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ESTIMATION OF HETEROSIS AND INBREEDING DEPRESSION IN QUANTITATIVE TRAITS OF RICE (*Oryza sativa* L.)

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ABSTRACT

It is important to know the degree and direction of heterosis for its commercial exploitation. Heterosis and in-breeding depression were estimated in 8x8 half diallel crosses of rice. The planted materials consisted ofeight parental inbred lines, their F_1 hybrids and F_2 populations using randomized complete block design with three replications. Data were collected on number of days to 50% flowering, plant height, number of tillers/plant, number of panicles/hill, panicle length, number of spikelets/panicle, number of fertile spikelets/panicle, number of days to maturity, 1000-seed weight and grain yield. Significant genetic differences were observed among the parents, their F_1 hybrids and F_2 populations for all the characters under study. Panicle length and number of spikelets/panicle showed highly significant heterosis in F_1 hybrids ranging from -6.1748 to 41.847% and -8.6957 to 41.847%, respectively while in breeding depression in the F_2 population ranged from -3.93 to 13.2231% and 3.6364 to 25.85% respectively.F_1 hybrids showed low level of heterosis in number of days to flowering (-11.25 to 11.95%),.The parent WAB 450-1-B-163-41 proved itself to be a good general combiner by making higher contribution towards heterosis both in F_1 hybrids and in F_2 population

Keywords: Genetic basis, *Oryza sativa*, hybrid vigor, quantitative traits, inbreeding depression

INTRODUCTION

Rice (*Oryza sativa* L.) is a well known cereal crop grown in almost every part of the world. Although, the plant is naturally self pollinated, strong heterosis is observed in their F_1 hybrids. The term heterosis was coined by Shull (1908) for quantitative measure of superiority of F_1 over its parents. The phenomenon of heterosis has been a powerful force in the evolution of plants and has been exploited extensively in crop production (Birchler et al., 2003). Heterosis in rice can often be poorly expressed as reported by some scientists (Mohammed and Mohanty 1992; Ram 1992, Virekananden and Giridheram 1995).

The phenomenon of heterosis has been observed in many self-pollinated crop species including several of the grain legumes. It is commonly found that the level of heterosis exhibited by a hybrid is a function of the genetic divergence between parents. Heterosis may be positive or negative. Depending on breeding objectives both positive and negative heterosis can be useful for crop improvement. Heterosis is a highly cross specific phenomenon. To successfully use heterosis in grain yield improvement, parental genotypes need to have a high yield potential. The exploration of hybrid vigor is widely recognized as the only readily available means to raise the genetic yield ceiling in areas where yields have already approached their potential. In this approach, developing highly heterotic rice hybrids with superior yield performance and evaluating them across environments are important. (Sitaramaiah et al., 1998). The project was initiated with the objectives to determine the heterotic effects in F_1 hybrids and the inbreeding of the plant behavior in both hybrid and selfed conditions.

MATERIALS AND METHODS

The research was conducted at the experimental field of the National Cereals Research Institute (NCRI), Amakanma sub-

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station Umuahia, Abia State. Eight upland rice breeding lines: IRAT 317, WAB 35-1-FX, IR 47-701-6-3-1, IRAT 239, WAB 450-1-163-14, WAB35—2-FX, WAB 56-144 FX and WAB 56-100) were crossed in a full diallel pattern.

In the production of F_1'sfour crossing blocks were established at two weekly intervals consisting of eight plots per block. Each crossing block measured 12.5m x 1m and there plot in the crossing block measured 12.5m x 1m and there plot in the crossing block measured 1m x 1m and a 0.5m alley separated each plot. Rice seeds from each of the selected eight breeding lines were seeded in each plot at a spacing of 20cm x 20cm. The purpose of establishing the crossing blocks at two weeks interval was to synchronize the flowering time of the breeding lines for the purpose of crossing. A total of four plantings were done. The F_2 generation was obtained by allowing natural self-pollination of the back crosses. The hybrids and parents were evaluated in a randomized complete block design at a spacing of 20cm x 20cm in lines. Each genotype was grown in a single row of ten plants. Data were collected from all plants, leaving one border plant on each side of each genotype (Dhaliwal and Sharma, 1990). Observations were recorded on 12 characters namely: number of days to 50% flowering, plant height, number of tillers/plants, number of tillers/m^2, number of panicles/hill, number of panicles/m^2, panicle length, number of spikelets/panicle, spikelet fertility, number of days to maturity, 1000-grain weight and grain yield.

