days to 50 percent flowering	Irrigated	Azucena x NDR-359	2.05	2.05	-18.12**	-11.11**	Present
		Azucena x BPT-5204	0.01	0.01	-19.60*	-9.80*	Present
	Rainfed	Azucena x NDR-359	0.05	0.05	-35.40**	-17.75**	Present
		Azucena x BPT-5204	0.01	0.01	-17.20**	-8.60**	Present
Plant Height (cm)	Irrigated	Azucena x NDR-359	0.01	0.02	-38.39**	-19.20**	Present
		Azucena x BPT-5204	-26.50**	26.51**	68.43**	34.21**	Present
	Rainfed	Azucena x NDR-359	0.01	0.01	45.13**	22.56**	Present
		Azucena x BPT-5204	0.01	0.02	33.67*	16.83*	Present
Panicle Length (cm)	Irrigated	Azucena x NDR-359	0.01	0.02	-22.99**	-11.50**	Present
		Azucena x BPT-5204	0.01	0.01	10.24**	5.12**	Present
	Rainfed	Azucena x NDR-359	-0.01	-0.01	10.50**	5.25**	Present
		Azucena x BPT-5204	-0.01	-5.50**	21.26	13.38*	Present
No. of Panicle bearing Tillers	Irrigated	Azucena x NDR-359	-3.14**	3.14**	10.05**	5.03**	Present
		Azucena x BPT-5204	-0.26	0.25	-0.96	-0.48	Absent
	Rainfed	Azucena x NDR-359	-0.11	0.22	0.48	0.18	Absent
		Azucena x BPT-5204	-3.82**	3.82**	-3.76	-1.88	Present
No. of Spikelets per panicle	Irrigated	Azucena x NDR-359	0.01	0.01	-156.97**	-78.49**	Present
		Azucena x BPT-5204	0.01	-0.01	17.50	8.75	Absent
	Rainfed	Azucena x NDR-359	-4.65	1.15	-37.00*	-16.75	Present
		Azucena x BPT-5204	0.01	0.01	36.30*	18.15*	Present
100 grain weight (g)	Irrigated	Azucena x NDR-359	-0.09	0.09	-0.30	-0.15	Absent
		Azucena x BPT-5204	-0.01	-0.01	0.44**	0.22**	Present
	Rainfed	Azucena x NDR-359	-0.19**	0.20**	0.05	0.02	Present
		Azucena x BPT-5204	-0.39**	0.39*	-0.72**	-0.36**	Present
Total Grain yield (g)	Irrigated	Azucena x NDR-359	-1.20	1.80*	36.25**	17.83**	Present
		Azucena x BPT-5204	-1.32*	1.33	-3.64	-1.82	Present
	Rainfed	Azucena x NDR-359	-0.79	0.79	-2.54*	-1.27*	Present
		Azucena x BPT-5204	-1.99**	1.99**	4.05**	2.02*	Present
Proline content	Irrigated	Azucena x NDR-359	0.01	0.01	8.50	4.24	Absent
		Azucena x BPT-5204	0.01	0.03	-11.73**	-5.87**	Present
	Rainfed	Azucena x NDR-359	0.08	0.01	6.41	3.17	Absent
		Azucena x BPT-5204	0.84	-1.66	-12.11**	-5.64**	Present
Chlorophyll content	Irrigated	Azucena x NDR-359	-0.01	0.01	-2.62	-1.31	Absent
		Azucena x BPT-5204	-4.79*	5.53*	-1.36	-1.05	Present
	Rainfed	Azucena x NDR-359	0.01	0.01	-9.36	-4.68	Absent
		Azucena x BPT-5204	-3.67*	3.67	1.35	0.68	Present
Stomatal Conductance	Irrigated	Azucena x NDR-359	-13.70	13.72	159.78	79.88	Absent
		Azucena x BPT-5204	0.01	0.01	121.30*	60.65	Present

	Rainfed	Azucena x NDR-359	0.01	0.01	-1.88	-0.94	Absent
		Azucena x BPT-5204	44.95	-44.95*	81.60	40.80	Present
Leaf rolling	Irrigated	Azucena x NDR-359	-0.15	0.35	0.90*	0.35	Present
		Azucena x BPT-5204	0.01	0.73*	0.13	-0.30	Present
	Rainfed	Azucena x NDR-359	-0.50	0.50	2.70**	1.35**	Present
		Azucena x BPT-5204	-0.63	0.73	7.03**	3.47**	Present

