IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 12, December 2015.
www.ijiset.com
ISSN 2348 – 7968

Combining Ability and Gene Action for Yield and Its Component Characters in Rice

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ABSTRACT

Combining ability study on grain yield and its components from line x tester analysis over the locations of eight CMS lines and ten testers of different eco-geographic origin reveled specific combining ability was significant for all the traits except number of secondary branches per panicle and 100 grain weight in all the three environments and indicated that the importance of non additive gene effects for the expression of characters. The percentage contribution of lines was high in comparison to testers for all the traits under three environments except 100 grain weight in E2 showing that lines were diverse for these characters. IR 80559 A and IR 80154 A and two testers *viz.*, IR 62037 R and ASD 06-8 R exhibited earliness was found to have significant *gca* for days to 50 per cent flowering, RR 363 R was found to be good general combiners for semi dwarf plant type in all the environments. The parents *viz.*, IR 75601 A, IR 72081 A, IR 62037 R and TP 1021 R were adjudged as the best general combiners for yield and yield component traits.

Key words: Rice, combining ability, gene action, grain yield and component traits

INTRODUCTION

For improvement of any plant character through hybridization, it is necessary to understand the nature of gene action and genetic architecture of the donor parents for that character. Combining ability is the ability of an inbred to transmit their desirable performance to its hybrid progeny. It helps in identification of parents with high general combining ability (*gca*) effects and cross combinations with high specific combining ability (*sca*) effects and gives an idea about the relative magnitude of additive and non-additive types of gene action in expression of trait. Among the different genetic analyses, Line × Tester model is an important one to find out the combining ability of parents with rapidity and confidence. With this consideration the present study was undertaken to study the gene action and combining ability in rice.

MATERIALS AND METHODS

Eight diverse CGMS lines of rice *viz.,* IR 80559 A, APMS 6 A, IR 72081 A, IR 75601 A, IR 75596 A, IR 80154 A, CRMS 32 A, IR 75608 A were crossed with ten diverse elite restorer lines as testers *viz.*, IR 62037-93-1-3-1-1 (IR 62037 R), IR 72865-94-3-3-2 (IR 72865 R), IR 68427-8-3-3-2 (IR 68427 R), MDU 5 R, ACK 99017 R, TP 1021 R, RR 363-1 (RR 363 R), RR 347-1 (RR 347 R), RR 286-1 (RR 286 R) and ASD 06-8 R) through Line x Tester mating design during rabi 2007. The resultant eighty hybrids along with their parents were sown in raised beds and 25 days old seedlings were transplanted in main field under puddled condition under three environments (E1: Coimbatore, E2: Bhavanisagar and E3: Aliyar Nagar). For each genotype, single seedling per hill was planted at 20 x 20 cm spacing in two rows of 2.0 m length. Recommended fertilizer dose and cultural practices were adopted. In each entry, five plants were selected randomly from two replications and biometrical observations were recorded for eight quantitative characters *viz.*, days to 50 per cent flowering, plant height, number of productive tillers per plant, panicle length, number of secondary branches per panicle, number of grains per panicle, 100-grain weight and grain yield per plant using Standard Evaluation System of rice proposed by International Rice Research Institute. The estimates of general combining ability effects of the parents and specific combining ability effects of the hybrids were worked out according to the model illustrated by Kempthorne (1957).

RESULTS AND DISCUSSION

Analysis of variance is the pre requisite for further analysis of combining ability effects, which are justified only when variances at different levels are significant. ANOVA for RBD in individual environment showed significant differences among the hybrids under study in all the three environments. Further, ANOVA for combining ability revealed that mean squares due to general and specific combining ability were highly significant for all the traits. The analysis of variance for combining ability (Table 1) indicated that variances due to lines, testers and interaction effect (Line × Tester) were highly significant for all the characters. This trend indicated the presence of both additive and non additive gene action. In the present study, specific combining ability was significant for all the traits except number of secondary branches per panicle and 100 grain weight in all the three environments and indicated that the importance of non additive gene effects for the expression of characters. The pooled analysis of variance for combining ability over three locations reveled that the variance due to parents, hybrids, parent x hybrids interaction, lines and line x tester interaction were found to be significant for all the characters while testers significantly differed among themselves for the character single plant yield alone.

