Egypt. J. Plant Breed. 27(3):343– 382(2023)

HETEROSIS FOR YIELD AND RELATED TRAITS IN AROMATIC RICE (*Oryza sativa* L.) IN EGYPT

A.M. Reda, E.F. Arafat, Samah M. Abdelkhalek, R.M. Abdallah, A. A. Hadifa and H.F. El-Mowafi

Rice Research Department, Field Crops Research Institute, ARC, Egypt.

ABSTRACT

Forty five aromatic hybrid rice combinations were produced using five basmati CMS and nine new Egyptian basmati restorers following line x tester mating design. This study aims to find out the best aromatic hybrid combinations in respect of their heterosis over the mid-parents (MP), better-parent (BP), the best inbred check variety Giza Basmati 201 and Basmati hybrid check EBHR11, for nine agronomic and yield traits. Hybrids with a yield advantage over the highest yielding inbred and hybrid check variety were considered as promising. Among 45 aromatic hybrid rice combinations evaluated, ten of them were most promising with mean performance of high grain yield ranging from 13.77 t/ha for Sakha Basmati 13A x EBR2 to 13.98 t/ha for Sakha Basmati 13A x Giza Basmati 201 with an average of 13.874 t/ha. The yield advantage values over best local inbred check Giza Basmati 201 ranged from 3.060 to 3.260 t/ha with superiority of 27.71 to 30.45%, respectively.

Key words**: *Hybrid rice, Basmati, CMS, Heterosis.***

INTRODUCTION

The demand for aromatic rice (*Oryza sativa* L.) has dramatically increased over the past three decades. There are three major types of aromatic rice in the U.S. market, which in order of importance are Jasmine, Basmati and Della (Sha and linscombe, 2003). Most of aromatic, jasmine and elongating basmati rice in Egypt market are imported, and the volume of such imports is increasing every year. Currently, only "Jasmine 85" a Jasmine-type developed at IRRI and released in 1997 by the National Rice Research Programe in Egypt. However, it has been grown on very limited area because of its inferior specialty attributes, which include weak aroma, weak flavor, and the undesirable characteristics of poor milling yield (Sha and Linscombe (2003), Rashid *et al* 2007 and El-Mowafi *et al* 2018).

The potential of hybrid rice in increasing production and productivity was clearly demonstrated. China was also the first to develop the aromatic rice hybrids using an aromatic male sterile line, Xiang xiang 2A and a non-aromatic restorer line Minghui 63, the first quasi-aromatic hybrid xiangyou63 was released in 1995. Only limited reports are available on the basic studies related to hybrid breeding in aromatic rices (Jarwar *et al* (2013), Abdelkhalik, (2015), Biswash and Haque (2015), El-Mowafi *et al* (2018) and El-Mowafi *et al* (2021).

Heterosis is the measure of superiority of the hybrid rice over its parents. The values of heterosis could be estimated over mid-parents (MP), the better parent or heterobeltiosis (BP) and heterosis over check variety or standard heterosis (SH). In commercial exploitation, positive standard heterosis alone holds relevance as a hybrid may be superior to its parents but may be necessarily superior to commercially cultivated best variety or hybrid (Annadurai and Nadarajan (2001), El-Mowafi (2001), El-Mowafi *et al* (2005), Patil *et al* (2012) and Reddy *et al* (2012).

Hybrid rice technology is such one innovative breakthrough that can further increase rice production leading to food security and reduction of poverty in Egypt (El-Mowafi *et al* 2005 and Neelam *et al* 2009). The aim of the present study was to estimate heterosis for yield and its component in Egyptian basmati hybrid rice combinations developed using new male sterility-fertility restoration system using basmati cytoplasmic male sterile lines (CMS) and Egyptian basmati restorer lines.

MATERIALS AND METHODS

The present investigation was carried out at the Experimental Research Farm of Sakha Research Station, Sakha, Kafr El-Sheikh, Egypt during the two rice growing seasons of 2020 and 2021. This study was funded by the national project to develop the production of hybrid and super rice under conditions of water scarcity and climatic changes in cooperation between the Agricultural Research Center (ARC) and the Academy of Scientific Research and Technology. The genetic materials used in this study comprised of 45 basmati hybrid rice combinations obtained using line x tester fashion involving five basmati cytoplasmic male sterile (CMS) lines, i.e. IR58025A, Sakha Basmati 11A, Sakha Basmati 12A, Sakha Basmati 13A and Sakha Basmati 14A and new nine Egyptian Basmati pollinators namely, EBR1, EBR2, EBR3, EBR15, EBR16, EBR20, EBR25, EBR30 and Giza basmati 201 developed by the national project program to advance the productivity and marketing of hybrid rice and the national project to develop the production of hybrid and super rice under conditions of water scarcity and climatic changes in cooperation between the Agriculture Research Center (ARC) and the Academy of Scientific Research and Technology. The F_1 hybrid rice combinations along with their respective parents and checks were grown in a randomized complete block design with three replications. Thirty day-old seedling were transplanted with one seedling $hill^{-1}$ adopting a spacing of 20 cm between rows and 20 cm between plants. Each test entry consisted of fourteen rows of 5m length. Observations were recorded on ten plants $plot^{-1}$ taken at random from each entry in each replication for days to maturity, plant height, panicle length, spikelets panicle^{-1}, panicles plant^{-1}, filled grains panicle^{-1}, spikelet fertility%, 1000-grain weight and grain yield (t/ha). Ten guarded rows (10 m^2) were harvested from each entry in each replication to determine grain yield (t/ha).

Data were subjected to analysis of variances for Randomized Complete Blocks Design as suggested by Panse and Sukhatme (1954) and the analysis of variance for Line x Tester design (Kempthorne, 1957). The data were subjected to arcsine transformation before analysis

The estimates of heterosis

The expression of increased vigor of the F_1 hybrids over its parents and best local check variety in certain characters is called heterosis as proposed by Mather (1949) and Mather and Jinkes (1982).

Heterosis over the mid-parents% (MP) was determined as the deviation of the F_1 hybrids mean over the average of its two parents as follows:

- Heterosis over the parents (MP)= $\dfrac{\overline{F}_1 - \overline{MP}}{\overline{MP}} x100$
- Heterosis over the better parent (BP%)= $\dfrac{\overline{F}_1 - \overline{BP}}{\overline{BP}} x100$

The better parent for any character is that having the higher mean value, except for days to maturity and plant height where the better parent which had the lower mean value.

- Superiority over inbred (SV) or hybrid check variety (SH).

The superiority over check variety was determined as the increase of the mean of F1 hybrid over the check inbred or hybrid variety (Giza Basmati 201 and Egyptian Basmati Hybrid 11).

Superiority percentage = $\dfrac{\overline{F}_1 - \text{check variet}\bar{y}}{\text{Check variet}\bar{y}} x\,100$

To the test significance of heterosis for the above cases L.S.D. values were estimated according to following formula suggested by wyanne *et al* (1970).

LSD for MP = $t^{0.05}_{0.01}\sqrt{\dfrac{3EMS}{2R}}$

LSD for better and check variety = $t^{0.05}_{0.01}\sqrt{\frac{2EMS}{R}}$

RESULTS AND DISCUSSION

Mean performance

Mean performance of 14 Basmati parental lines (five CMS and nine restorers) and their 45 basmati hybrid rice combination of line x tester for the nine studied traits are presented in Table 1.

As revealed in Table (1), the mean performance of the studied traits varied from one combination to another, for days to maturity, the F_1 mean values of 18 hybrids were towards the lower parents (early maturity parents), while 22 tended to the higher parents (late maturity parents) and intermediate between the parents.

With respect to plant height (Table 1), the most desirable mean values towards short stature were not found in all hybrid combinations complete to over dominance was observed in all hybrids towards the taller parents for plant height, panicle length varied from 22.94cm for Sakha Basmati 14A to 28.84cm for EBR 20. The most desirable mean values were detected by the hybrids, Sakha Basmati 14 A x EBR 20 (30.75cm), Sakha Basmati 14 A x EBR 3 (30.43cm) and Sakha Basmati 14 A x Giza Basmati 201 (20.07cm).

The hybrid combinations, IR 58025A x EBR 30, Sakha Basmati 13 A x EBR 30 and IR 58025A x EBR 15 gave the highest mean values for spikelets panicle^{-1} with values of 308.87, 305.46 and 294.79 spikelet, respectively. The highest mean values for panicles plant^{-1} were obtained from the female parent IR 58025A (19.08), the male parent Giza Basmati 201 (22.53) and the Basmati hybrid rice combinations, Sakha Basmati 13 A x Giza Basmati 201 (26.24), Sakha Basmati 12 A x EBR 3 (25.71) and Sakha Basmati 12A x Giza Basmati 201 (24.65). The results in Table (1) revealed that the Basmati CMS Sakha Basmati 14 A gave the minimum mean value of (149.49 grain), while, IR 58025A had the maximum mean value of 194.11 filled grains panicle^{-1} among CMS lines. Furthermore, EBR 30 expressed the maximum mean value of 312.34 among the pollen parents (testers).

Table 1. Mean performance of parents and their F1 hybrids for studied traits.

