STUDY ON HETEROSIS IN HYBRID RICE

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ABSTRACT

Studies of heterosis of five cytoplasmic male sterile lines and seven Egyptian testers (restorers) were estimated using line x tester analysis for some agronomic, yield and its components and panicle characters to get useful information for hybrid rice breeding program in Egypt. Hybrids with a yield advantage of 15% over the highest yielding check variety Giza 178 were considered as promising. Among 35 hybrid combinations, 10 were the most promising, IR 68897A x GZ 5121R, IR 69625Ax PR 2, IR 68888A x IR 25571R, IR 68888A x Giza 182R, IR 8897Ax PR 2, IR 69625Ax VHR 3, G 46A x Giza 178R , G 46A x Giza 182R, IR 69625A x Giza 178R and G 46A x IR 25571R.

Abbreviations:Cytoplasmic male sterility (CMS),Heterosis ,filled grains panicle^{-1} (FG/Pn), 100- grain weight (GW), days to heading (HDG), plant height (Ht), panicles plant^{-1} (Pn/P), panicle length (PnL), panicle weight (PnW), spikelet fertility % (SpFert%), tillers plant^{-1} (Ti/P), wild abortive (WA) and grain yield/m^2 (Yld/m^2).

INTRODUCTION

Exploitation of heterosis played a significant role in increasing productivity and production of several crops all over the world. Availability of suitable pollination control systems and the extent of outcrossing between female and male parents, existence of exploitable level of heterosis and feasibility of hybrid seed production on large scale are the key factors determining the success of commercial exploitation of heterosis in any crop.

Hybrid rice technology is such one innovative breakthrough that can further increase rice production leading to food security and reduction of poverty in Egypt. Hybrid rice varieties can outyield conventional cultivars by at least 15% under the same input levels. Hence, this technology can be used to break the current yield plateau in rice, where yield levels of the conventional released cultivars have stabilized.

Success of heterosis breeding in several self fertilizing species prompted scientists to study the prospects of its application in rice as well. With the serious limitations of strictly self fertilizing nature of rice and the absence of a useable for of male sterility, research continued, however, with no tangible results until the Chinese scientists surprised the world by releasing the first commercial hybrids in 1976 (Dwivedi *et al.*, 1998). These hybrids were capable of out yielding the best non-hybrid varieties by 25-30% (Lin and Yuan, 1980).

The need of further studies on heterosis for yield and other agronomic characters is one of the important objectives of research for the development of acceptable hybrids, (Yuan and Virmani, 1986). Therefore, the objective of present study was planned to estimate standard heterosis (

economic heterosis) for agronomic, yield and its components and panicle characters in F_1 hybrids developed using male sterility-fertility restoration system using five cytoplasmic male sterile lines (CMS) and seven Egyptian restorer lines.

MATERIAL AND METHODS

The present investigation was carried out at the farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt, during the two successive growing seasons of 2007 and 2008.

The materials for the study comprised 35 hybrids obtained using line X tester fashion involving five diverse cytoplasmic male sterile (CMS) lines, i.e. IR 68888A/B, IR 68897A/B, IR 69625A/B, IR 70368A/B (WA) and G 46A/B (Gambiaca) as lines and seven testers, viz., Giza 178R, Giza 182R, VHR3, PR 78, PR 2, GZ 5121R and IR 25571R were used as male parents (Table 1). The F_1 hybrid combinations were raised along with their respective parents in three-rows of 3 m length adopting a spacing of 20 x 20 cm in a randomized block design with three replications. Observation on filled grains panicle-1 (FG/Pn), 100- grain weight (GW), days to heading (HDG), plant height (Ht), panicles plant-1 (Pn/P), panicle length (PnL), panicle weight (PnW), spikelet fertility % (SpFert%), tillers plant-1 (Ti/P) and grain yield/m2 (Yld/m2) were recorded on ten randomly-selected competitive plants in each replication. The data were subjected to analysis of variance for randomized block design as suggested by Panse and Sukhatme (1954) and analysis of variance for line x tester crossing design Kempthorne (1957). For each hybrid, Mid Parent, Better Parent and standared heterosis were estimated using Giza 178 as the standard parent (CP).

Table (1): Cytoplasmic sources, parentage, origins and salient features of ctyoplasmic male sterile (CMS), maintainer and restorer lines used in this study.

No.	Genotypes	Parentage	Origin	Features
1	IR68888 A & B*	IR 46830B /IR58025B	IRRI	Indica type, early maturing med. long grain and med. amylose content
2	IR 68897 A & B*	Wild Abortive	IRRI	Indica type
3	IR69625 A & B*	Wild Abortive	IRRI	Indica type, med. early maturing med. grain type and med. amylose content
4	IR70368 A & B*	Wild Abortive	IRRI	Indica type, med. early maturing med. grain type and med. amylose content.
5	G 46 A & B*	Gambiaca	IRRI	Indica type, early maturing med. short grain and med. amylose content
6	Giza 178 R**	Giza 175/Milyang 49	Egypt	Indica-Japonica type, early maturing, short statured, tolerance to salinity, short grain, good grain quality, high yielder and good restorer for the most of indica cytoplasmic male sterile (CMS) lines
7	Giza 182 R**	Giza 181/IR39422-163-1-2//Giza 181	Egypt	Indica type, new released variety, early maturing, semi-dwarf, long grain, resistance to blast, high yielder and good restorer for cytoplasmic male sterile lines (CMS)
8	VHR 3**	IR 58025A/Pusa basmati-1 (A xPR)	Vitnam	Indica type, med. early maturing, long grain and good restorer for Indica CMS.
9	PR 78R**	IR58025A/Pusa basmati-1 (A x PR)	Egypt-India (Indica type)	Indica type, medium maturing, semi dwarf, selender grain and aromatic restorer.
10	PR 2R**	IR58025A/Pusa basmati-1 (A x PR)	Egypt-India (Indica type)	Medium maturing, semi dwarf, selender grain and aromatic restorer.
11	GZ 5121R**	GZ1368-S-5-4/LA110//Milyang 49	Egypt	Indica type, medium growth duration, medium stature, resis. To blast and good restorer for CMS lines
12	IR 25571R**		IRRI	