The GCA and SCA variances, additive and dominance genetic variances, their relative proportions and their interaction over environments estimated for all the eight traits were presented in table 1. The relative estimates of variances due to general and specific combining ability indicated that specific combining ability variances were predominant for all the characters in all the environment and pooled condition suggesting the significant role of non additive gene action. The ratio of variances due to general and specific combining ability ranged from -0.001:1 to 0.304:1. The results revealed that the dominance genetic variance (σ^2_D) was higher in magnitude for all the eight traits studied. The proportional contribution from Line × Tester was higher for days to 50 per cent flowering, plant height, number of productive tillers per plant, panicle length (except in environment 1), number of secondary branches per panicle, 100 grain weight, number of grains per panicle and single plant yield. This indicated the predominance of non additive gene action for these traits. The percentage contribution of lines was high in comparison to testers for all the traits under three environments except 100 grain weight in E2 showing that lines were diverse for these characters. Predominance of non additive gene action for grain yield and its components was also reported by Dalvi and Patel (2009). Therefore, heterosis breeding method is best suited to harness the dominance gene action.

A best general combiner is characterized by its better breeding value when crossed with number of other parents. Besides, mean performance of a parent is also considered with *gca* effects, since the former offers reliability / authenticity to *gca* effects as a guide in selection of parents. Parents that had negative and significant *gca* effects were taken for the traits, days to 50 per cent flowering and plant height, while for other traits, parents with positively significant *gca* effects were taken into consideration. The estimates of GCA effects revealed wide differences among the parental lines for different quantitative traits and parental line was identified as good general combiner for each character (Table 2). In the present study, two CGMS lines *viz.,* IR 80559 A and IR 80154 A and two testers *viz.,* IR 62037 R (except in E3) and ASD 06-8 R exhibited earliness combined with significant negative *gca* effects in all the environments. Good general combiner for earliness was reported by Raju *et al.* (2006). The parental lines IR 80154, IR 75608 (except in E3) and RR 363-1 were found to be good general combiners for semi dwarf plant type in all the environments as they showed significant negative *gca* effects combined with desirable low *per se* performance.

IR 80559 A and IR 80154 A and two testers *viz.,* IR 62037 R and ASD 06-8 R exhibited earliness was found to have significant *gca* for days to 50 per cent flowering, RR 363 R was found to be good general combiners for semi dwarf plant type in all the environments. The parents *viz.,* IR 75601 A, IR 72081 A, IR 62037 R and TP 1021 R were adjudged as the best general combiners for yield and yield component traits. Similar reports were reported by Rita Binse and Motiramani (2005) and Singh *et al.* (2007).

Selection of parents based on *per se* performance and *gca* effects is of great importance in breeding programmes, because it provides useful information on the choice of parents in terms of expected performance of hybrids and progenies (Dhillon, 1975). Based on desirable mean and *gca* effects of the trait, days to 50 per cent flowering, the parent MDU 5 R and ASD 06-8 R in E1and in E2 and IR 72865 R in E3 environments showed significant to early flowering. Similarly, the parent IR 75608 A in E1 and E2 and the parents TP 1021 R, IR 62037 R and ASD 06-8 R in E3 were the best general combiners with desirable mean for the trait plant height. Hence, the above mentioned parents can be utilized for developing early and dwarf hybrids respectively.

The parent, IR 75601 A was found to be the best one since, it possessed high *per se* and *gca* for three traits *viz.,* number of productive tillers per plant in all the environments and pooled, panicle length (E3, pooled) and single plant yield (E2, pooled). The parents MDU 5 R was early in flowering in E1, number of grains per panicle for all the environments and pooled condition, 100 grain weight in E3, pooled and single plant yield in E2, pooled and TP 1021 R recorded dwarf and more number of grains per panicle in E3, pooled, single plant yield in E1, E2 and in pooled were the best general combiners with desirable mean value. The parent IR 72081 A was identified as the best parents as they had high mean and *gca* effects for single plant yield in all the environments and pooled, number of grains per panicle in E1, E2, pooled and 100 grain weight in E1 and in pooled. Similar findings were observed by Sarma *et al.* (2007) for single plant yield, number of grains per panicle and panicle length.