Cate.	Genotypes	Days to maturity (day)	Plant height (cm)	Panicle length (cm)	Spikelets xpanicle	Panicles plant^{-1}
Lines	IR58025A	137.80	110.74	24.73	221.80	19.08
	Sakha Basmati11A	139.57	110.07	24.78	199.06	15.30
	Sakha Basmati12A	136.80	96.53	24.30	190.06	16.59
	Sakha Basmati13A	136.23	97.00	24.71	183.59	16.75
	Sakha Basmati14A	135.70	112.17	22.94	163.35	16.28
Testers	EBR1	134.27	114.74	27.92	223.71	19.94
	EBR2	134.50	117.54	27.61	197.97	19.24
	EBR3	133.77	111.04	28.24	199.27	20.05
	EBR15	130.40	105.56	28.02	286.16	19.62
	EBR16	132.03	109.94	23.60	259.25	19.19
	EBR20	133.47	111.27	28.84	250.56	18.86
	EBR25	136.43	112.81	25.17	265.25	17.60
	EBR30	130.80	110.94	22.69	338.74	21.39
	Giza Basmatic 201	134.07	116.46	28.52	212.68	22.53
Hybrid combinations	IR58025A x EBR1	136.03	112.21	29.39	247.58	20.95
	IR58025A x EBR2	133.80	111.86	29.65	240.68	19.69
	IR58025A x EBR3	128.97	113.49	29.10	252.19	21.33
	IR58025A x EBR15	132.67	109.17	28.53	294.79	20.31
	IR58025A x EBR16	134.10	115.04	25.93	278.28	20.49
	IR58025A x EBR20	134.90	116.12	28.51	275.73	20.06
	IR58025A x EBR25	136.97	117.28	26.23	283.13	23.29
	IR58025A x EBR30	131.30	114.19	25.95	308.87	23.29
	IR58025A x Giza Basmati201	132.37	114.25	29.38	257.24	20.68
	Sakha Basmati11A x EBR1	133.43	113.36	26.60	208.69	24.18
	Sakha Basmati11A x EBR2	132.53	115.29	26.72	244.44	19.71
	Sakha Basmati11A x EBR3	133.23	112.01	27.81	270.24	18.92
	Sakha Basmati11A x EBR15	134.53	108.52	28.14	286.22	20.14
	Sakha Basmati11A x EBR16	131.23	112.17	25.15	261.20	20.17
	Sakha Basmati11A x EBR20	134.27	115.65	28.04	254.99	22.77
	Sakha Basmati11A x EBR25	135.00	116.66	26.10	266.68	19.16
	Sakha Basmati11A x EBR30	133.40	113.59	25.64	273.57	24.70

Table 1. Cont.

Cate.	Genotypes	Days to maturity (day)	Plant height (cm)	Panicle length (cm)	Spikelets panicle	Panicles plant^{-1}
Hybrid combinations	Sakha Basmati11A x Giza Basmati201	137.30	112.32	27.97	269.61	20.85
	Sakha Basmati12A x EBR1	129.47	110.88	27.64	266.44	23.53
	Sakha Basmati12A x EBR2	129.30	109.70	27.44	267.42	21.82
	Sakha Basmati12A x EBR3	127.27	105.93	29.02	272.35	25.71
	Sakha Basmati12A x EBR15	132.33	103.81	28.41	281.89	19.41
	Sakha Basmati12A x EBR16	132.33	108.21	26.05	262.90	19.72
	Sakha Basmati12A x EBR20	134.40	110.48	28.65	252.07	23.53
	Sakha Basmati12A x EBR25	135.40	111.12	27.29	267.80	20.20
	Sakha Basmati12A x EBR30	131.43	109.15	25.30	292.85	20.93
	Sakha Basmati12A x Giza Basmati201	134.83	111.95	30.05	228.15	24.65
	Sakha Basmati13A x EBR1	131.30	111.11	27.85	234.64	24.53
	Sakha Basmati13A x EBR2	131.27	109.95	28.25	271.05	23.56
	Sakha Basmati13A x EBR3	129.47	106.26	28.18	270.47	23.01
	Sakha Basmati13A x EBR15	131.73	104.01	28.77	280.44	21.39
	Sakha Basmati13A x EBR16	134.13	108.87	25.97	252.13	22.63
	Sakha Basmati13A x EBR20	134.80	111.02	28.13	237.21	21.73
	Sakha Basmati13A x EBR25	135.33	111.42	26.37	276.79	20.16
	Sakha Basmati13A x EBR30	132.33	109.74	24.49	305.46	24.63
	Sakha Basmati13A x Giza Basmati201	135.07	111.81	28.90	238.83	26.24
	Sakha Basmati14A x EBR1	137.30	113.41	29.14	244.03	19.18
	Sakha Basmati14A x EBR2	136.83	113.96	29.27	240.58	20.62
	Sakha Basmati14A x EBR3	133.67	112.68	30.43	239.63	19.88
	Sakha Basmati14A x EBR15	133.27	108.85	28.66	255.64	20.19
	Sakha Basmati14A x EBR16	134.20	111.85	24.47	241.63	21.01
	Sakha Basmati14A x EBR20	135.10	114.02	30.75	231.17	20.46
	Sakha Basmati14A x EBR25	135.50	114.38	26.45	246.46	18.50
	Sakha Basmati14A x EBR30	133.57	112.25	25.07	286.64	23.75
	Sakha Basmati14A x Giza Basmati201	135.47	114.76	30.07	246.37	21.11

Table 1. Cont.

Cate.	Genotypes	Filled grains/panicle	Spikelets fertiliety%	1000 grain weight (g)	Grain yield (t/ha)
Lines	IR58025A	194.11	87.52	23.21	8.00
	Sakha Basmati11A	182.06	91.47	23.34	6.93
	Sakha Basmati12A	172.85	91.13	24.68	8.36
	Sakha Basmati13A	170.14	92.80	24.62	8.41
	Sakha Basmati14A	149.49	91.52	23.92	7.07
Testers	EBR1	201.75	90.23	28.79	10.22
	EBR2	185.52	93.76	28.78	10.17
	EBR3	188.50	94.61	29.74	10.53
	EBR15	273.11	95.44	24.29	10.78
	EBR16	249.46	96.22	24.75	10.77
	EBR20	244.73	97.69	26.47	10.87
	EBR25	244.13	92.06	25.14	10.69
	EBR30	312.34	92.21	22.67	10.83
	Giza Basmatic 201	191.75	90.17	29.85	10.72
Hybrid combinations	IR58025A x EBR1	220.90	89.22	26.59	12.25
	IR58025A x EBR2	218.15	90.64	26.49	12.30
	IR58025A x EBR3	226.84	89.96	27.10	12.59
	IR58025A x EBR15	270.99	91.93	25.32	12.90
	IR58025A x EBR16	251.29	90.30	26.28	12.81
	IR58025A x EBR20	249.23	90.39	26.87	12.80
	IR58025A x EBR25	254.18	89.77	26.20	13.00
	IR58025A x EBR30	278.50	90.18	26.36	13.13
	IR58025A x Giza Basmati201	227.37	88.39	28.26	13.24
	Sakha Basmati11A x EBR1	188.14	90.16	27.85	13.00
	Sakha Basmati11A x EBR2	218.38	89.34	27.54	13.16
	Sakha Basmati11A x EBR3	238.42	88.23	27.48	13.53
	Sakha Basmati11A x EBR15	261.52	91.38	27.08	13.31
	Sakha Basmati11A x EBR16	230.53	88.26	27.05	13.14
	Sakha Basmati11A x EBR20	231.96	90.98	27.12	13.41
	Sakha Basmati11A x EBR25	243.50	91.31	25.97	13.63
	Sakha Basmati11A x EBR30	250.36	91.52	26.26	13.76
	Sakha Basmati11A x Giza Basmati201	249.16	92.43	28.09	13.80

Table 1. Cont.

Cate.	Genotypes	Filled grains/panicle	Spikelets fertiliety%	1000 grain weight (g)	Grain yield (t/ha)
Hybrid combinations	Sakha Basmati12A x EBR1	235.20	88.28	27.55	13.69
	Sakha Basmati12A x EBR2	229.53	85.84	27.62	13.69
	Sakha Basmati12A x EBR3	241.54	88.69	28.23	13.78
	Sakha Basmati12A x EBR15	266.94	94.70	27.46	13.08
	Sakha Basmati12A x EBR16	246.50	93.76	27.20	13.57
	Sakha Basmati12A x EBR20	232.62	92.28	27.45	13.68
	Sakha Basmati12A x EBR25	252.57	94.31	26.88	13.87
	Sakha Basmati12A x EBR30	272.22	92.96	26.76	13.88
	Sakha Basmati12A x Giza Basmati201	208.02	91.17	28.24	13.78
	Sakha Basmati13A x EBR1	210.51	89.72	27.81	13.70
	Sakha Basmati13A x EBR2	228.19	84.56	27.72	13.77
	Sakha Basmati13A x EBR3	238.09	88.03	28.25	13.80
	Sakha Basmati13A x EBR15	255.13	90.97	27.53	13.50
	Sakha Basmati13A x EBR16	228.29	90.57	27.35	13.34
	Sakha Basmati13A x EBR20	212.34	89.53	27.43	13.55
	Sakha Basmati13A x EBR25	249.58	90.17	26.89	13.69
	Sakha Basmati13A x EBR30	268.32	87.84	26.82	13.91
	Sakha Basmati13A x Giza Basmati201	210.92	88.33	29.29	13.98
	Sakha Basmati14A x EBR1	221.65	90.84	26.49	13.70
	Sakha Basmati14A x EBR2	224.22	93.20	26.42	13.68
	Sakha Basmati14A x EBR3	223.90	93.44	27.76	13.74
	Sakha Basmati14A x EBR15	243.36	95.20	26.44	13.44
	Sakha Basmati14A x EBR16	232.27	96.13	26.75	13.41
	Sakha Basmati14A x EBR20	223.41	96.65	27.32	13.61
	Sakha Basmati14A x EBR25	238.54	96.79	26.27	13.79
	Sakha Basmati14A x EBR30	267.57	93.35	26.44	13.90
	Sakha Basmati14A x Giza Basmati201	233.86	94.92	27.80	13.85

The hybrids, IR 58025A x EBR 30, Sakha Basmati 12 A x EBR 30 and IR 58025A x EBR 15 had the highest mean values for filled grains panicle^{-1} with values of 278.50, 272.22 and 270.99, respectively.