* A= CMS line & B= Maintainer line, ** R = Restorer line.

$$MP\ \% = \frac{\overline{F}_1 - MP}{MP} \times 100$$

$$BP\% = \frac{\overline{F}_1 - B.\overline{P}}{B\overline{P}} \times 100$$

$$(SH) = \frac{\overline{F}_1 - CP}{CP} \times 100$$

RESULTS AND DISCUSSION

Analysis of variance presented in Table (2) showed significant differences among the 47 genotypes (Twelve female and male parents and their 35 F_1 hybrid combinations) for all the studied characters. The parents showed highly significant differences for all characters. In the same time, the hybrids exhibited highly significant differences for all the studied characters. The mean squares of parents vs hybrids estimates, as an indication to average of heterosis over all hybrids were found to be highly significant for most of the studied characters.

The mean performance of the parental lines (CMS, Maintainer and restorer lines) and their hybrid combinations for all agronomic , yield and its components and panicle characters are presented in Table (3). Results revealed that the CMS and their maintainer lines, IR 68888A/B, IR 68897A/B and IR 69625A/B showed the highest and best mean values for grain yield/m^2 and for most of the studied characters such as tillers plant^{-1} (Ti/P), panicles plant^{-1} (Pn/P) and spikelet fertility % (SpFert %). However, the CMS lines IR 70368A/B and G 46A/B showed the best filled grains panicle^{-1} (Fg/Pn), 100-grain weight (GW) and panicle weight (Pnw). The restorer varieties Giza 178R, Giza 182R and IR 25571R showed the highest mean values for grain yield and most of studied characters. However, the restorer lines PR 78 and PR2 were the best for GW, PnL, Ti/P, PnW and SpFert%.

The most desirable mean values were detected by the hybrid combinations, IR 68897A x GZ 5121R, IR 69625A x PR2, IR 68888A x IR 25571R, IR 68888A x Giza 182R, IR 69625A x VHR3, IR 68897A x PR 2, IR 6925A x Giza 178R, G 46A x Giza 178R, IR 68897A x PR 78 and G 46A x IR 25571R.

Table (2): Analysis of variance and mean squares of enotypes, parents, hybrids and parents v.s hybrids for all the studied characters.

s.o.v	d.f	Agronomic traits			Yield and its component traits			
		HDG	Ht(cm)	Ti/P	Yid/m^2	Pn/P	FG/Pn	GW
Reps.	2	14.69**	17.10*	11.19**	2548.1	6.819**	15.65	0.009
Genotypes	46	22.67**	143.98**	19.55**	77045.7**	16.88**	1121.7**	0.124**
Parents	11	52.81**	287.7**	8.262**	43752.8**	6.91**	644.4**	0.163**
Hybrids	34	13.54**	66.29**	21.44**	25797.6**	20.32**	932.4**	0.108**
Parents vs. hybrids	1	1.729	1203.9**	79.28**	2185702.9**	9.965**	12810.7**	0.237**
Error	92	1.173	5.348	0.51	865.4	1.370	55.03	0.005
CV %		1.12	2.08	3.24	2.58	6.43	4.69	2.54

Cont. Table (2): Analysis of variance and mean squares of genotypes, parents, hybrids and parents v.s hybrids for all the studied characters.

s.o.v	d.f	Panicle traits		
		PnL(cm)	PnW(g)	SpFert%
Reps.	2	4.338**	0.097	20.112
Genotypes	46	6.257**	1.362**	94.659**
Parents	11	5.672**	1.101**	84.972**
Hybrids	34	4.375**	0.939**	97.479**
Parents vs. hybrids	1	76.67**	18.63**	105.37*
Error	92	0.498	0.065	21.899
CV %		2.79	5.59	5.4

*, ** Significant at 0.05 and 0.01 levels, respectively.

Table (3): The mean performance for all studied characters.