Heterosis and inbreeding depression were estimated according to Falconer and MacKay (1996) for F_1 hybrids and inbreeding depression for F_2 populations were estimated using the following formulae:

Mid parent Heterosis (%) = $\frac{\overline{F_1} - MP}{MP} \times \frac{100}{1}$

Where
F_1 = Mean of F_1 hybrid for a trait
MP = Mid parent

Inbreeding depression on F_2 from F_1 (%) = $\frac{(\overline{F_1} - \overline{F_2})}{\overline{F_1}}$

Where
F_2 = Mean of F_2 population for a trait

The analysis of variance was performed according to the procedure outlined by Steel and Torrie (1980) and separation of treatment means for significant effect was done using the least significant difference (LSD) according to Obi (2002).

RESULTS AND DISCUSSION

The analysis of variance table presented in Table 1 show significant effect (P = 0.05) for the parameters studied except for number of tillers/plant, number of tillers/m^2 and number of panicle/hill which were non significant. In Table 2 is presented the mean performance of the twelve agronomic attributes of the eight size breeding lines used for the study. The results of the different morphological characters of the eight rice breeding lines, their twenty-eight hybrids and F_2 populations are presented in Table 3.

In the present study, different cross combinations were tested in order to develop high yielding hybrid rice varieties and some were found to be promising. The stability of hybrids was checked through their performance in the F_2 generation, and variable inbreeding depression was also observed for the studied traits in the different crosses.

Development of high yielding early maturing varieties is a highly desirable quality in most rice breeding programs. Among the twenty eight crosses, highly negative heterosis was observed in some crosses. While some of the crosses such as WAB 56-144-FX X WAB 56-100 and IRAT 317 x WAB 56-100 showed positive heterosis, others such as WAB 450-1-B-163-41 X WAB 35-2-FX and WAB 35-2-FX X IRAT 239 showed negative heterosis for both days to 50% flowering and number of days to maturity which suggests the possibility of developing early maturity lines from these combination. Negative heterosis for earliness was also reported by Khaleque *et al.*, (1977) and Nuruzzaman et al., (2002) in rice.

The number of panicles is one of the components used in determining grain yield. There were increase in panicle number in these hybrids WAB 450-1-B-163-41 x IRAT 317, IRAT 317 x WAB 56-144-FX, WAB 35-1-FX x WAB 56-144-FX, IR 47-701-6-3-1 x WAB 35-2-FX, RAT 317 x IR 47-701-6-3-1, IRAT 317 x IRAT 239 and IR 47-701-6-3-1 x IRAT-239 which had 8 panicles/hill each and WAB 35-1-FXx WAB 35-2-FX that had 9 panicles/hill over their respective parents. Increase in panicle number was earlier observed by Singh *et al.* (1980), Anandakumah and Sree Rangasamy (1986). The results show that two crosses IRAT 317 x IRAT 239 and IR 47-701-6-3-1 x IRAT 239 showed highly significant positive heterosis values of 45% in panicle number per hill., respectively.

Table 1: Form of Analysis of variance showing sources of Variation, Degrees of Freedom and Mean Square Estimates of Eight Rice breeding lines for twelve (12) Plant Attributes.

SV	DF	50%	Plant ht	Tiller /plant	Tillers/M^2	Panicles /hill	Panicles /M^2	Panicle ength	Spikelets panicles	FS/P	DTM	GW	GY
Block	3	2.083	2.57	5.583	6.948	10.417	54.88	6.38	631.2	347.7	2.088	1.616	0.2545
Genotypes	7	214.2**	936**	8.500ns	5620ns	4.286ns	3346*	27.86*	14171**	7673**	214.2**	153.3**	5.096
Error	21	2.179	17.99	4.345	0.970	3.464	1001	10.79	364.70	368.0	2.179	1.209	0.0823
Total	31												

*significant at 5%, ** highly significant at 1%

Table 2. Mean Performance of the ten agronomic attributes of the eight rice breeding lines evaluated at the NCRI Umudike, Abia State.