The hybrids *viz.*, CRMS 32 A X RR 363 R, IR 80154 A X IR 62037 R and IR 75596 A X MDU 5 R were found to be specific combination in all the three environments and in pooled for most of the yield contributing traits including single plant yield and were also found to have higher *per se* performance. The hybrid, APMS 6 A X TP 1021 R was found to be specific combination in all the three environments and in pooled for most of the yield contributing traits including single plant yield and also found to have higher *per se* performance in E1. These desirable cross combinations involved high x high type of general combiners. Salgotra et al. (2009) also reported about interaction between positive and positive alleles in crosses involving high x high combiners which can be fixed in subsequent generations if no repultion phase linkages are involved.

It could be concluded that, crosses involving IR 75601 A, IR 72081 A, ASD 06-8 R, MDU 5 R and TP 1021 R as parents would result in superior segregants with favourable alleles and can be used as potential donors for the improvement of yield and yield component traits (Table 3). CRMS 32 A x RR 363 R, IR 80154 A x IR 62037 R (Fig.1) and IR 75596 A x MDU 5 R were identified as most promising crosses for yield based on *sca* effects, better *per se* with high *gca* for yield per plant, could be exploited profitably for yield in rice.

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ISSN 2348 – 7968

Table 1. ANOVA for combining ability for different quantitative traits in individual and pooled environment

Source of variance	Envt.	df	DFF	PH	NPT	PL	NSB	100 GW	NG	SPY
Replication	E1	1	144.40**	26.57**	3.91**	0.18	0.53	0.02	585.03**	13.14**
	E2	1	60.03**	100.71**	4.23**	7.91**	0.02	0.00	618.46**	1.23
	E3	1	18.09**	111.49**	8.01**	6.92**	0.41	0.00	203.74**	0.43
	Pooled	1	192.28	221.00	15.70	8.39	0.02	0.00	1336.90	1.15
Hybrids	E1	79	72.19**	80.34**	47.24**	20.01**	2.52*	0.11	1391.95**	186.81**
	E2	79	94.23**	97.21**	45.36**	25.67**	2.49*	0.07	1329.91**	180.27**
	E3	79	125.69**	114.53**	45.81**	25.04**	3.02**	0.12	1300.74**	150.74**
	Pooled	79	225.49	150.11	125.97	38.48	2.65	0.13	2895.80	452.49
Lines	E1	7	174.16**	175.74**	85.23**	109.77**	6.53**	0.29	3807.46**	293.91**
	E2	7	273.24**	391.66**	67.79**	75.75**	3.99**	0.07	3890.75**	287.86**
	E3	7	194.74**	374.91**	92.03**	47.61**	7.02**	0.20	1105.32**	142.32**
	Pooled	7	493.20	414.41	230.68	101.97	7.36	0.20	7109.36	646.57
Testers	E1	9	92.26**	80.22**	42.30**	8.87**	1.43	0.09	1350.55**	133.50**
	E2	9	92.24**	48.33**	48.29**	8.61**	2.16**	0.09	1383.36**	176.25**
	E3	9	45.59**	148.95**	43.95**	25.79**	3.33**	0.05	2245.74**	135.99**
	Pooled	9	191.30	113.72	128.93	27.92	1.82	0.07	3283.99	373.14
L X T	E1	63	57.99**	69.76**	43.72**	11.63**	2.23*	0.09	1129.49**	182.53**
	E2	63	74.63**	71.47**	42.45**	22.54**	2.37*	0.06	1037.73**	168.89**
	E3	63	129.46**	80.68**	40.94**	22.42**	2.54*	0.12	1187.45**	153.78**
	Pooled	63	200.62	125.72	113.92	32.93	2.24	0.13	2372.17	442.26
GCA	E1	-	0.25	0.18	0.06	0.15	0.01	0.00	4.56**	0.07
	E2	-	0.34	0.45	0.05	0.05	0.00	0.00	5.08**	0.19
	E3	-	-0.07	0.59	0.08	0.05	0.01	-0.00	1.97	-0.05
	Pooled	-	6.26	4.77	3.27	1.15	0.07	0.00	93.91	9.31
SCA	E1	-	28.38**	30.46**	20.27**	4.48**	0.89	0.04	524.36**	87.42**
	E2	-	35.46**	33.61**	19.76**	9.75**	0.78	0.02	443.97**	80.62**
	E3	-	61.22**	37.18**	18.75**	9.42**	1.62	0.05	520.65**	74.01**
	Pooled	-	32.77	19.91	18.45	4.97	0.23	0.02	374.43	72.54
GCA/ SCA	E1	-	0.009	0.006	0.003	0.033	0.011	0.000	0.009	0.001
	E2	-	0.009	0.013	0.003	0.005	0.000	0.000	0.011	0.002
	E3	-	-0.001	0.16	0.004	0.005	0.016	0.000	0.004	-0.001
	Pooled	-	0.191	0.239	0.177	0.231	0.304	0.000	0.251	0.128
Error	E1	79	1.22	8.83	3.18	2.67	0.45	0.01	80.76	7.68
	E2	79	3.71	4.25	2.93	3.05	0.81	0.02	144.79	7.65
	E3	79	7.02	6.34	3.44	3.59	1.30	0.02	146.16	5.77
	Pooled	237	3.98	6.47	3.18	3.10	0.86	0.02	152.57	7.03