Characters / Genotypes	Agronomic characters			Yield and its components			
	HDG	Ht (cm)	Ti/P	Yld/m2 (g)	Pn/P	FG/Pn	GW (g)
Lines (Females):							
IR 68888 A	97.33	102.93	22.09	1026.33	20.33	119.87	2.30
IR 68897 A	94.67	100.47	24.29	1019.50	20.47	142.33	2.29
IR 69625 A	99.00	107.73	21.51	1094.83	17.20	136.27	2.60
IR 70368 A	100.00	111.73	20.51	852.83	16.47	163.33	2.61
G 46 A	86.67	101.87	19.47	683.50	16.73	160.93	2.57
Testers (Males):							
Giza 178 R	95.00	95.80	17.69	1046.27	15.40	145.80	2.48
Giza 182 R	96.33	95.73	19.96	974.00	17.87	127.27	2.65
Vitnam 3 R	99.33	107.93	19.82	908.83	17.40	125.07	2.93
PR 78 R	100.67	125.53	20.27	822.00	17.73	161.20	3.01
PR 2 R	100.33	123.07	20.44	857.83	16.73	139.40	2.95
GZ 5121 R	102.00	106.20	22.33	841.00	19.00	131.13	2.57
IR 25571R	94.00	97.20	20.73	1022.50	17.53	147.80	2.69
Hybrid combinations :							
IR 68888 A x Giza 178 R	93.33	106.73	27.16	1228.50	23.47	156.50	2.30
x Giza 182 R	95.67	102.00	24.13	1318.50	20.93	152.47	2.61
x Vitnam 3 R	93.67	106.93	22.14	1236.17	19.27	147.73	2.60
x PR 78 R	94.33	117.67	21.29	1232.50	18.60	155.93	2.83
x PR 2 R	93.33	113.27	22.47	1212.67	18.60	141.93	2.74
x GZ 5121 R	99.33	113.07	25.27	1243.33	21.67	169.47	2.40
x IR 25571 R	97.67	111.20	23.78	1321.50	20.73	215.67	2.76
IR 68897 A x Giza 178 R	95.33	110.73	27.13	1230.33	22.67	159.40	2.35
x Giza 182 R	96.00	104.80	26.18	1203.83	20.67	147.20	2.77
x Vitnam 3 R	95.00	113.80	22.36	1256.00	19.07	170.13	2.65
x PR 78 R	96.00	115.73	21.40	1266.33	18.47	149.33	2.79
x PR 2 R	95.00	118.93	23.27	1297.33	20.13	161.93	2.79
x GZ 5121 R	99.33	117.00	25.13	1411.17	21.20	166.93	2.55
x IR 25571 R	98.33	114.80	25.36	1251.50	19.80	195.53	2.88
IR 69625 A x Giza 178 R	97.67	111.80	23.44	1283.67	20.33	147.73	2.51
x Giza 182 R	94.00	106.33	23.49	1208.50	19.20	145.40	2.78
x Vitnam 3 R	97.00	110.53	22.33	1292.33	19.00	151.07	2.95
x PR 78 R	99.00	116.07	22.04	1174.67	17.60	184.60	2.84
x PR 2 R	98.00	117.87	20.91	1329.67	18.67	156.20	2.93
x GZ 5121 R	96.67	109.67	20.42	1179.83	18.13	129.00	2.71
x IR 25571 R	98.00	115.67	23.53	1237.33	20.27	164.07	2.75
IR 70368 A x Giza 178 R	101.67	108.33	17.69	1215.67	15.87	175.87	2.69
x Giza 182 R	95.00	111.47	25.56	1233.00	20.60	143.93	2.85
x Vitnam 3 R	98.67	113.33	25.29	1134.67	19.07	172.33	2.89
x PR 78 R	98.67	116.53	22.42	1139.50	17.07	177.60	2.92
x PR 2 R	98.33	114.13	23.27	1163.50	17.13	174.67	3.00
x GZ 5121 R	96.67	112.47	24.18	1008.50	16.40	164.13	2.73
x IR 25571 R	94.33	117.53	21.49	1166.00	15.73	176.47	2.81
G 46 A x Giza 178 R	99.00	114.80	20.71	1287.67	14.73	173.07	2.54
x Giza 182 R	97.00	111.73	19.27	1283.17	13.93	155.00	2.70
x Vitnam 3 R	94.67	107.87	18.64	1071.67	14.47	158.73	2.87
x PR 78 R	99.00	123.67	21.18	1030.00	14.73	184.47	2.86
x PR 2 R	98.33	114.93	19.62	1069.83	15.33	181.27	2.87
x GZ 5121 R	100.33	122.13	15.60	1015.00	12.80	141.93	2.33
x IR 25571 R	97.67	113.27	18.62	1279.17	15.87	182.73	2.69
LSD 0.05	1.76	3.76	1.16	47.80	1.90	12.05	0.11
0.01	2.33	4.98	1.54	63.39	2.52	15.98	0.15

Cont. Table (3)

Genotypes \ Characters		Panicle characters PnL (cm)	PnW (g)	SpFert %
Lines (Females):				
IR 68888 A		23.33	2.87	94.89
IR 68897 A		24.27	3.22	89.03
IR 69625 A		23.67	3.94	88.18
IR 70368 A		25.07	4.54	84.84
G 46 A		23.27	4.26	79.74
Testers (Males):				
Giza 178 R		24.27	3.67	94.23
Giza 182 R		23.73	3.65	89.30
Vitnam 3 R		22.67	4.09	82.16
PR 78 R		26.73	5.02	80.16
PR 2 R		26.00	4.54	91.30
GZ 5121 R		21.73	3.54	91.19
IR 25571R		23.93	4.08	93.30
Hybrid combinations :				
IR 68888 A	x Giza 178 R	27.07	4.16	79.65
	x Giza 182 R	27.07	4.38	83.45
	x Vitnam 3 R	26.40	4.30	77.18
	x PR 78 R	28.53	4.69	81.71
	x PR 2 R	27.93	4.28	79.77
	x GZ 5121 R	25.60	4.37	88.74
	x IR 25571 R	26.40	6.31	88.83
IR 68897 A	x Giza 178 R	25.67	4.21	75.85
	x Giza 182 R	25.80	4.31	82.03
	x Vitnam 3 R	26.27	4.93	81.13
	x PR 78 R	27.33	4.91	74.57
	x PR 2 R	27.20	4.88	79.94
	x GZ 5121 R	25.47	4.41	89.65
	x IR 25571 R	27.40	5.88	84.67
IR 69625 A	x Giza 178 R	25.40	4.13	84.85
	x Giza 182 R	24.20	4.32	91.80
	x Vitnam 3 R	24.73	4.74	91.45
	x PR 78 R	25.67	5.28	86.03
	x PR 2 R	25.20	4.88	89.22
	x GZ 5121 R	23.73	3.81	91.03
	x IR 25571 R	24.20	4.88	88.70
IR 70368 A	x Giza 178 R	25.53	5.03	90.16
	x Giza 182 R	25.80	4.46	89.88
	x Vitnam 3 R	25.73	5.20	93.33
	x PR 78 R	26.60	5.33	87.50
	x PR 2 R	26.33	5.46	90.37
	x GZ 5121 R	24.80	4.72	89.93
	x IR 25571 R	26.07	5.39	92.97
G 46 A	x Giza 178 R	24.27	4.73	91.16
	x Giza 182 R	23.93	4.65	88.73
	x Vitnam 3 R	23.33	4.69	90.60
	x PR 78 R	25.73	5.63	91.78
	x PR 2 R	25.80	5.33	84.62
	x GZ 5121 R	25.07	3.92	71.27
	x IR 25571 R	24.87	4.92	91.38
LSD	0.05	1.15	0.41	7.60
	0.01	1.52	0.55	10.08

Concerning agronomic, yield and its components and panicle characters, complete to over-dominance was observed in all or the most of the hybrid combinations towards highest plant height (Ht), higher tillers plant^{-1}, higher grain yield /m^2, higher panicles plant^{-1}, higher number of filled grains panicle^{-1}, longest panicle length and heavier panicle weight. However, 13 out of the 35 hybrids showed dominance effects towards the heavier 100-grain weight, on the other hand, the rest of hybrid combinations were intermediate between the parents involved for days to heading, plant height, panicles plant^{-1}, filled grains panicle^{-1}, 100-grain weight, panicle length and spikelet fertility %.