Genotypes Parents	Days to 50% Flowering	Plant height	No of Tillers/ Plant	No of Tillers/M^2	No of Panicles/Hill	No of Panicles/ M^2	Panicle Length	No of Spikelet/ Panicle	No of Fertile Spikelets /Panicle	No of Days to Maturity	1000 Grain Weight	Grain Yield
Grand mean	78.87	92.25	10.88	275.4	6.25	164.50	24.58	128.40	106.60	108.87	30.58	3.681
WAB 450-1-B-163-41	71	103.22	11	283	6	145	24.53	272	211	101	34.43	5.87
IRAT 317	90	86.70	12	302	7	195	21.98	96	88	120	23.10	2.810
WAB35-1-FX	84	66	12	310	7	165	23.52	116	91	114	39.33	3.850
IR 47-701-6-3-1	85	93.6	11	282	7	178	20.57	80	71	115	22.87	2.310
WAB35-2-FX	75	77.44	13	322	7	205	24.00	126	82	105	35.63	4.55
WAB56-144-FX	76	114.22	10	255	6	148	27.75	111	102	106	33.26	3.570
IRAT 239	81	101.5	9	227	4	115	26.32	123	108	111	25.23	2.850
WAB 56-100	69	95.33	9	222	6	165	27.98	111	100	99	30.82	3.640
F-LSD (P=0.05)	2.170	6.237	3.065	80.14	2.737	46.52	4.830	28.08	28.21	2.170	1.67	0.4217

Table 3. Mean values of the agronomic characters of the parents, F_1's, F_2's , mid parent heterosis (% het) for F_1 hybrids and Inbreeding depression (%ID for F_2 populations) in the rice breeding lines.

			Number of Days to 50 % flowering				Plant Height (cm)				Number of tillers/plant			
Cro	s	Ses	F_1	F_2	%Het	%ID	F_1	F_2	%Het	%ID	F_1	F_2	%Het	%ID
WAB 450-1-B-163-41	X	WAB35-2-FX	68	68	-6.8493	0	92.55	87.32	2.457	1.974	12	10	0	0
WAB 450-1-B-163-41	X	WAB56-144-FX	71	72	-3.4014	-1.4085	115.2	109.4	5.960	5.034	12	10	14.28	16.66
WAB 450-1-B-163-41	X	WAB 56-100	70	71	-1.4085	0	101.	98.48	0.950	5.651	10	9	-9.909	16.66
WAB35-2-FX	X	WAB56-144-FX	74	74	-1.9868	0	81.75	77.44	-14.6	5.272	13	12	13.04	7.693
WAB35-2-FX	X	WAB 56-100	73	72	1.3889	1.3699	81.03	87.80	-6.204	-1.835	12	11	9.091	8.333
WAB56-144-FX	X	WAB 56-100	75	73	3.4483	2.6667	110.7	102.7	5.678	7.206	12	11	26.31	8.3333
WAB 450-1-B-163-41	X	IRAT 317	81	81	0.6211	0	98.70	96.50	3.938	2.290	12	11	4.347	8.333