**** Significant at 1 % level** *** Significant at 5 % level**

Table 3. Parents selected based on *per se* performance and *gca* effects

Character	Coimbatore (E_1)	Bhavanisagar (E_2)	Aliyar Nagar (E_3)
Days to 50 per cent flowering	MDU 5, ASD 06-8	ASD 06-8	IR 72865
Plant height	IR 75608	IR 75608	IR 62037, TP 1021, ASD 06-8
Number of productive tillers per plant	IR 75601	IR 75601	IR 75601, CRMS 32
Panicle length	IR 80559	RR 363-1	IR 75601, IR 80154
Number of secondary branches per panicle	ASD 06-8	ACK 99017	IR 80559, IR 80154
100 grain weight	IR 72081, IR 75596, IR 62037	-	MDU 5
Number of grains per panicle	IR 72081, MDU 5	IR 72081, MDU 5	MDU 5, TP 1021, IR 75596
Single plant yield	IR 72081, IR 75596, TP 1021	IR 72081, IR 75601, IR 62037, MDU 5, TP 1021	IR 72081, APMS 6
Best performers	**MDU 5, IR 72081, IR 75596, ASD 06-8**	**ASD 06-8, IR 75601 IR 72081, MDU 5**	**IR 75601, IR 72081, MDU 5, TP 1021**

Table 2. The *gca* effects of parents for yield and component traits in individual and pooled environment.