However, few crosses exhibited dominance effect towards the lower parents, 14 hybrid combinations for days to heading, six hybrids for tillers plant^{-1}, nine hybrids for panicles plant^{-1}, one hybrid for filled grains panicle and 100-grain weight and 14 hybrids for spikelet fertility % with respect to characters i.e. days to heading. The 100-grains weight and spikelet fertility % in most of F_1 hybrid combinations values were higher, longer and heavier than their corresponding parents.

These findings suggested the presence of over-dominance for agronomic and grain yield and its components characters, and long and heavy panicle, over lower plant height, tillers plant^{-1}, panicles plant^{-1}, over the short panicle and low panicle weight.

It could be noticed that 14 out of the 35 F_1 hybrids mean values of days to heading characters were tended to the direction of earlier parents.

A range of heterosis over the better parent, mid-parents and standard variety Giza 178R was observed in hybrids of CMS and restorer lines for agronomic, yield and its components and panicle characters (Tables 4,5,6 and 7).

The scope for exploitation of heterosis in hybrids depends on their mean performance or magnitude of heterosis and sca effects. The summarized information on the number of hybrids showing significant heterosis and range of heterosis over B.P., M.P. and S.H. % are given in the same Table. Heterosis was observed for all the studied characters but the magnitude was varied according to kinds of hybrids and characters. The highest better parents heterosis of 54.66% was observed for panicle weight (PnW), followed by filled grains panicle (45.92%), grain yield / m^2 (38.42%), tillers plant^{-1} (24.60%) and panicles plant^{-1} (23.74%). The highest mid-parents heterosis of 81.66% was observed for panicle weight followed by filled grains panicle^{-1} (61.15 %), grain yield / m^2 (54.83 %) and tillers plant^{-1} (36.54 %).

Among the three types of heterosis i.e. heterobeltiosis, mid-parents and standard heterosis, the standard heterosis is most important because the effects are more being made to develop hybrids which are better than the existing high yielding varieties grown commercially by the farmers. Evaluation based on the standard heterosis (Tables 4, 5, 6 and 7) revealed that out of 35 hybrid combinations, 18 and 34 recorded highly significant and significant positive standard heterosis for days to heading and plant height, respectively. None of the hybrids recorded significant negative standard heterosis for early and dwarf plant stature. Desirable standard heterosis was recorded by 31 hybrids for tillers palnt^{-1}, 30 hybrids for yield grain / m^2, 23 hybrids for panicles plant^{-1} , 28 hybrids for 100-grain weight, 23 hybrids for panicle length and 33 hybrids for panicle weight. These results agreed with that obtained by **Hammoud (1996 & 2004)**

,Ammar(1997),Rogbell and Subbaraman (1997), Vishwakarama *et al.* (1998), El-Mowafi (2001),El Refaee(2002), El Mowafi and Abou Shousha (2003), El Mowafi *et al.*, (2005) and Abd Allah (2008).

Evaluation of hybrids for heterosis breeding based on mean performance, better parent, mid-parents and standard heterosis would be

Table 4: A range of heterosis over the better parent, mid-parents and standard variety for all the studied characters.

characters		Better parent heterosis (heterobeltiosis)		Mid-parent heterosis		Standard heterosis	
		%	NO	%	NO	%	NO
Agronomic characters:							
HDG	A	-4.11 to 15.76	35	-5.56 to 8.99	35	-1.75 to 7.02	35
	B	2.06 to 15.76	13	1.79 to 8.99	10	2.11 to 7.02	18
	C	-2.02 to -4.11	7	-1.66 to -5.56	16	-	-
Ht (cm)	A	2.15 to 21.40	35	-2.78 to 17.40	35	6.47 to 29.09	35
	B	3.89 to 21.40	32	3.01 to 17.40	23	6.47 to 29.09	34
	C	-	-	-2.78	1	-	-
Ti /P	A	-30.14 to 24.60	35	-25.36 to 36.54	35	-11.81 to 53.52	35
	B	6.37 to 24.60	15	5.53 to 36.54	22	8.92 to 53.52	31
	C	- 5.93 to -30.14	7	-5.09 to -25.36	5	-11.81	1
Yield and its components:							
Yld /m^2	A	7.29 to 35.63	35	16.83 to 54.83	35	-3.61 to 34.88	35
	B	7.29 to 25.63	35	16.83 to 54.83	35	8.45 to 34.88	30
	C	-	-	-	-	-	-
Pn / P	A	-32.28 to 23.74	35	-28.36 to 31.34	35	-16.88 to 52.38	35
	B	13.46 to 23.74	5	9.51 to 31.34	13	14.29 to 52.38	23
	C	-11.79 to -32.28	8	-14.51to -28.36	4	-16.88	1
FG / Pn	A	-11.88 to 45.92	35	-4.23 to 61.15	35	-11.52 to 47.92	35
	B	7.54 to 45.92	19	7.56 to 61.15	30	8.87 to 47.92	20
	C	-9.55 to -11.88	3	-	-	-11.52	1
GW (g)	A	-11.15 to 7.55	35	-10.06 to 10.48	35	-7.00 to 21.00	35
	B	4.34 to 7.55	7	4.00 to 10.48	11	5.11 to 21.00	28
	C	-4.87 to -11.15	12	-4.44 to -10.06	4	-4.98 to -7.00	3
Panicle characters:							
PnL (cm)	A	-3.98 to 12.90	35	1.48 to 15.01	35	-3.85 to 17.58	35
	B	4.62 to 12.90	14	4.55 to 15.01	24	4.95 to 17.58	23
	C	-	-	-	-	-	-
PnW (g)	A	-8.06 to 54.66	35	0.49 to 81.66	35	3.87 to 71.91	35
	B	10.70 to 54.66	19	8.50 to 81.66	33	12.44 to 71.91	33
	C	-	-	-	-	-	-
SpFert %	A	-21.23 to 10.01	35	-16.61 to 13.67	35	-24.37 to -0.95	35
	B	10.01	1	8.05 to 13.67	7	-	-
	C	– 8.87 to -21.23	12	-7.62 to -16.61	5	-9.95 to -24.37	14

A: Over all range B: positive significant range C: Negative significant range
Standard heterosis = Giza 178

Table (5): Estimates of heterosis over the better-parents (BP) for all studied characters.