Number of filled grains panicle^{-1} was more than the check cultivar Giza Basmati 201 for all hybrids tested. The results indicated that the parental lines EBR 20, EBR 16 and EBR 15 showed the highest mean values of spikelet fertility% with values of 97.69%, 96.22% and 95.44%, respectively. In the same time, the hybrid rice combinations, Sakha Basmati 14 A x EBR 25 (96.79%), Sakha Basmati 14 A x EBR 20 (96.65%) and Sakha Basmati 14 A x EBR 16 (96.13%) gave the highest mean performance for spikelet fertility%. The results in Table (1) revealed that, the mean values of male parents, Giza Basmati 201 (29.85g) and EBR 3 (29.74g) exhibited the heaviest 1000 grain weight. Similarly the F_1 hybrids, Sakha Basmati 13 A x Giza Basmati 201 (29.29g), IR 58025A x Giza Basmati 201 (28.26g) and Sakha Basmati 13 A x EBR 3 (28.25g) had the highest mean values.

Concerning grain yield t/ha^{-1} results in Table (1) indicated that the male Basmati parents EBR 20, EBR 30 and EBR 15 had the highest mean performance with values of 10.870, 10.830 and 10.780 t/ha, respectively. The most desirable mean values were detected by the hybrid rice combinations, Sakha Basmati 13 A x Giza Basmati 201 (13.980 t/ha), Sakha Basmati 13 A x EBR 30 (13.910 t/ha) and Sakha Basmati 14 A x EBR 30 (13.900 t/ha). The results revealed that, all hybrids were higher than the check variety Giza Basmati 201 for grain yield t/ha.

The estimates of heterosis of the 45 F_1 basmati hybrid rice combinations over the mid parents (MP), better –parent (BP), superiority to the check variety Giza Basmati 201 (SV) and Egyptian Basmati Hybrid 11 (SH) for nine agronomic and yield traits were estimated and the results are presented in Tables (1, 2 and 3).

Heterosis and the superiority

Days to maturity

The negative estimates of heterosis for days to maturity are preferred to develop early maturing aromatic rice hybrids. The results in Tables (1 and 3) illustrated that the estimates of heterosis as a deviation from the mid-parent were found to be significant and negative for 32 hybrid combinations. The extent of heterosis ranged from -5.93% to 1.72% for the hybrids, Sakha Basmati 12A x EBR1.

Table 2. Estimates of heterosis (%) over mid-parents (MP), better-parents (BP), superiority to standard variety (SV) and Standard hybrid (SH) for studied agronomic characters.

Genotypes	Days to maturity (%)			
	MP	BP	SV	SH
IR58025A x EBR1	0.00	1.32**	1.47**	0.89**
IR58025A x EBR2	-1.73**	-0.52**	-0.20*	-0.77**
IR58025A x EBR3	-5.02**	-3.59**	-3.80**	-4.35**
IR58025A x EBR15	-1.07**	1.74**	-1.04**	-1.61**
IR58025A x EBR16	-0.61**	1.57**	0.02	-0.54**
IR58025A x EBR20	-0.54**	1.07**	0.62**	0.05
IR58025A x EBR25	-0.11	0.39**	2.16**	1.58**
IR58025A x EBR30	-2.23**	0.38**	-2.06**	-2.62**
IR58025A x Giza Basmati201	-2.62**	-1.27**	-1.27**	-1.83**
Sakha Basmati11A x EBR1	-2.54**	-0.62**	-0.47**	-1.04**
Sakha Basmati11A x EBR2	-3.28**	-1.46**	-1.14**	-1.71**
Sakha Basmati11A x EBR3	-2.51**	-0.40**	-0.62**	-1.19**
Sakha Basmati11A x EBR15	-0.33**	3.17**	0.35**	-0.22*
Sakha Basmati11A x EBR16	-3.36**	-0.61**	-2.11**	-2.67**
Sakha Basmati11A x EBR20	-1.65**	0.60**	0.15	-0.42**
Sakha Basmati11A x EBR25	-2.17**	-1.05**	0.70**	0.12
Sakha Basmati11A x EBR30	-1.32**	1.99**	-0.50**	-1.06**
Sakha Basmati11A x Giza Basmati201	0.35**	2.41**	2.41**	1.83**
Sakha Basmati12A x EBR1	-4.48**	-3.57**	-3.43**	-3.98**
Sakha Basmati12A x EBR2	-4.68**	-3.87**	-3.56**	-4.10**
Sakha Basmati12A x EBR3	-5.93**	-4.86**	-5.07**	-5.61**
Sakha Basmati12A x EBR15	-0.95**	1.48**	-1.29**	-1.85**
Sakha Basmati12A x EBR16	-1.55**	0.23*	-1.29**	-1.85**
Sakha Basmati12A x EBR20	-0.54**	0.70**	0.25**	-0.32**
Sakha Basmati12A x EBR25	-0.89**	-0.76**	0.99**	0.42**
Sakha Basmati12A x EBR30	-1.77**	0.48**	-1.96**	-2.52**
Sakha Basmati12A x Giza Basmati201	-0.44**	0.57**	0.57**	0.00

Table 2. Cont.

Genotypes	Days to maturity (%)			
	MP	BP	SV	SH
Sakha Basmati13A x EBR1	-2.92**	-2.21**	-2.06**	-2.62**
Sakha Basmati13A x EBR2	-3.03**	-2.40**	-2.09**	-2.65**
Sakha Basmati13A x EBR3	-4.10**	-3.21**	-3.43**	-3.98**
Sakha Basmati13A x EBR15	-1.19**	1.02**	-1.74**	-2.30**
Sakha Basmati13A x EBR16	0.00	1.59**	0.05	-0.52**
Sakha Basmati13A x EBR20	-0.04	1.00**	0.55**	-0.02
Sakha Basmati13A x EBR25	-0.73**	-0.66**	0.94**	0.37**
Sakha Basmati13A x EBR30	-0.89**	1.17**	-1.29**	-1.85**
Sakha Basmati13A x Giza Basmati201	-0.06	0.75**	0.75**	0.17
Sakha Basmati14A x EBR1	1.72**	2.26**	2.41**	1.83**
Sakha Basmati14A x EBR2	1.28**	1.73**	2.06**	1.48**
Sakha Basmati14A x EBR3	-0.79**	-0.07	-0.30**	-0.87**
Sakha Basmati14A x EBR15	0.16*	2.20**	-0.60**	-1.16**
Sakha Basmati14A x EBR16	0.25**	1.64**	0.10	-0.47**
Sakha Basmati14A x EBR20	0.38**	1.22**	0.77**	0.20*
Sakha Basmati14A x EBR25	-0.42**	-0.54**	1.07**	0.49**
Sakha Basmati14A x EBR30	0.24**	2.12**	-0.37**	-0.94**
Sakha Basmati14A x Giza Basmati201	0.43**	1.04**	1.04**	0.47**
LSD 0.05	0.183	0.243	0.243	0.243
0.01	0.260	0.347	0.347	0.347

Table 2. Cont.

Genotypes	Plant height (%)			
	MP	BP	SV	SH
IR58025A x EBR1	-0.47**	1.33**	-3.65**	0.23
IR58025A x EBR2	-1.99**	1.02**	-3.95**	-0.08
IR58025A x EBR3	2.35**	2.49**	-2.55**	1.38**
IR58025A x EBR15	0.95**	3.42**	-6.26**	-2.48**
IR58025A x EBR16	4.26**	4.64**	-1.22**	2.76**
IR58025A x EBR20	4.61**	4.86**	-0.29	3.72**
IR58025A x EBR25	4.93**	5.91**	0.70**	4.76**
IR58025A x EBR30	3.03**	3.12**	-1.95**	2.00**
IR58025A x Giza Basmati201	0.57**	3.17**	-1.90**	2.05**
Sakha Basmati11A x EBR1	0.85**	2.99**	-2.66**	1.26**
Sakha Basmati11A x EBR2	1.30**	4.74**	-1.01**	2.98**
Sakha Basmati11A x EBR3	1.32**	1.77**	-3.82**	0.06
Sakha Basmati11A x EBR15	0.66**	2.81**	-6.82**	-3.06**
Sakha Basmati11A x EBR16	1.97**	2.03**	-3.69**	0.19
Sakha Basmati11A x EBR20	4.50**	5.07**	-0.70**	3.30**
Sakha Basmati11A x EBR25	4.68**	5.98**	0.17	4.20**
Sakha Basmati11A x EBR30	2.79**	3.20**	-2.46**	1.47**
Sakha Basmati11A x Giza Basmati201	-0.84**	2.04**	-3.56**	0.33
Sakha Basmati12A x EBR1	4.97**	14.87**	-4.79**	-0.95**
Sakha Basmati12A x EBR2	2.49**	13.64**	-5.81**	-2.01**
Sakha Basmati12A x EBR3	2.06**	9.73**	-9.05**	-5.38**
Sakha Basmati12A x EBR15	2.74**	7.54**	-10.86**	-7.27**
Sakha Basmati12A x EBR16	4.82**	12.10**	-7.08**	-3.34**
Sakha Basmati12A x EBR20	6.34**	14.45**	-5.13**	-1.31**
Sakha Basmati12A x EBR25	6.16**	15.11**	-4.59**	-0.74**
Sakha Basmati12A x EBR30	5.22**	13.07**	-6.28**	-2.50**
Sakha Basmati12A x Giza Basmati201	5.12**	15.97**	-3.88**	0.00

Table 2. Cont.