WAB 450-1-B-163-41	X	WAB35-1-FX	74	75	-4.516	-1.3514	88.67	78.07	4.7985	11.954	14	12	21.73	14.25
WAB 450-1-B-163-41	X	IR 47-701-6-3-1	78	78	0	-1.3514	99.80	97.50	1.4125	11.954	13	11	18.18	14.25
WAB 450-1-B-163-41	X	IRAT 239	78	77	2.6316	0	108.93	97.25	6.4185	2.3046	11	11	10	15.38
WAB35-2-FX	X	IRAT 239	71	73	-8.874	1.2821	79.90	96.90	-10.696	10.722	12	12	9.090	0
WAB56-144-FX	X	IRAT 239	71	74	-9.534	-2.8169	116.22	109.30	15.3548	-21.26	12	10	26.31	0
IRAT 317	X	WAB35-2-FX	85	83	3.0303	2.3529	80.15	81.40	-2.339	-1.559	11	10	-6.6667	25
IRAT 317	X	WAB56-144-FX	86	84	3.6145	2.3256	93.80	98.75	-6.629	-5.277	12	11	23.6769	4.348
IRAT 317	X	WAB 56-100	89	84	11.9500	5.6180	90.25	90.38	-0.846	-0.144	12	11	7.6923	4.7619
WAB35-1-FX	X	WAB35-2-FX	81	80	1.8868	1.2346	69.71	69.40	-4.196	-1.004	15	12	20	13.0443
WAB35-1-FX	X	WAB56-144-FX	71	73	-11.25	-2.8169	82.40	78.10	-8.556	5.2184	10	9	23.0769	14.2857
WAB35-1-FX	X	WAB 56-100	75	78	-1.9608	-4	73.44	71.40	-8,962	2.7778	12	11	7.6923	10
IR 47-701-6-3-1	X	WAB35-2-FX	80	80	0	0	80.55	82.80	-5.811	-2.793	14	10	6.6667	25
IR 47-701-6-3-1	X	WAB56-144-FX	82	81	1.8634	1.2195	105.60	103.95	1.6266	1.5625	12	13	1.3575	4.348
IR 47-701-6-3-1	X	IRAT 239	80	78	3.8961	2.500	94.00	94.00	-0.486	0	13	10	13.4021	4.7619
IRAT 239	X	WAB 56-100	80	77	6.6667	3.75	96.50	97.31	-0.944	-0.839	11	10	4.7619	13.0443
IRAT 317	X	WAB35-1-FX	90	83	3.4483	2.222	75.00	75.00	2.2495	-1.0484	15	14	25	8.333
IRAT 317	X	IR 47-701-6-3-1	90	89	2.8571	2.222	89.66	89.66	0.5435	2.667	12	11	4.348	6.6667
IRAT 317	X	IRAT 239	88	**86**	2.9240	.272	94.00	94.00	-10.106	1.1702	11	**10**	4.7619	9.0909
WAB35-1-FX	X	IR 47-701-6-3-1	80	82	-5.3254	2.500	70.43	70.43	-117419	-0.8093	13	12	13.0443	7.6923
WAB35-1-FX	X	IRAT 239	85	83	3.0303	2.3529	69.00	69.00	17.6119	-2.7536	12	11	14.2857	8.333
IR 47-701-6-3-1	X	IRAT 239	84	83	1.2048	1.1905	95.41	95.41	-2.1957	-4.0771	11	11	10	0
F-LSD (p=0.05)			2.182	3.23	-	-	4.371	5.3721	-	-	2.359	2.011	-	-