Characters / Genotypes	Agronomic characters			Yield and its component			
	HDG	Ht (cm)	Ti/P	Yld/m2 (g)	Pn/P	FG/Pn	GW (g)
IR 68888 A x Giza 178 R	-1.75	11.41**	22.93**	17.42**	23.74*	7.34	-7.12**
x Giza 182 R	-0.69	6.55**	9.25**	28.47**	0.24	19.80**	-1.51
x Vitnam 3 R	-3.76**	3.89*	0.25	20.45**	-6.10	18.12**	-11.15**
x PR 78 R	-3.08**	14.32**	-3.63	20.09**	-11.79*	-3.27	-5.87**
x PR 2 R	-4.11**	10.04**	1.71	18.16**	-8.18	1.82	-7.12**
x GZ 5121 R	2.06*	9.85**	13.15**	21.14**	5.04	29.23**	-6.74**
x IR 25571 R	3.90**	14.40**	7.64**	28.76**	0.24	45.92**	2.48
IR 68897 A x Giza 178 R	0.70	15.59**	11.71**	17.59**	12.14	9.33*	-5.11*
x Giza 182 R	1.40	9.47**	7.77**	18.08**	5.30	3.42	4.40*
x Vitnam 3 R	0.35	13.27**	-7.96**	23.20**	-8.70	19.53**	-9.44**
x PR 78 R	1.40	15.19**	-11.90**	24.21**	-8.05	-7.36	-7.20**
x PR 2 R	0.35	18.38**	-4.21	27.25**	1.83	13.77**	-5.42**
x GZ 5121 R	4.93**	16.45**	3.47	38.42**	5.52	17.29**	-0.91
x IR 25571 R	2.48**	18.11**	4.39	22.40**	2.26	32.30**	6.94**
IR 69625 A x Giza 178 R	2.81**	16.70**	8.99**	17.25**	15.76**	-9.55*	-3.33
x Giza 182 R	-2.42**	11.08**	9.20**	10.38**	9.31	-0.27	4.78*
x Vitnam 3 R	-2.02*	2.60	3.83	18.04**	6.51	9.25*	0.80
x PR 78 R	0.00	7.74**	2.48	7.29**	2.65	33.51**	-5.54**
x PR 2 R	-1.01	9.41**	-2.78	21.45**	0.90	-3.10	-0.56
x GZ 5121 R	-2.36**	3.26	-8.54**	7.76**	-13.80**	-7.46	4.10*
x IR 25571 R	4.26**	19.00**	9.41**	13.02**	13.46*	18.66**	2.35
IR 70368 A x Giza 178 R	7.02**	13.08**	-13.75**	16.19**	-10.81	18.99**	2.94
x Giza 182 R	-1.38	16.44**	24.60**	26.59**	18.63**	-11.88**	7.55**
x Vitnam 3 R	-0.67	5.01**	23.30**	24.85**	13.54*	5.51	-1.37
x PR 78 R	-1.33	4.30**	9.32**	33.61**	-2.49	8.74*	-2.99
x PR 2 R	-1.67	2.15	13.44**	35.63**	2.68	6.94	1.58
x GZ 5121 R	-3.33**	5.90**	8.27**	18.25**	-12.28*	0.49	4.73*
x IR 25571 R	0.35	20.92**	3.66	14.03**	-10.00	8.04*	4.34*
G 46 A x Giza 178 R	14.23**	19.83**	6.37*	23.07**	-12.47*	7.54*	-1.04
x Giza 182 R	11.92**	16.72**	-3.47	31.74**	-21.41**	-3.68	1.76
x Vitnam 3 R	9.23**	5.89**	-5.93*	17.92**	-19.41**	-1.36	-2.05
x PR 78 R	14.23**	21.40**	4.48	25.30**	-15.90**	14.43**	-4.87**
x PR 2 R	13.46**	12.82**	-4.00	24.71**	-10.47	12.64**	-2.60
x GZ 5121 R	15.76**	19.89**	-30.14**	20.69**	-32.28**	-11.80**	-9.34**
x IR 25571 R	12.69**	16.53**	-10.17**	25.10**	-10.88	13.55**	0.12
LSD 0.05	**1.76**	**3.76**	**1.16**	**47.80**	**1.90**	**12.05**	**0.11**
0.01	**2.33**	**4.98**	**1.54**	**63.39**	**2.52**	**15.98**	**0.15**

*, ** Significant at 0.05 and 0.01 levels, respectively.