	Days to 50 % flowering				Plant height				Number of productive tillers per plant				Panicle length			
A lines	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**
IR 80559	**-6.25** **	**-5.40** **	-1.87 **	**-4.51****	2.34 **	**5.72** **	1.36 *	**3.14****	-2.13 **	-2.54 **	**-3.30** **	**-2.66****	**2.96** **	1.61 **	0.96 *	**1.84****
APMS 6	-0.45	-0.80	1.64 **	0.13	-0.56	0.71	-4.13 **	-1.33**	0.35	0.15	0.40	0.30	1.45 **	0.77	-1.46 **	0.25
IR 72081	1.35 **	1.05 *	-2.80 **	-0.13	0.34	1.95 **	2.87 **	1.72**	2.16 **	2.07 **	1.69 **	1.97**	-0.07	-0.27	-0.79	-0.38
IR 75601	-0.30	-2.30 **	-2.78 **	-1.79**	-0.09	2.44 **	2.07 **	1.47**	2.31 **	1.83 **	**3.07** **	2.40**	1.60 **	1.18 **	1.26 **	1.35**
IR 75596	**3.45** **	3.35 **	**4.69** **	**3.83****	3.04 **	1.30 **	4.16 **	2.84**	0.70	0.00	-0.83 *	-0.04	0.26	-0.63	0.70	0.11
IR 80154	-1.25 **	-2.30 **	**-3.62** **	-2.39**	**-5.22** **	**-7.37** **	0.80	**-3.93****	-2.29 **	-2.39 **	-1.39 **	-2.02**	**-4.42** **	**-4.00** **	1.03 *	**-2.47****
CRMS 32	2.15 **	-0.16	2.48 **	1.49**	3.16 **	1.29 **	**-8.88** **	-1.48**	1.57 **	1.76 **	1.94 **	1.76**	-2.26 **	-0.83 *	1.22 **	-0.63
IR 75608	1.30 **	**6.55** **	2.27 **	3.37**	-3.02 **	-6.03 **	1.75 **	-2.44**	**-2.64** **	-0.90 *	-1.59 **	-1.71**	0.48	**2.18** **	**-2.89** **	-0.08
SE	**0.25**	**0.43**	**0.59**	**0.26**	**0.66**	**0.46**	**0.56**	**0.33**	**0.39**	**0.38**	**0.42**	**0.23**	**0.37**	**0.39**	**0.42**	**0.23**
R lines																
IR 62037	-2.56 **	-3.09 **	0.43	-1.74**	0.10	-1.35 *	-1.74 **	-0.10	1.75 **	1.66 **	1.17 *	1.53**	-0.29	-0.29	-1.86 **	-0.81**
IR 72865	-1.31 **	-1.34 **	-3.13 **	-1.93**	0.33	0.37	-2.55 **	-0.62	-0.66	-0.76	-0.76	-0.73**	0.62	-0.06	-0.02	0.18
IR 68427	-0.44	-0.41	0.95	0.03	-1.61 *	-0.48	3.22 **	0.38	-0.36	-1.30 **	-1.82 **	-1.16**	-1.11 **	-1.12 *	-0.82	-1.02**
MDU 5	-0.69 *	-0.39	0.19	-0.31	-0.74	-1.38 **	1.54 *	-0.19	0.99 *	1.20 **	1.27 **	1.15**	1.02 *	0.52	1.24 *	0.92**
ACK 99017	3.25 **	4.16 **	2.68 **	3.36**	1.91 *	1.18 *	1.85 **	1.65**	0.03	0.03	1.19 *	0.41	-0.60	-1.06 *	0.18	-0.49
TP 1021	2.19 **	0.81	-0.35	0.88**	0.78	2.02 **	-1.96 **	0.28	**3.19** **	**3.20** **	2.79 **	**3.06****	0.46	0.45	**2.31** **	1.07**
RR 363-1	1.81 **	1.67 **	-0.07	1.14**	-4.92 **	-3.18 **	-2.69 **	-3.59**	-2.34 **	**-2.71** **	-2.43 **	-2.49**	0.71	0.93 *	-1.03 *	0.20
RR 347-1	2.00 **	2.42 **	1.86 **	2.09**	**3.45** **	1.66 **	-1.87 **	1.08**	-0.54	0.56	0.41	0.15	0.52	0.85	1.27 **	0.88**
RR 286-1	0.25	-0.16	-0.69	-0.20	-0.43	-0.87	**6.27** **	1.66**	-1.79 **	-1.65 **	-1.59 **	-1.68**	-0.82 *	0.27	-0.61	-0.39
ASD 06-8	-4.50 **	-3.69 **	-1.87 **	-3.35**	1.14	2.01 **	-2.05 **	0.37	-0.27	-0.22	-0.23	-0.24	-0.49	-0.50	-0.65	-0.55**
SE	**0.28**	**0.48**	**0.66**	**0.29**	**0.74**	**0.52**	**0.63**	**0.37**	**0.44**	**0.43**	**0.46**	**0.26**	**0.41**	**0.44**	**0.47**	**0.25**

ISSN 2348 – 7968

Table 2. The *gca* effects of parents for yield and component traits in individual and pooled environment. **(Contd.,)**