Genotypes	Plant height (%)			
	MP	BP	SV	SH
Sakha Basmati13A x EBR1	4.95**	14.55**	-4.60**	-0.75**
Sakha Basmati13A x EBR2	2.50**	13.35**	-5.59**	-1.79**
Sakha Basmati13A x EBR3	2.16**	9.55**	-8.76**	-5.08**
Sakha Basmati13A x EBR15	2.70**	7.23**	-10.69**	-7.09**
Sakha Basmati13A x EBR16	5.22**	12.24**	-6.52**	-2.75**
Sakha Basmati13A x EBR20	6.61**	14.45**	-4.68**	-0.83**
Sakha Basmati13A x EBR25	6.22**	14.87**	-4.33**	-0.47*
Sakha Basmati13A x EBR30	5.55**	13.14**	-5.77**	-1.97**
Sakha Basmati13A x Giza Basmati201	4.76**	15.28**	-3.99**	-0.12
Sakha Basmati14A x EBR1	-0.04	1.11**	-2.62**	1.31**
Sakha Basmati14A x EBR2	-0.78**	1.59**	-2.15**	1.80**
Sakha Basmati14A x EBR3	0.97**	1.48**	-3.25**	0.66**
Sakha Basmati14A x EBR15	-0.01	3.12**	-6.53**	-2.77**
Sakha Basmati14A x EBR16	0.71**	1.74**	-3.96**	-0.09
Sakha Basmati14A x EBR20	2.06**	2.47**	-2.10**	1.85**
Sakha Basmati14A x EBR25	1.68**	1.97**	-1.79**	2.17**
Sakha Basmati14A x EBR30	0.62**	1.18**	-3.61**	0.27
Sakha Basmati14A x Giza Basmati201	0.39**	2.31**	-1.46**	2.51**
LSD 0.05	0.374	0.498	0.498	0.498
0.01	0.532	0.709	0.709	0.709

Table 2. Cont.

Genotypes	Panicle length%			
	MP	BP	SV	SH
IR58025A x EBR1	11.64**	5.27**	3.04**	-2.22**
IR58025A x EBR2	13.30**	7.39**	3.95**	-1.35**
IR58025A x EBR3	9.90**	3.07**	2.05**	-3.16**
IR58025A x EBR15	8.18**	1.82**	0.04	-5.07**
IR58025A x EBR16	7.33**	4.88**	-9.07**	-13.71**
IR58025A x EBR20	6.44**	-1.16**	-0.04	-5.14**
IR58025A x EBR25	5.12**	4.18**	-8.04**	-12.73**
IR58025A x EBR30	9.45**	4.93**	-9.02**	-13.66**
IR58025A x Giza Basmati201	10.34**	3.00**	3.00**	-2.25**
Sakha Basmati11A x EBR1	0.96**	-4.72**	-6.73**	-11.49**
Sakha Basmati11A x EBR2	2.01**	-3.21**	-6.31**	-11.09**
Sakha Basmati11A x EBR3	4.91**	-1.51**	-2.49**	-7.46**
Sakha Basmati11A x EBR15	6.58**	0.42	-1.34**	-6.38**
Sakha Basmati11A x EBR16	3.97**	1.49**	-11.82**	-16.32**
Sakha Basmati11A x EBR20	4.57**	-2.80**	-1.69**	-6.71**
Sakha Basmati11A x EBR25	4.51**	3.69**	-8.47**	-13.14**
Sakha Basmati11A x EBR30	8.05**	3.48**	-10.09**	-14.67**
Sakha Basmati11A x Giza	4.94**	-1.94**	-1.94**	-6.94**
Sakha Basmati12A x EBR1	5.86**	-0.99**	-3.09**	-8.03**
Sakha Basmati12A x EBR2	5.71**	-0.62*	-3.80**	-8.71**
Sakha Basmati12A x EBR3	10.47**	2.77**	1.75**	-3.44**
Sakha Basmati12A x EBR15	8.61**	1.40**	-0.37	-5.46**
Sakha Basmati12A x EBR16	8.77**	7.20**	-8.65**	-13.31**
Sakha Basmati12A x EBR20	7.81**	-0.67*	0.46	-4.67**
Sakha Basmati12A x EBR25	10.33**	8.42**	-4.30**	-9.18**
Sakha Basmati12A x EBR30	7.67**	4.09**	-11.30**	-15.83**
Sakha Basmati12A x Giza	13.79**	5.38**	5.38**	0.00

Table 2. Cont.

Genotypes	Panicle length%			
	MP	BP	SV	SH
Sakha Basmati13A x EBR1	5.83**	-0.25	-2.36**	-7.34**
Sakha Basmati13A x EBR2	8.01**	2.34**	-0.94**	-5.99**
Sakha Basmati13A x EBR3	6.46**	-0.19	-1.18**	-6.22**
Sakha Basmati13A x EBR15	9.12**	2.68**	0.88**	-4.27**
Sakha Basmati13A x EBR16	7.50**	5.09**	-8.95**	-13.60**
Sakha Basmati13A x EBR20	5.07**	-2.46**	-1.36**	-6.39**
Sakha Basmati13A x EBR25	5.73**	4.75**	-7.54**	-12.26**
Sakha Basmati13A x EBR30	3.33**	-0.90**	-14.14**	-18.52**
Sakha Basmati13A x Giza Basmati201	8.57**	1.32**	1.32**	-3.85**
Sakha Basmati14A x EBR1	14.58**	4.37**	2.16**	-3.05**
Sakha Basmati14A x EBR2	15.79**	6.01**	2.62**	-2.62**
Sakha Basmati14A x EBR3	18.93**	7.78**	6.71**	1.26**
Sakha Basmati14A x EBR15	12.49**	2.30**	0.50	-4.63**
Sakha Basmati14A x EBR16	5.15**	3.69**	-14.20**	-18.58**
Sakha Basmati14A x EBR20	18.77**	6.62**	7.83**	2.33**
Sakha Basmati14A x EBR25	9.93**	5.06**	-7.27**	-12.00**
Sakha Basmati14A x EBR30	9.88**	9.27**	-12.10**	-16.58**
Sakha Basmati14A x Giza Basmati201	16.85**	5.42**	5.42**	0.04
LSD 0.05	0.116	0.155	0.155	0.155
0.01	0.165	0.221	0.221	0.221

Table 2. Cont.

Genotypes	Spikelets/panicle%			
	MP	BP	SV	SH
IR58025A x EBR1	11.15**	10.67*	16.41**	8.51*
IR58025A x EBR2	14.67**	8.51*	13.17**	5.49
IR58025A x EBR3	19.78**	13.70**	18.57**	10.53*
IR58025A x EBR15	16.07**	3.01	38.60**	29.21**
IR58025A x EBR16	15.70**	7.34*	30.84**	21.97**
IR58025A x EBR20	16.75**	10.05*	29.65**	20.85**
IR58025A x EBR25	16.27**	6.74	33.12**	24.10**
IR58025A x EBR30	10.20**	-8.82**	45.23**	35.38**
IR58025A x Giza Basmati201	18.41**	15.98**	20.95**	12.75**
Sakha Basmati11A x EBR1	-1.28	-6.71	-1.88	-8.53*
Sakha Basmati11A x EBR2	23.13**	22.80**	14.93**	7.14
Sakha Basmati11A x EBR3	35.69**	35.62**	27.06**	18.45**
Sakha Basmati11A x EBR15	17.97**	0.02	34.57**	25.45**
Sakha Basmati11A x EBR16	13.98**	0.75	22.81**	14.48**
Sakha Basmati11A x EBR20	13.42**	1.77	19.89**	11.76**
Sakha Basmati11A x EBR25	14.87**	0.54	25.39**	16.89**
Sakha Basmati11A x EBR30	1.74	-19.24**	28.63**	19.91**
Sakha Basmati11A x Giza Basmati201	30.96**	26.76**	26.76**	18.17**
Sakha Basmati12A x EBR1	28.79**	19.10**	25.27**	16.78**
Sakha Basmati12A x EBR2	37.83**	35.08**	25.73**	17.21**
Sakha Basmati12A x EBR3	39.91**	36.67**	28.05**	19.37**
Sakha Basmati12A x EBR15	18.39**	-1.49	32.54**	23.55**
Sakha Basmati12A x EBR16	17.02**	1.41	23.61**	15.23**
Sakha Basmati12A x EBR20	14.42**	0.60	18.52**	10.48*
Sakha Basmati12A x EBR25	17.64**	0.96	25.91**	17.38**
Sakha Basmati12A x EBR30	10.76**	-13.55**	37.69**	28.36**
Sakha Basmati12A x Giza Basmati201	13.30**	7.27	7.27	0.00

Table 2. Cont.