Cont. Table (5)

Characters / Genotypes		Panicle characters		
		PnL (cm)	PnW (g)	SpFert %
IR 68888 A	x Giza 178 R	11.52**	13.35*	-16.07**
	x Giza 182 R	14.06**	20.06**	-12.05**
	x Vitnam 3 R	13.16**	5.10	-18.66**
	x PR 78 R	6.75**	-6.65	-13.89**
	x PR 2 R	7.44**	-5.73	-15.94**
	x GZ 5121 R	9.73**	23.67**	-6.49
	x IR 25571 R	10.32**	54.66**	-6.39
IR 68897 A	x Giza 178 R	5.75*	14.60*	-19.51**
	x Giza 182 R	6.30**	18.13**	-8.14
	x Vitnam 3 R	8.23**	20.33**	-8.87*
	x PR 78 R	2.26	-2.36	-16.24**
	x PR 2 R	4.62*	7.57	-12.44**
	x GZ 5121 R	4.93*	24.68**	-1.69
	x IR 25571 R	12.90**	44.09**	-9.25*
IR 69625 A	x Giza 178 R	4.66	4.77	-9.96*
	x Giza 182 R	1.98	9.75	2.80
	x Vitnam 3 R	4.49	15.93**	3.71
	x PR 78 R	-3.98	5.19	-2.44
	x PR 2 R	-3.08	7.43	-2.28
	x GZ 5121 R	0.27	-3.21	-0.18
	x IR 25571 R	1.13	19.59**	-4.93
IR 70368 A	x Giza 178 R	1.85	10.70*	-4.32
	x Giza 182 R	2.91	-1.76	0.65
	x Vitnam 3 R	2.65	14.60**	10.01*
	x PR 78 R	-0.49	6.14	3.13
	x PR 2 R	1.28	20.21**	-1.02
	x GZ 5121 R	-1.08	3.98	-1.38
	x IR 25571 R	3.98	18.74**	-0.35
G 46 A	x Giza 178 R	-0.01	11.10*	0.27
	x Giza 182 R	0.86	9.09	2.95
	x Vitnam 3 R	0.27	10.00	1.68
	x PR 78 R	-3.73	12.15**	1.83
	x PR 2 R	-0.77	17.50**	-4.64
	x GZ 5121 R	7.72**	-8.06	-21.23**
	x IR 25571 R	3.91	15.60**	1.39
LSD	**0.05**	**1.15**	**0.41**	**7.60**
	0.01	**1.52**	**0.55**	**10.08**

*, ** Significant at 0.05 and 0.01 levels, respectively.

Table (6): Estimates of heterosis over mid-parents (MP) for all studied characters.

Characters / Genotypes	Agronomic characters			Yield and its component			
	HDG	Ht (cm)	Tl/P	Yld/m2 (g)	Pn/P	FG/Pn	GW (g)
IR 68888 A x Giza 178 R	-2.94**	7.41**	36.54**	18.55**	31.34**	17.82**	-3.63
x Giza 182 R	-1.20	2.68	14.80**	31.83**	9.60*	23.39**	5.67**
x Vitnam 3 R	-4.74**	1.42	5.67*	27.76**	2.12	20.63**	-5.85**
x PR 78 R	-4.71**	3.01*	0.52	33.36**	-2.28	10.96**	0.83
x PR 2 R	-5.56**	0.24	5.64*	28.72**	0.36	9.49*	-0.72
x GZ 5121 R	-0.33	8.13**	13.76**	33.17**	10.17*	35.03**	-5.08**
x IR 25571 R	2.09*	11.13**	11.05**	29.00**	9.51*	61.15**	3.25
IR 68897 A x Giza 178 R	0.53	12.84**	29.27**	19.12**	26.39**	10.64**	-10.06**
x Giza 182 R	0.52	6.83**	18.33**	20.78**	7.83*	9.20*	-1.54
x Vitnam 3 R	-2.06*	9.21**	1.36	30.27**	0.70	27.25**	-4.44*
x PR 78 R	-1.71*	2.42	-3.94	37.53**	-3.32	-1.60	3.39
x PR 2 R	-2.56**	6.41**	4.02	38.21**	8.24	14.96**	2.76
x GZ 5121 R	1.02	13.23**	7.82**	51.70**	7.43	22.09**	8.37**
x IR 25571 R	2.12*	16.16**	12.64**	22.58**	4.21	34.79**	7.20**
IR 69625 A x Giza 178 R	0.69	9.86**	19.61**	19.91**	24.74**	4.01	1.41
x Giza 182 R	-3.75**	4.52**	13.29**	16.83**	9.51*	9.52*	-0.83
x Vitnam 3 R	-2.18**	2.50	8.06**	29.00**	9.83*	14.73**	9.52**
x PR 78 R	-0.84	-0.49	5.53*	22.56**	0.76	23.29**	9.57**
x PR 2 R	-1.67*	2.14	-0.32	36.19**	10.02*	12.51**	5.77**
x GZ 5121 R	-3.81**	2.52	-6.84**	21.89**	0.18	-4.23	10.48**
x IR 25571 R	1.55	12.88**	11.42**	16.88**	16.70**	14.71**	-2.42
IR 70368 A x Giza 178 R	4.27**	4.40**	-7.39**	28.03**	-0.42	13.78**	4.00*
x Giza 182 R	-3.22**	7.46**	26.30**	34.99**	20.00**	-0.94	2.33
x Vitnam 3 R	-1.00	3.19*	25.40**	28.82**	12.60*	19.51**	0.64
x PR 78 R	-1.66*	-1.77	9.97**	36.07**	-0.19	9.45**	8.35**
x PR 2 R	-1.83*	-2.78*	13.62**	36.03**	3.21	15.39**	3.16
x GZ 5121 R	-4.29**	3.21*	12.86**	19.08**	-7.52	11.48**	4.73*
x IR 25571 R	-2.75**	12.51**	4.20	24.35**	-7.45	13.43**	1.51
G 46 A x Giza 178 R	8.99**	16.16**	11.48**	48.88**	-8.30	12.85**	-9.81**
x Giza 182 R	6.01**	13.09**	-2.25	54.83**	-19.46**	7.56*	-5.27**
x Vitnam 3 R	1.79*	2.83	-5.09*	34.60**	-15.23**	11.00**	-1.43
x PR 78 R	5.69**	8.77**	6.60*	36.83**	-14.51**	14.53**	1.78
x PR 2 R	5.17**	2.19	-1.67	38.82**	-8.37	20.71**	4.11*
x GZ 5121 R	6.36**	17.40**	-25.36**	33.16**	-28.36**	-2.81	-9.34**
x IR 25571 R	8.12**	13.80**	-7.35**	49.96**	-7.39	18.38**	2.41
LSD 0.05	1.52	3.25	1.00	41.39	1.65	10.44	0.10
0.01	2.02	4.32	1.33	54.89	2.18	13.84	0.13

*, ** Significant at 0.05 and 0.01 levels, respectively.