Table 3 (cont). Mean values of the agronomic characters of the parents, F_1's, F_2's , mid parent heterosis (% het) for F_1 hybrids and Inbreeding depression (%ID for F_2 populations) in the rice breeding lines.

			Number of tillers/M^2				panicles/hill				panicles/M^2			
Cro	s	Ses	F_1	F_2	%Het	%ID	F_1	F_2	%Het	%ID	F_1	F_2	%Het	%ID
WAB 450-1-B-163-41	X	WAB35-2-FX	296	281	2.857	9.3069	8	6	5.6860	16.667	180	160	2.8571	-1.290
WAB 450-1-B-163-41	X	WAB56-144-FX	272	260	-0.3413	4.4118	6	6	-1.6073	0	146	136	-0.341	6.8493
WAB 450-1-B-163-41	X	WAB 56-100	276	262	-7.2727	5.0676	7	6	16.666	25	153	147	-7.272	11.111
WAB35-2-FX	X	WAB56-144-FX	326	320	12.9983	1.8405	7	7	16.666	0	189	176	10.588	1.4184
WAB35-2-FX	X	WAB 56-100	315	311	5.8088	1.2698	6	5	0	1.2698	194	190	13.661	4.4776
WAB56-144-FX	X	WAB 56-100	251	240	5.2411	4.3824	6	5	0	4.384	151	145	3.7344	3.2895
WAB 450-1-B-163-41	X	IRAT 317	285	280	-2.5641	1.7544	8	6	5.6860	16.667	162	158	-4.705	2.469
WAB 450-1-B-163-41	X	WAB35-1-FX	280	270	-5.5649	3.5714	6	6	-1.6073	0	155	151	0	2.581
WAB 450-1-B-163-41	X	IR 47-701-6-3-1	278	265	-5929	4.6763	7	6	16.666	25	158	148	-2.310	6.329
WAB 450-1-B-163-41	X	IRAT 239	282	272	10.588	3.5461	7	7	16.666	0	141	139	8.461	1.418
WAB35-2-FX	X	IRAT 239	312	299	13.6612	4.1667	6	5	0	1.2698	201	192	25.62	4.478
WAB56-144-FX	X	IRAT 239	250	243	3.7344	2.800	6	5	0	4.384	152	147	15.58	3.290
IRAT 317	X	WAB35-2-FX	310	300	-0.6410	3.2258	7	7	-6.6667	0	199	190	-0.5	4.5226
IRAT 317	X	WAB56-144-FX	296	290	6.2837	2.0270	8	6	23.6769	25	181	175	5.5394	3.3149
IRAT 317	X	WAB 56-100	287	280	7.6923	2.4390	7	7	7.6923	0	180	179	0	0.5556
WAB35-1-FX	X	WAB35-2-FX	315	296	20	6.0317	9	8	20	11.1111	187	182	1.0811	2.6738
WAB35-1-FX	X	WAB56-144-FX	296	290	4.7788	2.0270	8	7	23.0769	12.50	160	158	2.2364	1.250
WAB35-1-FX	X	WAB 56-100	300	295	12.7820	1.6667	7	5	7.6923	28.5714	172	166	4.2424	3.4884
IR 47-701-6-3-1	X	WAB35-2-FX	298	291	-1.3245	2.3490	8	7	6.6667	12.50	194	192	1.3055	1.0309
IR 47-701-6-3-1	X	WAB56-144-FX	280	275	4.2831	1.7857	6	7	1.3575	0.8929	180	176	-9.0683	7.3315
IR 47-701-6-3-1	X	IRAT 239	271	261	7.5397	3.6900	7	7	13.4021	1.8182	167	180	-4.3657	5..2541
IRAT 239	X	WAB 56-100	235	234	4.6771	0.4274	6	6	4.7619	2.7273	143	141	-0.7735	11.2828
IRAT 317	X	WAB35-1-FX	300	295	-1.9608	2.3333	7	6	0	12.50	185	186	2.7778	-0.5405
IRAT 317	X	IR 47-701-6-3-1	296	291	1.3700	1.6892	8	7	14.2857	14.2857	198	187	6.1662	5.5556
IRAT 317	X	IRAT 239	284	**279**	7.372	1.7606	8	6	45.4545	25	181	**178**	16.774	1.6575
WAB35-1-FX	X	IR 47-701-6-3-1	304	296	2.7027	2.6318	7	6	-6.6667	14.285	177	172	3.8123	2.8249
WAB35-1-FX	X	IRAT 239	308	301	14.7114	2.2727	6	6	0	0	142	138	2.1583	2.8169
IR 47-701-6-3-1	X	IRAT 239	271	262	6.4833	3.3210	8	6	45.4545	25	183	152	24.915	16.9399
F-LSD (p=0.05)			45.21	38.0	-	-	2.021	2.122	-	-	34.66	35.33	-	-

Table 3 (cont). Mean values of the agronomic characters of the parents, F_1's, F_2's , mid parent heterosis (% het) for F_1 hybrids and Inbreeding depression (%ID for F_2 populations) in the rice breeding lines.