Genotypes	Spikelets/panicle%			
	MP	BP	SV	SH
Sakha Basmati13A x EBR1	15.22**	4.89	10.33*	2.84
Sakha Basmati13A x EBR2	42.08**	36.92**	27.44**	18.80**
Sakha Basmati13A x EBR3	41.29**	35.73**	27.17**	18.55**
Sakha Basmati13A x EBR15	19.40**	-2.00	31.86**	22.92**
Sakha Basmati13A x EBR16	13.87**	-2.75	18.55**	10.51*
Sakha Basmati13A x EBR20	9.27**	-5.33	11.53*	3.97
Sakha Basmati13A x EBR25	23.33**	4.35	30.14**	21.32**
Sakha Basmati13A x EBR30	16.96**	-9.83**	43.62**	33.88**
Sakha Basmati13A x Giza Basmati201	20.54**	12.30*	12.30*	4.68
Sakha Basmati14A x EBR1	26.10**	9.09*	14.74**	6.96
Sakha Basmati14A x EBR2	33.17**	21.52**	13.12**	5.45
Sakha Basmati14A x EBR3	32.17**	20.26**	12.67**	5.03
Sakha Basmati14A x EBR15	13.74**	-10.67**	20.20**	12.05**
Sakha Basmati14A x EBR16	14.35**	-6.80	13.61**	5.91
Sakha Basmati14A x EBR20	11.70**	-7.74*	8.69	1.32
Sakha Basmati14A x EBR25	15.01**	-7.08*	15.88**	8.02
Sakha Basmati14A x EBR30	14.18**	-15.38**	34.77**	25.63**
Sakha Basmati14A x Giza Basmati201	31.04**	15.84**	15.84**	7.99
LSD 0.05	13.945	18.593	18.593	18.593
0.01	19.859	26.478	26.478	26.478

***, ** significant at 0.05 and 0.01 levels of probability, respectively.**

However, the negative and significant estimates ranged from -0.593 to -0.42%. It could be noticed that the highest negative estimates were obtained by the hybrids Sakha Basmati 12A x EBR3 (-5.93%), IR5805A x EBR3 (-5.02%) and Sakha Basmati12A x EBR2 (-4.68%). Seventeen hybrids were identified as early maturing and showed significant and negative over the better parent heterosis. The magnitude of BP heterosis observed ranged from -4.86 to 3.17%. negative and significant estimates ranged from -4.86% for the hybrids, Sakha Basmati 12A x EBR3 and Sakha Basmati 11A x EBR3, respectively.

The superiority over standard basmati variety, Giza Basmati 201 and standard basmati hybrid (EBHR1) was significant or highly significant in 24 and 30 hybrid combinations, respectively. The magnitude of superiority over standard inbred or hybrid variety ranged from -5.07% and -5.61% for the same above-mentioned basmati hybrid Sakha Basmati 12A x EBR3 to -0.20% and -0.22 for the hybrids, IR58025A x EBR2 and Sakha Basmati 11A x EBR15, respectively.

The best five superior hybrids having, mid-parents heterosis, heterobeltiosis, superiority over standard variety and hybrid (SV) were Sakha Basmati 12A x EBR3, IR58025A x EBR3, Sakha Basmati 12A x EBR2, Sakha Basmati 12A x EBR1 and Sakha Basmati 13A x EBR3. Heterosis in both negative and positive directions for days to maturity have also been reported by El-Mowafi (2001b), El-Mowafi *et al* (2005), Neelam *et al* (2009), Priyanaka *et al* (2014) and Mahrous (2022)

Plant height

Semi-dwarf plant height (90-110) is desirable for recording new plant type and high yield in rice variety as vigor in plant height may lead to unfavorable grain straw ratios and low grain yield due to lodging. The results in Table (1 and 3) indicated that estimates of heterosis as a deviation from the mid-parents were found to be highly significant and positive for 42 hybrids ranging from -1.99 to 6.61%. Estimates of mid-parent heterosis were found to be highly significant and negative for four hybrids. The highest negative estimates were recorded for the hybrids, IR58025A x EBR2 (-1.99%), Sakha Basmati 11A x Giza Basmati 201 (-0.84%), Sakha Basmati 14A x EBR2 and IR58025A x EBR1 (-0.47%).

For the heterosis over the better parent, for all the 45 basmati hybrid rice combinations was highly significant and positive. Such estimates ranged from 1.02% for the hybrid IR58025A x EBR2 to 15.97% for the hybrid Sakha Basmati 12A x Giza Basmati 201. Data in Table (1) reveals that most of hybrid combinations (42) exhibit desirable negative and highly significant superiority over the standard variety check Giza Basmati 201 towards shortness estimates. Estimates of superiority over hybrid check EBHR11 showed that 19 hybrids were significant and negative for plant height trait. the most promising basmati hybrid combination for short stature plant were Sakha Basmati 12A x EBR15, Sakha Basmati 13A x EBR 15, Sakha Basmati 12A x EBR3, Sakha Basmati 13A x EBR3 and Sakha Basmati 12A x EBR16. The present observations are in close agreement with El- Mowafi (2001b), El-Mowafi *et al* (2005), Abdallah (2008), El-Mowafi *et al* (2018) and El-Mowafi *et al* (2021).

Panicle length

In general, longer panicle is associated with high number of filled grains panicle^{-1} resulting higher grains yield. However, hybrid rice combinations with positive heterosis for panicle length are desirable. All 45 hybrids tested showed highly significant and positive and higher panicle length over the mid-parents heterosis and ranged from 0.96% for Sakha Basmati 11A x EBR1 to 18.93% for Sakha Basmati 14A x EBR3. The results in Tables (1 and 3) revealed that heterosis over better-parent (heterobeltiosis) was positive and highly significant (desirable) for 30 basmati hybrid combinations. The highest estimated values were detected for the hybrids, Sakha Basmati 14A x Giza Basmati 201 (9.27%), Sakha Basmati 12A x EBR25 (8.42%) and Sakha Basmati 12A x EBR 3 (7.78%).

Tables (1 and 3) revealed that out of 45 hybrids only 13 basmati hybrid combinations showed significant and positive superiority (SV%) over basmati check variety Giza Basmati 201 for the longest panicle length. The highest values were recorded for the hybrids, Sakha Basmati14A x EBR 20 (7.83%), Sakha Basmati14A x EBR 3 (6.70%), Sakha Basmati14A x Giza Basmati 201 (5.42%) and Sakha Basmati 12A x Giza Basmati 201 (5.38%). Only two hybrid rice combinations namely Sakha Basmati 14A x EBR20 (2.33%) and Sakha Basmati 14A x EBR3 (1.26%) recorded highly significant superiority (SH%) over the hybrid check EBHR11 for panicle length trait. On the other hand, 41 hybrids showed highly significant and negative superiority over the hybrid check EBHR11. El-Mowafi (2001), El-Mowafi and Abou-Shousha (2003), El-Mowafi *et al* (2005), Abdallah (2008), El-Mowafi *et al* (2021) reported positive as well as negative heterosis and superiority over mid-parents, better –parent and superiority over check variety for panicle length trait.

Spikelets panicle^{-1}

The results in Tables (1 and 3) indicated that heterosis over mid-parents was significant and positive (desirable) for 43 hybrid combinations. The highest estimated values for spikelets panicle^{-1} were detected for the hybrids Sakha Basmati 13A x EBR2 (42.08%), Sakha Basmati 13A x EBR3 (41.29%), Sakha Basmati 12A x EBR3 (39.91%), Sakha Basmati 12A x EBR2 (37.83%) and Sakha Basmati 11A x EBR3 (35.68%). However highly significant and significant and positive heterosis was observed for 19 basmati hybrid combinations out of 45 deviation from the better-parent (BP) values. The results also indicated that the highest heterotic effects over the BP were exhibited for the same combinations mentioned above with values of 36.92%, 35.73%, 36.67%, 35.08% and 35.62%, respectively. The estimates of positive superiority (SV%) over the best check variety Giza Basmati 201 were significant in 43 combinations for spikelets panicle^{-1}. The highest estimates of superiority (SV%) over the check Giza Basmati 201 were recorded for the basmati hybrid rice combinations, IR58025A x EBR30 (45.23%), Sakha Basmati 13A x EBR30(43.62%), IR58.025A x EBR15 (38.60%) and Sakha Basmati 12A x EBR30 (37.69%).

On the basis of superiority over basmati hybrid EBHR11, 31 hybrids had positive and significant or highly significant estimates. The highest estimates were detected for the hybrids, IR58025A x EBR30 (35.38%), Sakha Basmati 13A x EBR30 (33.88%) and IR58025A x EBR15 (29.21%). These results are in accordance with those reported by Abdelkhalik (2015), El-Mowafi *et al* (2018) and El-Mowafi *et al* (2021).

Panicle plant^{-1}

The results in Tables (2 and 3) indicated that significant and positive (desirable) heterosis over mid –parent (MP) were detected for 43 out of 45 hybrid combinations tested and ranged from 4.98 to 4.35% for the hybrids IR58025A x EBR10 and Sakha Basmati 12A x EBR3, respectively. In case of better-parent heterosis, the data showed that 27 hybrid rice combinations recorded significant and highly significant values. The highest value was 28.23% for the hybrid Sakha Basmati 12A x EBR3 but the lowest value was recorded for the hybrid IR58025A x EBR3 with value of 6.37%.

Table 3. Estimates of (%) heterosis over mid-parents (MP), better-parents (BP), and superiority to standard variety (SV) and Standard hybrid (SH) for yield and its component studied characters.