	Number of secondary branches per panicle				100 grain weight				Number of grains per panicle				Single plant yield			
A lines	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**	**E1**	**E2**	**E3**	**Pooled**
IR 80559	**0.63** **	**0.58** **	**0.72** **	**0.64****	-0.12 **	-0.01	0.07 *	-0.02	6.71 **	10.70 **	-1.34	5.36**	-1.38 *	-2.51 **	-0.86	-1.58**
APMS 6	0.51 **	0.17	-0.68 **	0.00	0.02	-0.02	-0.10 **	-0.03	**14.65** **	8.90 **	0.00	7.85**	3.91 **	3.74 **	3.64 **	3.76**
IR 72081	0.34 *	0.36	0.03	0.24*	0.06 *	0.06 *	-0.02	0.03	12.95 **	**15.73** **	3.96	10.88**	3.32 **	3.80 **	3.16 **	3.43**
IR 75601	0.17	-0.54 **	0.66 *	0.10	**0.21** **	0.08 *	0.09 **	**0.13****	12.08 **	14.22 **	10.36 **	12.22**	4.02 **	4.04 **	2.63 **	3.56**
IR 75596	-0.11	-0.20	-0.31	-0.20	0.10 **	-0.06	-0.11 **	-0.02	1.24	-5.47 *	6.80 *	0.86	1.88 **	0.88	-2.06 **	0.23
IR 80154	**-1.12** **	**-0.63** **	0.60 *	-0.38**	**-0.13** **	-0.10 **	**0.16** **	-0.03	-16.96 **	-10.97 **	-1.69	-9.88**	**-6.16** **	**-5.17** **	-1.66 **	**-4.33****
CRMS 32	-0.46 **	-0.14	-0.69 **	**-0.43****	-0.08 **	0.01	-0.11 **	**-0.06****	-15.21 **	**-19.70** **	-4.06	-12.99**	-1.93 **	-0.06	-2.13 **	-1.37**
IR 75608	0.03	0.39	-0.34	0.03	-0.06 **	0.04	0.01	-0.01	-15.46 **	-13.42 **	-14.02 **	-14.30**	-3.65 **	-4.72 **	-2.72 **	-3.69**
SE	**0.15**	**0.20**	**0.26**	**0.12**	**0.02**	**0.03**	**0.03**	**0.02**	**2.01**	**2.74**	**2.70**	**1.45**	**0.62**	**0.62**	**0.54**	**0.34**
R lines																
IR 62037	-0.39 *	0.18	0.08	-0.04	0.08 **	**0.12** **	-0.05	0.05*	7.28 **	8.94 **	-9.30 **	2.31	2.17 **	1.96 **	0.69	1.61**
IR 72865	0.04	0.07	-0.36	-0.08	-0.08 **	-0.05	0.03	-0.03	2.60	-3.90	0.12	-0.39	-3.20 **	-4.31 **	-2.56 **	-3.35**
IR 68427	-0.26	0.48 *	-0.03	0.07	-0.04	-0.10 **	-0.01	-0.05*	1.75	2.97	-0.72	1.34	-4.08 **	-3.73 **	0.04	-2.59**
MDU 5	0.51 **	-0.56 *	0.71 *	0.22	-0.02	0.08 *	0.10 **	0.06**	10.48 **	14.87 **	**22.12** **	**15.82****	3.12 **	**4.68** **	**6.95** **	**4.92****
ACK 99017	0.04	0.60 **	0.43	0.36**	-0.09 **	0.06	0.01	-0.01	-8.03 **	-0.24	5.96	-0.77	-1.06	0.68	0.91	0.18
TP 1021	-0.24	0.06	-0.14	-0.11	0.13 **	0.02	-0.08 *	0.02	6.05 **	5.81	15.14 **	8.99**	**4.97** **	3.91 **	0.93	3.27**
RR 363-1	0.24	-0.29	0.46	0.14	-0.03	-0.10 **	-0.05	-0.06**	3.87	-4.95	**-18.70** **	-6.59**	-1.98 **	-4.34 **	**-3.40** **	-3.24**
RR 347-1	-0.04	-0.03	**-0.84** **	-0.30**	0.00	-0.03	0.02	-0.00	2.87	-4.79	-4.89	-2.27	1.09	0.73	0.21	0.68
RR 286-1	-0.27	-0.08	0.01	-0.11	-0.04	0.03	0.06	0.12**	-6.31 **	0.57	-5.75	-3.83*	0.57	1.90 **	-1.31 *	0.39
ASD 06-8	0.36 *	-0.43	-0.33	-0.13	0.08 **	-0.02	-0.04	0.01	**-20.56** **	-19.28 **	-3.97	**-14.60****	-1.60 *	-1.49 *	-2.46 **	-1.85**
SE	**0.17**	**0.23**	**0.29**	**0.13**	**0.03**	**0.03**	**0.03**	**0.02**	**2.25**	**3.06**	**3.02**	**1.62**	**0.69**	**0.69**	**0.60**	**0.38**

**** Significant at 1 % level** *** Significant at 5 % level**

ISSN 2348 – 7968

Fig.1. IR 80154 A x IR 62037 R