Table (7): Estimates of standard heterosis (SH) for all studied characters.

Characters / Genotypes	Agronomic characters			Yield and its component			
	HDG	Ht (cm)	Ti/P	Yld/m2 (g)	Pn/P	FG/Pn	GW (g)
IR 68888 A x Giza 178 R	-1.75	11.41	53.52**	17.42**	52.38**	7.34	-7.00**
x Giza 182 R	0.70	6.47**	36.43**	26.02**	35.93**	4.57	5.38*
x Vitnam 3 R	-1.40	11.62**	25.19**	18.15**	25.11**	1.33	5.11*
x PR 78 R	-0.70	22.83**	20.35**	17.80**	20.78**	6.95	14.40**
x PR 2 R	-1.75	18.23**	27.01**	15.90**	20.78**	-2.65	10.63**
x GZ 5121 R	4.56**	18.02**	42.84**	18.84**	40.69**	16.23**	-3.23
x IR 25571 R	2.81**	16.08**	34.42**	26.31**	34.63**	47.92**	11.31**
IR 68897 A x Giza 178 R	0.35	15.59**	53.39**	17.59**	47.19**	9.33*	-4.98*
x Giza 182 R	1.05	9.39**	47.99**	15.06**	34.20**	0.96	11.71**
x Vitnam 3 R	0.00	18.79**	26.38**	20.05**	23.81**	16.69**	7.13**
x PR 78 R	1.05	20.81**	20.98**	21.03**	19.91**	2.42	12.79**
x PR 2 R	0.00	24.15**	31.53**	24.00**	30.74**	11.07**	12.65**
x GZ 5121 R	4.56**	22.13**	42.09**	34.88**	37.66**	14.49**	2.83
x IR 25571 R	1.40	19.83**	43.34**	19.62**	28.57**	34.11**	16.15**
IR 69625 A x Giza 178 R	2.81**	16.70**	32.54**	22.69**	32.03**	1.33	1.48
x Giza 182 R	-1.05	11.00**	32.79**	15.51**	24.68**	-0.27	12.11**
x Vitnam 3 R	2.11*	15.38**	26.26**	23.52**	23.38**	3.61	19.25**
x PR 78 R	4.21**	21.16**	24.62**	12.27**	14.29*	26.61**	14.80**
x PR 2 R	3.16**	23.03**	18.22**	27.09**	21.21**	7.13	18.44**
x GZ 5121 R	1.75	14.47**	15.45**	12.77**	17.75**	-11.52**	9.29**
x IR 25571 R	3.16**	20.74**	33.04**	18.26**	31.60**	12.53**	11.17**
IR 70368 A x Giza 178 R	7.02**	13.08**	0.00	16.19**	3.03	20.62**	8.48**
x Giza 182 R	0.00	16.35**	44.47**	17.85**	33.77**	-1.28	15.07**
x Vitnam 3 R	3.86**	18.30**	42.96**	8.45**	23.81**	18.20**	16.69**
x PR 78 R	3.86**	21.64**	26.76**	8.91**	10.82	21.81**	17.90**
x PR 2 R	3.51**	19.14**	31.53**	11.20**	11.26	19.80**	21.00**
x GZ 5121 R	1.75	17.40**	36.68**	-3.61	6.49	12.57**	10.36**
x IR 25571 R	-0.70	22.69**	21.48**	11.44**	2.16	21.03**	13.32**
G 46 A x Giza 178 R	4.21**	19.83**	17.09**	23.07**	-4.33	18.70**	2.69
x Giza 182 R	2.11*	16.63**	8.92**	22.64**	-9.52	6.31	8.88**
x Vitnam 3 R	-0.35	12.60**	5.40	2.43	-6.06	8.87*	15.88**
x PR 78 R	4.21**	29.09**	19.72**	-1.55	-4.33	26.52**	15.61**
x PR 2 R	3.51**	19.97**	10.93**	2.25	-0.43	24.33**	16.02**
x GZ 5121 R	5.61**	27.49**	-11.81**	-2.99	-16.88**	-2.65	-5.92**
x IR 25571 R	2.81**	18.23**	5.28	22.26**	3.03	25.33**	8.75**
LSD 0.05	**1.76**	**3.76**	**1.16**	**47.80**	**1.90**	**12.05**	**0.11**
0.01	**2.33**	**4.98**	**1.54**	**63.39**	**2.52**	**15.98**	**0.15**

*, ** Significant at 0.05 and 0.01 levels, respectively.

Cont. Table (6):