			Panicle length (cm)				Number of spikelets/panicle				Number of fertile spikelets/panicle			
Cro	s	Ses	F_1	F_2	%Het	%ID	F_1	F_2	%Het	%ID	F_1	F_2	%Het	%ID
WAB 450-1-B-163-41	X	WAB35-2-FX	25.65	24.62	5.686	12.14	213	205	7.0352	25.848	200	195	36.518	31.832
WAB 450-1-B-163-41	X	WAB56-144-FX	25.71	24.00	-1.607	6.651	218	210	13.838	3.6697	184	164	17.577	10.869
WAB 450-1-B-163-41	X	WAB 56-100	29.45	23.82	5.253	4.015	241	221	-11.39	3.7559	205	195	-2.843	2.500
WAB35-2-FX	X	WAB56-144-FX	24.31	22.75	-5.99	6.417	120	113	1.2658	5.8333	88	81	-4.347	7.9545
WAB35-2-FX	X	WAB 56-100	24.87	24.80	-4.30	0.281	118	112	-0.4219	5.0847	90	87	-1.098	3.3333
WAB56-144-FX	X	WAB 56-100	26.80	24.35	-3.77	9.141	110	106	-0.900	3.6364	100	90	-0.990	10.00
WAB 450-1-B-163-41	X	IRAT 317	23.51	22.51	41.847	4.253	261	187	41.847	4.2126	200	187	33.779	6.5
WAB 450-1-B-163-41	X	WAB35-1-FX	23.52	24.21	35.051	-3.93	262	163	35.051	4.1984	190	163	25.827	14.210
WAB 450-1-B-163-41	X	IR 47-701-6-3-1	23.67	23.21	27.840	-3.93	225	172	27.840	4.1984	180	172	27.659	14.210
WAB 450-1-B-163-41	X	IRAT 239	25.01	24.21	20.607	1.943	254	192	20.607	11.111	180	172	12.852	4.4444
WAB35-2-FX	X	IRAT 239	24.82	23.40	2.008	3.198	127	88	2.008	7.0866	97	88	2.1053	-6.666
WAB56-144-FX	X	IRAT 239	27.11	26.22	4.2735	5.721	122	100	4.2735	13.385	106	100	0.9524	9.2784
IRAT 317	X	WAB35-2-FX	22.66	20.62	-1.430	9.0026	120	113	8.1281	5.833	85	80	0	5.8824
IRAT 317	X	WAB56-144-FX	23.84	21.21	-4.0644	11.0319	113	96	9.1787	15.0442	108	83	13.6842	23.1481
IRAT 317	X	WAB 56-100	24.45	23.41	-2.1217	4.2530	108	104	4.3478	4.6296	95	90	1.0638	5.2633
WAB35-1-FX	X	WAB35-2-FX	21.66	19.49	-8.838	10.0185	118	102	-2.4793	13.5593	87	72	0.5780	17.2413
WAB35-1-FX	X	WAB56-144-FX	24.21	22.20	5.5035	8.3024	116	101	2.2026	14.736	95	81	-1.5544	14.736
WAB35-1-FX	X	WAB 56-100	34.16	23.01	-6.1748	4.7599	114	100	0.4405	12.2807	84	74	-12.041	11.9048
IR 47-701-6-3-1	X	WAB35-2-FX	21.27	20.11	-4.5760	5.4537	110	101	6.791	8.1818	76	70	-7.3171	7.8947
IR 47-701-6-3-1	X	WAB56-144-FX	21.96	20.35	-2.6178	6.4516	93	88	-8.6957	10.7143	84	75	-3.5464	3.0616
IR 47-701-6-3-1	X	IRAT 239	23.22	22.00	-1.5707	9.5745	98	85	-7.6923	4.7619	84	80	-0.8939	3.7204
IRAT 239	X	WAB 56-100	26.94	23.90	3.4188	13.2231	121	105	1.9231	10.3774	106	95	-7.9201	2.3247
IRAT 317	X	WAB35-1-FX	22.02	20.63	12.2855	12.2855	108	98	1.8868	17.3469	90	85	0.5587	13.333
IRAT 317	X	IR 47-701-6-3-1	22.14	19.42	6.3124	6.3124	98	81	0.1136	9.2593	90	78	13.2075	5.5556
IRAT 317	X	IRAT 239	22.04	**20.0**	9.0290	9.0290	108	**101**	-1.3699	6.4815	91	**87**	-7.1429	4.3956
WAB35-1-FX	X	IR 47-701-6-3-1	30.14	28.32	6.0385	6.0385	114	100	10.6796	12.2807	89	76	9.8765	14.6.67
WAB35-1-FX	X	IRAT 239	23.87	22.63	5.1948	5.1948	117	102	-6.0241	12.8205	100	91	0.5025	9
IR 47-701-6-3-1	X	IRAT 239	22.31	21.32	4.4375	4.4375	110	100	8.3744	9.0909	91	87	1.6760	4.3956
F-LSD (p=0.05)			2.909	2.55	-	-	17.550	18.233	-	-	13.043	15.335		

Table 3 (cont). Mean values of the agronomic characters of the parents, F_1's, F_2's , mid parent heterosis (% het) for F_1 hybrids and Inbreeding depression (%ID for F_2 populations) in the rice breeding lines.