Genotypes	Panicles plant^{-1} (%)			
	MP	BP	SV	SH
IR58025A x EBR1	7.38**	5.05	-7.03**	-15.01**
IR58025A x EBR2	2.79	2.36	-12.60**	-20.11**
IR58025A x EBR3	9.01**	6.37	-5.36*	-13.48**
IR58025A x EBR15	4.98*	3.53	-9.87**	-17.61**
IR58025A x EBR16	7.10**	6.77	-9.05**	-16.86**
IR58025A x EBR20	5.76*	5.15	-10.98**	-18.62**
IR58025A x EBR25	27.02**	22.10	3.37	-5.50*
IR58025A x EBR30	15.13**	8.92	3.37	-5.50*
IR58025A x Giza Basmati201	-0.62	-8.24	-8.24**	-16.12**
Sakha Basmati11A x EBR1	37.24**	21.26	7.32**	-1.89
Sakha Basmati11A x EBR2	14.15**	2.46	-12.51**	-20.03**
Sakha Basmati11A x EBR3	7.04**	-5.64	-16.04**	-23.25**
Sakha Basmati11A x EBR15	15.38**	2.68	-10.61**	-18.28**
Sakha Basmati11A x EBR16	16.97**	5.11	-10.47**	-18.16**
Sakha Basmati11A x EBR20	33.35**	20.77	1.07	-7.61**
Sakha Basmati11A x EBR25	16.49**	8.88	-14.96**	-22.26**
Sakha Basmati11A x EBR30	34.65**	15.49**	9.62**	0.20
Sakha Basmati11A x Giza Basmati201	10.22**	-7.47**	-7.47**	-15.42**
Sakha Basmati12A x EBR1	28.81**	17.97**	4.41	-4.56*
Sakha Basmati12A x EBR2	21.81**	13.41**	-3.17	-11.48**
Sakha Basmati12A x EBR3	40.35**	28.23**	14.10**	4.30*
Sakha Basmati12A x EBR15	7.23**	-1.05	-13.86**	-21.26**
Sakha Basmati12A x EBR16	10.25**	2.76	-12.47**	-19.99**
Sakha Basmati12A x EBR20	32.78**	24.78**	4.42	-4.54*
Sakha Basmati12A x EBR25	18.16**	14.75**	-10.37**	-18.07**
Sakha Basmati12A x EBR30	10.24**	-2.14	-7.12**	-15.09**
Sakha Basmati12A x Giza Basmati201	26.02**	9.39**	9.39**	0.00

Table 3. Cont.

Genotypes	Panicles plant^{-1} (%)			
	MP	BP	SV	SH
Sakha Basmati13A x EBR1	33.72**	23.02**	8.88**	-0.47
Sakha Basmati13A x EBR2	30.93**	22.45**	4.56*	-4.42*
Sakha Basmati13A x EBR3	25.07**	14.78**	2.13	-6.64**
Sakha Basmati13A x EBR15	17.64**	9.04**	-5.07*	-13.23**
Sakha Basmati13A x EBR16	25.94**	17.92**	0.44	-8.18**
Sakha Basmati13A x EBR20	22.07**	15.26**	-3.55	-11.83**
Sakha Basmati13A x EBR25	17.38**	14.55**	-10.53**	-18.22**
Sakha Basmati13A x EBR30	29.18**	15.18**	9.32**	-0.07
Sakha Basmati13A x Giza Basmati201	33.58**	16.43**	16.43**	6.44**
Sakha Basmati14A x EBR1	5.93*	-3.81	-14.87**	-22.18**
Sakha Basmati14A x EBR2	16.13**	7.19*	-8.48**	-16.34**
Sakha Basmati14A x EBR3	9.43**	-0.86	-11.79**	-19.36**
Sakha Basmati14A x EBR15	12.50**	2.92	-10.40**	-18.09**
Sakha Basmati14A x EBR16	18.47**	9.47**	-6.76**	-14.77**
Sakha Basmati14A x EBR20	16.47**	8.50**	-9.20**	-17.00**
Sakha Basmati14A x EBR25	9.20**	5.09	-17.91**	-24.96**
Sakha Basmati14A x EBR30	26.14**	11.07**	5.41*	-3.64
Sakha Basmati14A x Giza Basmati201	8.80**	-6.30*	-6.30*	-14.35**
LSD 0.05	0.819	1.092	1.092	1.092
0.01	1.167	1.556	1.556	1.556

Table 3. Cont.

Genotypes	Filled grains panicle^{-1} (%)			
	MP	BP	SV	SH
IR58025A x EBR1	11.60**	9.49**	15.20**	6.19**
IR58025A x EBR2	14.93**	12.38**	13.77**	4.87**
IR58025A x EBR3	18.58**	16.86**	18.30**	9.05**
IR58025A x EBR15	16.00**	-0.78	41.33**	30.27**
IR58025A x EBR16	13.30**	0.73	31.05**	20.80**
IR58025A x EBR20	13.58**	1.84*	29.97**	19.81**
IR58025A x EBR25	16.00**	4.12**	32.56**	22.19**
IR58025A x EBR30	9.98**	-10.83**	45.24**	33.88**
IR58025A x Giza Basmati201	17.85**	17.13**	18.57**	9.30**
Sakha Basmati11A x EBR1	-1.96**	-6.74**	-1.88*	-9.56**
Sakha Basmati11A x EBR2	18.82**	17.71**	13.89**	4.98**
Sakha Basmati11A x EBR3	28.68**	26.48**	24.34**	14.61**
Sakha Basmati11A x EBR15	14.91**	-4.24**	36.39**	25.72**
Sakha Basmati11A x EBR16	6.84**	-7.59**	20.22**	10.82**
Sakha Basmati11A x EBR20	8.70**	-5.22**	20.97**	11.51**
Sakha Basmati11A x EBR25	14.27**	-0.26	26.99**	17.05**
Sakha Basmati11A x EBR30	1.28*	-19.84**	30.57**	20.35**
Sakha Basmati11A x Giza Basmati201	33.31**	29.94**	29.94**	19.77**
Sakha Basmati12A x EBR1	25.58**	16.58**	22.66**	13.07**
Sakha Basmati12A x EBR2	28.10**	23.72**	19.70**	10.34**
Sakha Basmati12A x EBR3	33.69**	28.14**	25.96**	16.11**
Sakha Basmati12A x EBR15	19.72**	-2.26**	39.21**	28.32**
Sakha Basmati12A x EBR16	16.74**	-1.19	28.55**	18.50**
Sakha Basmati12A x EBR20	11.41**	-4.95**	21.31**	11.82**
Sakha Basmati12A x EBR25	21.14**	3.46**	31.72**	21.41**
Sakha Basmati12A x EBR30	12.21**	-12.84**	41.97**	30.86**
Sakha Basmati12A x Giza Basmati201	14.11**	8.49**	8.49**	0.00

Table 3. Cont.

Genotypes	Filled grains panicle^{-1} (%)			
	MP	BP	SV	SH
Sakha Basmati13A x EBR1	13.21**	4.35**	9.79**	1.20
Sakha Basmati13A x EBR2	28.32**	23.00**	19.00**	9.69
Sakha Basmati13A x EBR3	32.77**	26.31**	24.17**	14.45
Sakha Basmati13A x EBR15	15.12**	-6.58**	33.05**	22.64
Sakha Basmati13A x EBR16	8.81**	-8.49**	19.06**	9.74
Sakha Basmati13A x EBR20	2.36**	-13.24**	10.74**	2.08*
Sakha Basmati13A x EBR25	20.49**	2.24**	30.16**	19.98**
Sakha Basmati13A x EBR30	11.23**	-14.09**	39.93**	28.99**
Sakha Basmati13A x Giza Basmati201	16.57**	10.00**	10.00**	1.39
Sakha Basmati14A x EBR1	26.21**	9.86**	15.59**	6.55**
Sakha Basmati14A x EBR2	33.86**	20.86**	16.93**	7.79**
Sakha Basmati14A x EBR3	32.49**	18.78**	16.77**	7.63**
Sakha Basmati14A x EBR15	15.17**	-10.89**	26.92**	16.99**
Sakha Basmati14A x EBR16	16.44**	-6.89**	21.13**	11.65**
Sakha Basmati14A x EBR20	13.34**	-8.71**	16.51**	7.40**
Sakha Basmati14A x EBR25	21.20**	-2.29**	24.40**	14.67**
Sakha Basmati14A x EBR30	15.87**	-14.33**	39.54**	28.62**
Sakha Basmati14A x Giza Basmati201	37.06**	21.96**	21.96**	12.42**
LSD 0.05	2.615	3.486	3.486	3.486
0.01	3.723	4.964	4.964	4.964

Table 3. Cont.

Genotypes	Spikelets fertility %			
	MP	BP	SV	SH
IR58025A x EBR1	0.39	-1.12	-1.05	-2.13
IR58025A x EBR2	0.00	-3.33	0.52	-0.58
IR58025A x EBR3	-1.22	-4.92**	-0.24	-1.33
IR58025A x EBR15	0.49	-3.68*	1.95	0.83
IR58025A x EBR16	-1.71	-6.15**	0.15	-0.95
IR58025A x EBR20	-2.39	-7.47**	0.24	-0.86
IR58025A x EBR25	-0.01	-2.48	-0.44	-1.53
IR58025A x EBR30	0.35	-2.20	0.01	-1.09
IR58025A x Giza Basmati201	-0.51	-1.98	-1.98	-3.05
Sakha Basmati11A x EBR1	-0.76	-1.44	-0.02	-1.11
Sakha Basmati11A x EBR2	-3.53*	-4.71*	-0.92	-2.01
Sakha Basmati11A x EBR3	-5.18**	-6.75**	-2.16	-3.23
Sakha Basmati11A x EBR15	-2.22	-4.26*	1.34	0.23
Sakha Basmati11A x EBR16	-5.95**	-8.27**	-2.12	-3.19
Sakha Basmati11A x EBR20	-3.81**	-6.87**	0.89	-0.21
Sakha Basmati11A x EBR25	-0.50	-0.81	1.26	0.15
Sakha Basmati11A x EBR30	-0.35	-0.74	1.49	0.38
Sakha Basmati11A x Giza Basmati201	1.76	1.04	2.50	1.38
Sakha Basmati12A x EBR1	-2.65*	-3.13	-2.10	-3.17
Sakha Basmati12A x EBR2	-7.14**	-8.44**	-4.80*	-5.84**
Sakha Basmati12A x EBR3	-4.50**	-6.26**	-1.64	-2.72
Sakha Basmati12A x EBR15	1.51	-0.78	5.02*	3.87*
Sakha Basmati12A x EBR16	0.09	-2.56	3.98*	2.85
Sakha Basmati12A x EBR20	-2.25	-5.53**	2.34	1.22
Sakha Basmati12A x EBR25	2.97*	2.45	4.59*	3.45
Sakha Basmati12A x EBR30	1.41	0.82	3.09	1.96
Sakha Basmati12A x Giza Basmati201	0.57	0.04	1.11	0.00

Table 3. Cont.