Genotypes \ Characters		Panicle characters		
		PnL (cm)	PnW (g)	SpFert %
IR 68888 A	x Giza 178 R	13.73**	27.27**	-15.77**
	x Giza 182 R	15.01**	34.45**	-6.41
	x Vitnam 3 R	14.78**	23.60**	-9.38*
	x PR 78 R	13.98**	18.85**	-0.96
	x PR 2 R	13.24**	15.53**	-6.72
	x GZ 5121 R	13.61**	36.55**	-4.28
	x IR 25571 R	11.71**	81.66**	-2.71
IR 68897 A	x Giza 178 R	5.77**	22.11**	-6.24
	x Giza 182 R	7.50**	25.50**	0.27
	x Vitnam 3 R	11.93**	34.69**	-3.69
	x PR 78 R	7.19**	19.00**	-13.74**
	x PR 2 R	8.22**	25.84**	-7.62*
	x GZ 5121 R	10.72**	30.50**	6.49
	x IR 25571 R	13.69**	61.08**	-1.71
IR 69625 A	x Giza 178 R	5.98**	8.50*	10.89*
	x Giza 182 R	2.11	13.99**	12.13**
	x Vitnam 3 R	6.76**	18.07**	13.67**
	x PR 78 R	1.85	17.85**	5.36
	x PR 2 R	1.48	15.09**	5.73
	x GZ 5121 R	4.55*	2.05	10.00*
	x IR 25571 R	1.68	21.70**	6.42
IR 70368 A	x Giza 178 R	3.51	22.38**	8.64*
	x Giza 182 R	5.74**	8.90*	8.05*
	x Vitnam 3 R	7.82**	20.49**	8.91*
	x PR 78 R	2.70	11.39**	-0.39
	x PR 2 R	3.13	20.20**	3.94
	x GZ 5121 R	5.98**	16.88**	2.27
	x IR 25571 R	6.39**	25.03**	3.01
G 46 A	x Giza 178 R	2.10	19.34**	0.39
	x Giza 182 R	1.84	17.53**	0.88
	x Vitnam 3 R	1.60	12.19**	-0.73
	x PR 78 R	2.93	21.28**	2.82
	x PR 2 R	4.74*	21.27**	-1.06
	x GZ 5121 R	11.41**	0.49	-16.61**
	x IR 25571 R	5.37*	18.09**	5.62
LSD	**0.05**	**0.99**	**0.36**	**6.58**
	0.01	**1.32**	**0.48**	**8.73**

*, ** Significant at 0.05 and 0.01 levels, respectively.

Cont. Table (7):

Genotypes \ Characters		Panicle characters		
		PnL (cm)	PnW (g)	SpFert %
IR 68888 A	x Giza 178 R	11.54**	13.35*	-15.48**
	x Giza 182 R	11.54**	19.32**	-11.43**
	x Vitnam 3 R	8.79**	17.18**	-18.09**
	x PR 78 R	17.58**	27.75**	-13.29**
	x PR 2 R	15.11**	16.52**	-15.35**
	x GZ 5121 R	5.49*	19.08**	-5.83
	x IR 25571 R	8.79**	71.91**	-5.73
IR 68897 A	x Giza 178 R	5.77*	14.60*	-19.50**
	x Giza 182 R	6.32**	17.40**	-12.95**
	x Vitnam 3 R	8.24**	34.16**	-13.90**
	x PR 78 R	12.64**	33.61**	-20.86**
	x PR 2 R	12.09**	32.96**	-15.16**
	x GZ 5121 R	4.95*	20.07**	-4.86
	x IR 25571 R	12.91**	60.16**	-10.15*
IR 69625 A	x Giza 178 R	4.67	12.44*	-9.95*
	x Giza 182 R	-0.27	17.78**	-2.58
	x Vitnam 3 R	1.92	29.14**	-2.95
	x PR 78 R	5.77*	43.84**	-8.70*
	x PR 2 R	3.85	32.85**	-5.32
	x GZ 5121 R	-2.20	3.87	-3.40
	x IR 25571 R	-0.27	32.90**	-5.87
IR 70368 A	x Giza 178 R	5.22*	36.90**	-4.32
	x Giza 182 R	6.32**	21.48**	-4.61
	x Vitnam 3 R	6.04*	41.71**	-0.95
	x PR 78 R	9.62**	45.12**	-7.14
	x PR 2 R	8.52**	48.65**	-4.09
	x GZ 5121 R	2.20	28.58**	-4.56
	x IR 25571 R	7.42**	46.83**	-1.33
G 46 A	x Giza 178 R	0.00	28.91**	-3.26
	x Giza 182 R	-1.37	26.58**	-5.83
	x Vitnam 3 R	-3.85	27.64**	-3.84
	x PR 78 R	6.04*	53.35**	-2.59
	x PR 2 R	6.32**	45.31**	-10.20*
	x GZ 5121 R	3.30	6.68	-24.37**
	x IR 25571 R	2.47	34.14**	-3.02
LSD	0.05	1.15	0.41	7.60
	0.01	1.52	0.55	10.08

*, ** Significant at 0.05 and 0.01 levels, respectively.

meaningful from this point of view. Out of 35 hybrid combinations, 30 recorded significant positive values.

Hybrids with a yield advantage of 15% over the highest yielding check variety, Giza 178, were considered as promising combinations. Among the 30 significant hybrids, 12 were most promising. Mean estimates standard heterosis ranged from 20.05% to 34.88%.

The most of promising hybrids were IR 68897A x GZ 5121R (34.88%), IR 69625Ax PR 2 (27.09%), IR 68888A x IR 25571R (26.31%), IR 68888A x Giza 182R (26.02%), IR 8897Ax PR 2 (24.00%), IR 69625Ax VHR 3 (23.52%), G 46A x Giza 178R (23.07%), G 46A x Giza 182R (22.64%), IR 69625A x Giza 178R (22.69%) and G 46A x IR 25571R (22.26%).

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الملخص العربي

دراسة علي قوة الهجين في الارز الهجين

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في هذه الدراسة تم دراسة قوة الهجين لخمسة سلالات ذات عقم سيتوبلازمي وراثي مع سبعة سلالات معيدة للخصوبة بإستخدام تحليل السلالة x الكشاف وذلك لبعض الصفات الحقلية ، المحصول ومكوناته وكذلك صفات السنبلة وذلك للاستفادة منها في برنامج تربية الارز الهجين.

تم حصر الهجن التي أعطت زيادة محصولية تصل الي ١٥% أعلي من أفضل الاصناف المحلية وهو الصنف جيزة ١٧٨ وإعتبرت هجن مبشرة. وقد تم الحصول علي ١٠ هجين مبشر من بين ٣٥ تركيب هجيني جديد وهذه الهجن هي كما يلي :

IR 68897A x GZ 5121R, IR 69625Ax PR 2, IR 68888A x IR 25571R, IR 68888A x Giza 182R, IR 8897Ax PR 2, IR 69625Ax VHR 3, G 46A x Giza 178R , G 46A x Giza 182R, IR 69625A x Giza 178R and G 46A x IR 25571R.