			Number of days to maturity				1000-grain weight (g)				Grain yield (tons/ha)			
Cro	s	Ses	F_1	F_2	%Het	%ID	F_1	F_2	%Het	%ID	F_1	F_2	%Het	%ID
WAB 450-1-B-163-41	X	WAB35-2-FX	98	98	-4.854	0	34.92	32.15	-0.14	6.405	4.96	4.72	-4.798	-11.34
WAB 450-1-B-163-41	X	WAB56-144-FX	101	102	-2.415	-0.901	34.02	33.00	0.502	2.998	4.2	3.95	-11.0	5.952
WAB 450-1-B-163-41	X	WAB 56-100	100	100	-0.990	0	34.72	30.35	0.842	7.932	4.22	4.05	-28.10	4.838
WAB35-2-FX	X	WAB56-144-FX	104	104	-1.421	0	35.01	35.02	1.625	-0.02	4.2	4.29	3.448	-2.142
WAB35-2-FX	X	WAB 56-100	103	102	0.9709	0.9709	34.71	32.92	4.453	5.157	4.1	3.85	0	6.098
WAB56-144-FX	X	WAB 56-100	105	103	2.4390	1.9048	32.81	32.60	2.371	0.640	3.72	3.60	3.047	3.2258
WAB 450-1-B-163-41	X	IRAT 317	112	111	1.3575	0.8929	35.33	30.21	22.80	14.49	3.84	3.68	-11.52	4.1667
WAB 450-1-B-163-41	X	WAB35-1-FX	104	105	-3.255	-0.901	3.01	35.26	-2.35	2.082	4.15	4.112	-11.51	0.722
WAB 450-1-B-163-41	X	IR 47-701-6-3-1	108	108	0	-0.901	32.31	29.66	12.77	2.082	3.62	3.45	-11.49	0.722
WAB 450-1-B-163-41	X	IRAT 239	108	107	1.8868	0	35.21	34.16	18.03	8.201	3.80	3.60	-12.84	4.698
WAB35-2-FX	X	IRAT 239	101	104	-6.481	0.9259	34.61	33.00	13.73	2.982	3.45	4.11	-6.756	5.263
WAB56-144-FX	X	IRAT 239	101	104	-6.912	-2.970	33.05	33.00	12.99	4.651	3.00	2.89	-6.542	-19.1
IRAT 317	X	WAB35-2-FX	115	113	2.222	1.7391	27.11	27.00	-7.694	0.4058	3.82	3.80	3.8043	0.5236
IRAT 317	X	WAB56-144-FX	116	114	2.6549	1.7241	28.01	26.73	-0.603	4.5698	3.40	3.32	6.5831	2.3529
IRAT 317	X	WAB 56-100	119	114	0.9925	4.2017	27.10	26.23	0.4820	3.2103	3.58	3.51	10.8359	1.9553
WAB35-1-FX	X	WAB35-2-FX	111	110	1.3699	-0.9009	38.60	36.32	2.9883	5.9067	4.25	4.16	1.1905	2.1176
WAB35-1-FX	X	WAB56-144-FX	101	103	-8.1818	-1.9802	37.21	35.68	2.5069	4.1112	9.225	9.11	-9.9730	-2.0958
WAB35-1-FX	X	WAB 56-100	113	109	6.1033	3.5398	40	39.69	14.606	0.775	3.94	3.61	5.0667	8.3756
IR 47-701-6-3-1	X	WAB35-2-FX	110	110	0	0	24.10	23.10	-17.60	4.1493	3.30	3.20	-3.7901	3.0303
IR 47-701-6-3-1	X	WAB56-144-FX	112	111	-4.7619	17.1429	27.11	26.28	-7.692	-16.666	2.80	2.32	-4.7619	17.1429
IR 47-701-6-3-1	X	IRAT 239	110	108	1.3423	0.6623	26.61	25.62	7.6923	0	3.02	3.00	1.3423	0.6623
IRAT 239	X	WAB 56-100	110	107	4.5383	-5.5625	25.81	25.21	20	0	3.20	3.25	0.6623	-5.5623
IRAT 317	X	WAB35-1-FX	108	98	2.5641	1.6667	28.10	26.20	-9.9936	7.5630	2.96	2.81	-11.111	2.8125
IRAT 317	X	IR 47-701-6-3-1	98	81	2.128	1.6667	23.80	22.00	3.5233	6.7616	3.20	3.11	25	5.0676
IRAT 317	X	IRAT 239	108	**101**	2.164	1.6949	24.01	**22.45**	-0.6620	6.4973	2.97	**2.95**	4.9470	0.6734
WAB35-1-FX	X	IR 47-701-6-3-1	114	100	-3.9301	-1.8182	39.41	38.00	26.7202	3.5778	2.92	2.90	-5.1948	0.6849
WAB35-1-FX	X	IRAT 239	117	102	2.2222	1.7391	38.01	35.67	17.7509	29.2135	3.10	3.05	-7.4627	1.6129
IR 47-701-6-3-1	X	IRAT 239	110	100	0.8850	0.8772	23.91	21.92	-0.5821	12.5052	2.96	2.82	14.728	4.7297
F-LSD (p=0.05)			0.685	0.79	-	-	1.8604	1.4566	-	-	0.4865	0.5342	-	-