Genotypes	Spikelets fertility%			
	MP	BP	SV	SH
Sakha Basmati13A x EBR1	-1.97	-3.32	-0.51	-1.59
Sakha Basmati13A x EBR2	-9.35**	-9.81**	-6.23**	-7.25**
Sakha Basmati13A x EBR3	-6.06**	-6.96**	-2.38	-3.45
Sakha Basmati13A x EBR15	-3.34*	-4.68*	0.89	-0.22
Sakha Basmati13A x EBR16	-4.17**	-5.88**	0.44	-0.66
Sakha Basmati13A x EBR20	-5.99**	-8.34**	-0.71	-1.80
Sakha Basmati13A x EBR25	-2.44	-2.83	0.00	-1.09
Sakha Basmati13A x EBR30	-5.04**	-5.34**	-2.58	-3.65*
Sakha Basmati13A x Giza Basmati201	-3.45*	-4.81*	-2.04	-3.11
Sakha Basmati14A x EBR1	-0.04	-0.74	0.74	-0.36
Sakha Basmati14A x EBR2	0.61	-0.59	3.36	2.23
Sakha Basmati14A x EBR3	0.40	-1.24	3.62	2.48
Sakha Basmati14A x EBR15	1.84	-0.25	5.58**	4.42*
Sakha Basmati14A x EBR16	2.41	-0.09	6.61**	5.44**
Sakha Basmati14A x EBR20	2.16	-1.06	7.18**	6.01**
Sakha Basmati14A x EBR25	5.45**	5.14**	7.34**	6.17**
Sakha Basmati14A x EBR30	1.61	1.24	3.52	2.39
Sakha Basmati14A x Giza Basmati201	4.49**	3.72	5.27**	4.12*
LSD 0.05	2.423	3.230	3.230	3.230
0.01	3.450	4.600	4.600	4.600

Table 3. Cont.

Genotypes	1000 grain weight (%)			
	MP	BP	SV	SH
IR58025A x EBR1	2.28**	-7.64**	-10.92**	-5.82**
IR58025A x EBR2	1.92**	-7.95**	-11.27**	-6.19**
IR58025A x EBR3	2.36**	-8.89**	-9.22**	-4.03**
IR58025A x EBR15	6.60**	4.23**	-15.20**	-10.34**
IR58025A x EBR16	9.61**	6.18**	-11.96**	-6.92**
IR58025A x EBR20	8.17**	1.51**	-10.00**	-4.85**
IR58025A x EBR25	8.37**	4.20**	-12.25**	-7.22**
IR58025A x EBR30	14.89**	13.57**	-11.71**	-6.66**
IR58025A x Giza Basmati201	6.52**	-5.34**	-5.34**	0.08
Sakha Basmati11A x EBR1	6.84**	-3.29**	-6.72**	-1.38**
Sakha Basmati11A x EBR2	5.71**	-4.29**	-7.74**	-2.46**
Sakha Basmati11A x EBR3	3.55**	-7.60**	-7.94**	-2.67**
Sakha Basmati11A x EBR15	13.70**	11.47**	-9.30**	-4.11**
Sakha Basmati11A x EBR16	12.48**	9.26**	-9.40**	-4.21**
Sakha Basmati11A x EBR20	8.91**	2.47**	-9.16**	-3.95**
Sakha Basmati11A x EBR25	7.13**	3.29**	-13.02**	-8.04**
Sakha Basmati11A x EBR30	14.15**	15.82**	-12.04**	-7.00**
Sakha Basmati11A x Giza Basmati201	5.63**	-5.90**	-5.90**	-0.51**
Sakha Basmati12A x EBR1	3.04**	-4.32**	-7.72**	-2.43**
Sakha Basmati12A x EBR2	3.32**	-4.03**	-7.49**	-2.20**
Sakha Basmati12A x EBR3	3.74**	-5.09**	-5.44**	-0.02
Sakha Basmati12A x EBR15	12.14**	11.25**	-8.03**	-2.76**
Sakha Basmati12A x EBR16	10.05**	9.88**	-8.89**	-3.67**
Sakha Basmati12A x EBR20	7.33**	3.70**	-8.06**	-2.80**
Sakha Basmati12A x EBR25	7.92**	6.93**	-9.95**	-4.79**
Sakha Basmati12A x EBR30	13.02**	8.43**	-10.36**	-5.23**
Sakha Basmati12A x Giza Basmati201	3.56**	-5.42**	-5.42**	0.00

Table 3. Cont.

Genotypes	1000 grain weight (%)			
	MP	BP	SV	SH
Sakha Basmati13A x EBR1	4.14**	-3.42**	-6.84**	-1.51**
Sakha Basmati13A x EBR2	3.83**	-3.67**	-7.15**	-1.83**
Sakha Basmati13A x EBR3	3.95**	-5.01**	-5.36**	0.06
Sakha Basmati13A x EBR15	12.58**	11.83**	-7.78**	-2.50**
Sakha Basmati13A x EBR16	10.80**	10.49**	-8.39**	-3.14**
Sakha Basmati13A x EBR20	7.41**	3.65**	-8.11**	-2.85**
Sakha Basmati13A x EBR25	8.09**	6.96**	-9.93**	-4.77**
Sakha Basmati13A x EBR30	13.44**	8.96**	-10.15**	-5.01**
Sakha Basmati13A x Giza Basmati201	7.56**	-1.88**	-1.88**	3.74**
Sakha Basmati14A x EBR1	0.51**	-8.00**	-11.27**	-6.19**
Sakha Basmati14A x EBR2	0.27*	-8.20**	-11.51**	-6.45**
Sakha Basmati14A x EBR3	3.47**	-6.67**	-7.01**	-1.69**
Sakha Basmati14A x EBR15	9.69**	8.85**	-11.43**	-6.36**
Sakha Basmati14A x EBR16	9.92**	8.07**	-10.40**	-5.27**
Sakha Basmati14A x EBR20	8.44**	3.21**	-8.50**	-3.26**
Sakha Basmati14A x EBR25	7.11**	4.51**	-11.99**	-6.95**
Sakha Basmati14A x EBR30	13.50**	10.55**	-11.43**	-6.36**
Sakha Basmati14A x Giza Basmati201	3.39**	-6.89**	-6.89**	-1.56**
LSD 0.05	0.054	0.072	0.072	0.072
0.01	0.077	0.102	0.102	0.102

Table 3. Cont.

Genotypes	Grain Yield t ha^{-1} (%)			
	MP	BP	SV	SH
IR58025A x EBR1	34.41**	19.79**	14.28**	-11.13**
IR58025A x EBR2	35.42**	20.98**	14.81**	-10.72**
IR58025A x EBR3	35.92**	19.59**	17.51**	-8.61**
IR58025A x EBR15	37.44**	19.73**	20.40**	-6.36**
IR58025A x EBR16	36.53**	18.97**	19.56**	-7.01**
IR58025A x EBR20	35.67**	17.76**	19.44**	-7.11**
IR58025A x EBR25	39.10**	21.62**	21.28**	-5.68**
IR58025A x EBR30	39.52**	21.31**	22.55**	-4.69**
IR58025A x Giza Basmati201	41.44**	23.51**	23.51**	-3.94**
Sakha Basmati11A x EBR1	51.57**	27.16**	21.31**	-5.66**
Sakha Basmati11A x EBR2	53.88**	29.37**	22.77**	-4.52**
Sakha Basmati11A x EBR3	54.94**	28.46**	26.22**	-1.84**
Sakha Basmati11A x EBR15	50.34**	23.51**	24.20**	-3.41**
Sakha Basmati11A x EBR16	48.44**	21.97**	22.58**	-4.67**
Sakha Basmati11A x EBR20	50.64**	23.34**	25.10**	-2.71**
Sakha Basmati11A x EBR25	54.78**	27.57**	27.22**	-1.06**
Sakha Basmati11A x EBR30	55.02**	27.12**	28.43**	-0.12*
Sakha Basmati11A x Giza Basmati201	56.40**	28.77**	28.77**	0.15*
Sakha Basmati12A x EBR1	47.27**	33.88**	27.71**	-0.68**
Sakha Basmati12A x EBR2	47.73**	34.61**	27.74**	-0.65**
Sakha Basmati12A x EBR3	45.87**	30.86**	28.58**	0.00
Sakha Basmati12A x EBR15	36.68**	21.37**	22.05**	-5.08**
Sakha Basmati12A x EBR16	41.88**	26.03**	26.66**	-1.50**
Sakha Basmati12A x EBR20	42.25**	25.85**	27.65**	-0.73*
Sakha Basmati12A x EBR25	45.62**	29.79**	29.42**	0.65**
Sakha Basmati12A x EBR30	44.66**	28.20**	29.52**	0.73**
Sakha Basmati12A x Giza Basmati201	44.44**	28.58**	28.58**	0.00

Table 3. Cont.