** - Significant at P=0.01 * - Significant at P=0.05

The estimates of gene effect for traits under study for both the crosses in both the environments (irrigated and rainfed condition) is presented in Table 2. Positive and Results revealed that, the dominance gene effect [h] was prevailing in majority of the traits in both the environment in both the directions. Further, results also revealed that dominance gene effect [h] was contributing higher as compared to additive gene effect [d], suggesting the preponderance of the dominance gene effects in the inheritance of these traits. These findings were in agreement with earlier reports of Thirumeni *et al.* (2000) [12], Renata *et al.* (2006) [8] and Srivastava *et al.*, (2012) [10]. In the present study carried out, only few traits like days to 50 percent flowering, plant height, number of panicle bearing tillers, proline content and stomatal conductance displayed significant additive gene effect either in rainfed or irrigated environment. Kumar *et al*. 2007 [5] reported in their study that number of tillers per plant was showing additive effect. Overall observations recorded that duplicate type of epistasis was found for most of the traits under both the conditions except plant height, panicle length and number of spikelet per panicle indicating preponderance of dominant gene effects for the expression of traits studied. These findings were in the line with reports of Awasthi and Lal (2014) [1]. Among the interactions, additive x addtitive and dominance x dominance gene interaction showed significance for majority of the traits followed by additive x dominance gene interaction. Similar findings were also observed by Verma *et al*. (2006) [13]. Additive x dominance type of interaction showed negative values in higher number then additive x additive and dominance x dominance interactions. These findings clearly demonstrate the complex nature of traits under study and therefore, early generation selection for these traits might not be fruitful and also misleading. Further, preponderance of non-additive gene action for majority of the traits in both the environments in both the crosses demonstrated that that selection carried out in later generations will be very effective. These reports are in agreement with earlier findings of Xu *et al.* (1998) [14] and Malinee *et al.* (2013) [6].

Table 2: Estimates of gene effects for eleven traits in rice under rainfed and irrigated conditions

Traits	Environ.	Crosses	m	d	h	i	J	l	Epistasis
Days to 50 percent flowering	Irrigated	Azucena x NDR-359	11.99**	2.05	20.17**	22.22**	1.42	-26.31**	D
		Azucena x BPT-5204	102.15**	2.55	19.60*	19.60*	2.42	-19.60*	D
	Rainfed	Azucena x NDR-359	92.88**	4.45**	35.45**	35.50**	-0.01	-35.60**	D
		Azucena x BPT-5204	98.55**	5.75	17.20**	17.20**	0.01	-17.20*	D
Plant Height (cm)	Irrigated	Azucena x NDR-359	92.57**	11.34**	38.40**	38.40**	-0.03	38.40**	C
		Azucena x BPT-5204	17.03**	-13.25	-69.08**	68.42	-26.51**	68.41**	D
	Rainfed	Azucena x NDR-359	91.03**	21.15**	47.28**	-45.12	0.01	45.11**	C
		Azucena x BPT-5204	12.50**	7.35*	-34.73*	-33.67	-0.02	33.66	D
Panicle Length (cm)	Irrigated	Azucena x NDR-359	18.42**	0.51	22.99**	22.99	0.02	-23.00**	D
		Azucena x BPT-5204	24.88**	2.14	-10.66**	-10.24	0.01	-10.24**	C
	Rainfed	Azucena x NDR-359	21.72**	3.85	-10.50**	-10.50	-0.01	10.50*	D
		Azucena x BPT-5204	27.22**	5.40	-26.76*	-26.76	2.75**	-32.26**	C
No. of Panicle bearing Tillers	Irrigated	Azucena x NDR-359	12.82**	-1.57**	-10.05**	-10.06**	-3.14**	10.06**	D
		Azucena x BPT-5204	7.91**	0.13	1.91	-	-	-	-
	Rainfed	Azucena x NDR-359	9.02**	0.08	-0.67	-	-	-	-
		Azucena x BPT-5204	8.75**	-1.91*	3.76	3.76	-3.82**	-3.76	D
No. of Spikelets per panicle	Irrigated	Azucena x NDR-359	90.48**	26.38	156.97**	156.97**	0.01	-166.98**	D
		Azucena x BPT-5204	62.45**	11.15*	-35.35	-	-	-	-
	Rainfed	Azucena x NDR-359	90.53**	22.80	33.25	33.50	-2.90	30.00	C
		Azucena x BPT-5204	14.28**	12.40*	-36.30*	-36.30*	0.01	36.30	D
100 grain weight (g)	Irrigated	Azucena x NDR-359	46.88**	0.60*	-70.70**	-	-	-	-
		Azucena x BPT-5204	2.09**	0.02	-0.58**	-0.45**	0.02	0.45*	D
	Rainfed	Azucena x NDR-359	2.02**	-0.10	-0.05	-0.05	-0.20**	0.04*	D
		Azucena x BPT-5204	1.92**	-0.20*	0.72**	0.72**	-0.39**	-0.72*	D
Total Grain yield (g)	Irrigated	Azucena x NDR-359	20.29**	-0.90	-35.65**	-11.65**	-1.50*	35.05**	D
		Azucena x BPT-5204	9.81**	-0.66	3.65	1.65	-1.33**	-3.65	D
	Rainfed	Azucena x NDR-359	6.38**	-0.39	2.54*	12.54	-0.79*	-2.54	D
		Azucena x BPT-5204	8.62**	-0.99*	-4.05*	-3.05*	-1.99**	4.05	D
Proline content	Irrigated	Azucena x NDR-359	40.94**	5.09**	-16.97	-	-	-	-
		Azucena x BPT-5204	32.26**	3.52**	12.35**	11.73**	-0.01	-11.73*	D
	Rainfed	Azucena x NDR-359	41.02**	3.87**	-12.54	-	-	-	-
		Azucena x BPT-5204	33.06**	4.63**	12.07**	11.29**	1.25	-10.47*	D
Clorophyll content	Irrigated	Azucena x NDR-359	33.67**	3.15	5.24	-	-	-	-
		Azucena x BPT-5204	42.00**	-2.58	2.74	2.10	-5.16**	-2.85	D