This indicates that these crosses could be good materials for developing high yielding hybrids because panicle number, total dry mater and spikelet number/grain number per panicle reportedly contributes greatly to high grain yield production (Dwivedi, *et al*., 1998). Earlier, negative heterosis for panicle number had been reported by Virmani *et al*., (1981, 1982) and Jennings (1967). The use of the number of panicles alone is not enough in determining yield in Oryza spp. Gravais and McNew (1993) have earlier suggested that the selection for increased yield via selection for either panicle weight or panicle number alone would be in effective. Therefore, selection for both increased panicle weight and panicle number to increase yield was estimated to be 91% as effective as selecting for yield directly (Surek and Beser, 2005).

Hybrid vigor for panicle length was observed in some of the crosses such as WAB 35-1-FX X WAB 56-100 and WAB 35-1-FX x IR 47-701-6-3-1. The result also show that some of the crosses that had high tillering ability also have an appreciable increase in terms of grain yield. The hybrids WAB 35-1-FX X WAB 35-2-FX and IRAT 317 X WAB 35-1-FX had the highest number of tillers/plant of 15 each in the F_1 progeny. The hybrid IRAT 317 X WAB35-1-FX also had the highest number of tillers/plant of 14 in the F_2. The result presented in Table 3 show that the hybrids WAB 144-FX X WAB 56-100 and WAB 56-144-FX X IRAT 239 had the highest heterotic values of 26.31% each. This is in line with the report of Basavavaja *et al*., (1998) that productive tillers/plant can have a high positive effect contribution towards grain yield per plant. The result also agrees with the findings of Ibrahim *et al.* (1990) that productive tillers was one of the most reliable character in selecting genotypes of rice.

The results obtained, suggests that heterosis in yield were due to yield components like tiller number, panicle length, spikelet number and 1000-grain weight. Grafius (1959) had earlier suggested that there is no separate gene system for yield per second and that the grain yield is an end product of the multiplication interaction between the yield components.This was, confirmed by the present research where more showed hybrid vigor for yield alone. Hybrid vigor for yield is the result of interaction of simultaneous increase in the expression of yield components.

Inbreeding depression was not found to be significant in most of the studied characters. Positive (ID) in F_2 generation was observed in the characters of tiller number per plant, panicle length, spikelet fertility, 1000 grain weight and grain yield resulting is it hybrid vigour hybrid. However some of the hybrids such as WAB 35-1-2FX x WAB 56-144-FX and R 47-701-6-3-1-x IRAT 239 exhibited a low level of inbreeding depression for yield characters such as panicle number and 1000 grain weight showing their high level of stability as F_1 variety. Morrover, hybrid break down in self pollinated plant species such as rice has been observed by many researchers (Li *et al;*, 1997a ; b and 1997b).

CONCLUSION

The results of the investigation showed that F_1 rice hybrids are useful not only for their high grain yield per cropping season but also the possibility of obtaining more heterotic hybrids in specific cross combinations with them. The findings that most of the F_1 hybrids were superior to their F_2 populations and F_2 populations showed considerable inbreeding depression in majority of the cases, thus, the possibility of getting F_2 seed with a performance of anyway near, F_1 seed is not feasible.

It can be concluded from this study that with appropriate choice of parental lines, it is possible to develop F_1 rice hybrid possessing distinct yield superiority over the best-inbred lines.

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