	Rainfed	Azucena x NDR-359	24.52**	3.90**	18.73	-	-	-	-
		Azucena x BPT-5204	39.44**	-1.83	-2.38	-1.35	-3.67**	1.35	D
Stomatal Conductance	Irrigated	Azucena x NDR-359	117.87**	6.85	-319.53	-	-	-	-
		Azucena x BPT-5204	1039.03**	43.40	-127.90*	-121.30	0.01	121.30	D
	Rainfed	Azucena x NDR-359	30.38**	3.41	3.78	-	-	-	-
		Azucena x BPT-5204	48.65**	89.90**	-81.60	-81.60	44.95*	81.60	D
Leaf rolling	Irrigated	Azucena x NDR-359	1.27**	-0.20	-0.70	-0.70	-0.25	0.50	D
		Azucena x BPT-5204	1.15**	-0.20	0.50	0.60	-0.37	-1.33	D
	Rainfed	Azucena x NDR-359	2.08**	0.01	-3.30**	-2.70**	-0.50	2.70*	D
		Azucena x BPT-5204	3.37**	-0.37	-6.88**	-6.93**	-0.68**	6.83**	D

** - Significant at P=0.01 * - Significant at P=0.05
C= Complementary gene action D = Duplicate gene action

In case of presence of epistasis, the dominance gene effect [h] and dominance x dominance gene effect [l] indicatong opposite sign for majority of the traits revealed the presence of duplicate epistasis except plant height, panicle length and number of spikelet per panicle. These findings were in agreement with Kumar *et al.* (2007) [5]. Similar findings were also reported by Roy and Senapati (2011) [9]. This may be resultant due to the presence of dispersed alleles which are located at interacting loci for these traits. Duplicate epistasis hinders the improvement through selection and in such situation, postponement of the selection for generations until a high level of gene fixation is realized would be rewarding.

Conclusion

Based on the observations it might be concluded that non allelic interaction (epistasis) play a key role in the expression of the traits under study in both the environments in both the crosses. Thus, breeding program carried out only based upon additive and dominance gene effects will be misleading. Non-allelic interactions along with dominance gene effect have major effects on the expression of majority of the yield traits. Based on the findings, bi-parental mating followed by recurrent selection or diallel-selective mating would be suggested. This allows to recover superior homozygote in later generations.

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