Genotypes	Grain yield t ha^{-1} (%)			
	MP	BP	SV	SH
Sakha Basmati13A x EBR1	47.05**	34.01**	27.84**	-0.58**
Sakha Basmati13A x EBR2	48.26**	35.43**	28.52**	-0.05
Sakha Basmati13A x EBR3	45.72**	31.05**	28.77**	0.15*
Sakha Basmati13A x EBR15	40.76**	25.30**	26.00**	-2.01**
Sakha Basmati13A x EBR16	39.07**	23.83**	24.45**	-3.22**
Sakha Basmati13A x EBR20	40.53**	24.62**	26.41**	-1.69**
Sakha Basmati13A x EBR25	43.34**	28.07**	27.71**	-0.68**
Sakha Basmati13A x EBR30	44.65**	28.51**	29.83**	0.97**
Sakha Basmati13A x Giza Basmati201	46.18**	30.45**	30.45**	1.45**
Sakha Basmati14A x EBR1	58.47**	34.01**	27.84**	-0.58**
Sakha Basmati14A x EBR2	58.77**	34.55**	27.68**	-0.70**
Sakha Basmati14A x EBR3	56.17**	30.48**	28.21**	-0.29**
Sakha Basmati14A x EBR15	50.64**	24.71**	25.41**	-2.47**
Sakha Basmati14A x EBR16	50.36**	24.51**	25.13**	-2.69**
Sakha Basmati14A x EBR20	51.79**	25.24**	27.03**	-1.21**
Sakha Basmati14A x EBR25	55.39**	29.07**	28.71**	0.10
Sakha Basmati14A x EBR30	55.37**	28.39**	29.70**	0.87**
Sakha Basmati14A x Giza Basmati201	55.80**	29.27**	29.27**	0.53**
LSD 0.05	0.014	0.019	0.019	0.019
0.01	0.020	0.027	0.027	0.027

***, ** significant at 0.05 and 0.01 levels of probability, respectively.**

Tables (2 and 3) revealed that 8 and 2 hybrids showed superiority over check variety Giza Basmati 201 and EBHR 11, respectively for panicles plant. The highest values were estimated for the hybrids Sakha Basmati 13A x Giza Basmati 201 and Sakha Basmati 12A x EBR 16.

The results in Tables (2 and 3) revealed that the presence of significant highly significant and positive estimates of MP heterosis of 44 basmati hybrid rice combinations and ranged from 1.28 to 37.01%. The highest estimates values were 37.06%, 33.86% and 33.69 for the hybrids, Sakha Basmati 14A x Giza Basmati 201, Sakha Basmati 14A x EBR2 and Sakha Basmati 12A x EBR3, respectively. As many as 23 hybrids out of 45 showed significant or highly significant and positive heterosis over BP and ranged from 1.84% to 29.94% for the basmati hybrids, IR58025A x EBR20 and Sakha Basmati 11A x Giza Basmati 201, respectively. Data in Table (2) showed that 44 and 42 hybrids exhibited significantly and positive superiority over the inbred check variety Giza Basmati 201 and the hybrid check EBHR11, respectively. The best basmati hybrids with highest superiority values over the inbred and hybrid checks were IR58025A x EBR30 (45.24 and 33.88%), Sakha Basmati 12A x EBR30 (41.97% and 30.86%) and IR58025A x EBR15 (41.33% and 30.27%), respectively. These findings are in agreement with Annadurai and Nadarajan (2001), El-Mowafi and Abou-Shousha (2003) Biswash and Haque (2015), El-Mowafi *et al* (2018) and Mahrouse (2022).

Spikelet fertility percentage

The results in Tables (2 and 3) indicated that the presence of significant or highly significant and positive estimates of heterosis over the mid-parents for only three hybrids out of 45 hybrid combinations. The three highest estimated values of heterosis over MP for spikelet fertility% were observed for the hybrids, Sakha Basmati 14A x EBR25 (5.45%), Sakha Basmati 14A x Giza Basmati 201 (4.49%) and Sakha Basmati 12A x EBR25 (2.98%).

Significant and positive heterosis over the BP (heterobeltiosis) was observed only in one hybrid, Sakha basmati 14A x EBR25 with value of 5.14%.

Eight and five hybrid combinations showed significant and positive estimates of superiority over the inbred and hybrid basmati checks, Giza Basmati 201 and EBHR11, respectively. The hybrids, Sakha Basmati 14A x EBR25 (7.34% and 6.17%), Sakha Basmati 14A x EBR20 (7.18% and 6.01%) and Sakha Basmati 14A x EBR16 (6.61% and 5.44%) had the highest superiority over the best check variety and hybrid, respectively. the report of Abdelkhalik (2015), El-Mowafi *et al* (2018), Kumar *et al* (2012), Priyanka *et al* (2014), and El-Mowafi *et al* (2021) also revealed high level of negative and positive heterosis of spikelet fertility% trait.

1000-grain weight (g)

For 1000-grain weight Tables (2 and 3) revealed significant and positive heterosis as deviation from the mid-parents for all 45 hybrid combinations tested. The estimates ranged from 0.27% in Sakha Basmati 14A x EBR2 to 14.89% for the hybrid IR58025A x EBR30. Moreover heterosis as deviation from better-parent value was highly significant and positive for 25 out of 45 hybrid combinations and ranged from 1.55% for IR58025A x EBR20 to 15.82% for Sakha Basmati 11A x EBR30. Evaluation based on the superiority revealed that all 45 and 41 hybrids recorded negative and highly significant superiority over Giza Basmati 201 and EBHR11, respectively. Only the hybrid combination Sakha Basmati 14A x Giza Basmati 201 (3.74%) showed the highest with highly significant and positive superiority over the hybrid check variety EBHR 11.El-Mowafi *et al* (2005), Vennila *et al* (2011), Veeresha *et al* (2015) and El-Mowafi *et al* (2021)were in agreement with the findings.

Grain yield t ha^{-1}

For grain yield t ha^{-1}, the calculated values of heterosis versus the better-parent, mid-parents and superiority over the check variety and hybrid are presented in Tables (2 and 3). The results revealed highly significant and positive (desirable) mid-parent heterosis (MP), heterobeltiosis (BP) and superiority over standard variety Giza Basmati 201 (SV) for all evaluated 45 F_1 basmatic hybrid rice combinations. The ranges of heterosis and superiority for grain yield (t/ha) were 34.41 to 58.77% for mid parent heterosis, 17.76 to 35.43% for better-parent and 14.28 to 30.45% for superiority over the standard variety Giza Basmati 201 (SV).

Significant and positive superiority (desirable) over the hybrid check EBHR11 was detected for only seven hybrid combinations and ranged from 0.15 to 1.45%. The best basmati hybrid rice combinations identified were Sakha Basmati 13A x Giza basmati 201, Sakha Basmati 13A x EBR30, Sakha Basmati 14A x EBR30, Sakha Basmati 12A x EBR30, Sakha Basmati 12A x EBR25, Sakha Basmati 14A x Giza Basmati 201 and Sakha Basmati 13A x EBR3, No single hybrid rice combination indicated heterotic response for all the traits. However, the female parents Sakha Basmati 12A, Sakha Basmati 13A and IR58025A were involved as more one of the parents in at least three hybrid combinations which exhibited significant and high magnitude of heterotic effect for most the traits studied. This indicated that Sakha Basmati 12A, Sakha Basmati 13A and IR58025A can be used as one of the parents to get high heterotic hybrids. The hybrid combination Sakha Basmati 13A x Giza Basmati 201 showed high heterotic response with respect to panicles plant^{-1}, 1000-grain and grain yield t/ha^{-1} the basmati hybrid combination, Sakha Basmati 13A x EBR30 was found to be highly heterotic followed by Sakha Basmati 14A x EBR30 for grain yield t/ha^{-1}. It is interesting here to note that in all the best three hybrids, Giza Basmati 201 and EBR30 were the common parents, because of the fact that, they were very good general combiners (Table 4).

Table 4. Heterosis, heterobeltiosis, standard variety and standard hybrid for nine characters in basmati hybrid rice.

Characters	Mid-parent heterosis		Better parent heterosis (heterobeltiosis)		Standard variety (G.B.21)		Standard hybrid (EBHR11)	
	%	NO	%	NO	%	NO	%	NO
Agronomic characters:								
Days to maturity (day) A	-5.93 to 1.72	-	-4.86 to3.17	-	-5.07 to 2.41	-	-5.61 to 1.83	-
B	0.16 to 1.72	8	0.23 to3.17	27	0.25 to 2.41	17	0.20 to 1.83	10
C	-5.93 to -0.42	32	-4.86 to -0.40	17	-5.07 to 0.20	24	-5.61 to -0.22	30
Plant height (cm) A	-1.99 to 6.61	-	-	-	-10.86 to 0.70	-	-7.27 to 4.76	-
B	0.39 to 6.61	39	1.02 to 15.97	45	0.70	1	0.66 to 4.76	17
C	-1.99 to -0.47	4	-	-	-10.86 to -0.70	42	-7.27 to -0.47	19
Panicle length A	-	-	-4.72 to 9.27	-	-14.20 to 7.83	-	-18.52 to 2.33	-
B	0.96 to18.93	45	1.32 to 9.27	30	0.88 to 7.83	13	1.26 to 2.33	2
C	-	-	-4.72 to -0.62	11	-14.20 to -0.94	27	-18.52 to -1.35	41
Spikelets panicle^{-1} A	-1.28 to42.08	-	-19.24 to 36.92	-	-1.88 to 45.23	-	-8.53 to 35.83	-
B	9.27 to 42.08	43	7.34 to 36.92	19	10.33 to45.23	43	8.51 to 35.83	31
C	-	-	-19.24 to -7.08	8	-	-	-8.53	1

Table 4. Cont.

Characters	Mid-parent heterosis		Better parent heterosis (heterobeltiosis)		Standard Variety (G.B.21)		Standard Hybrid (EBHR11)	
	%	NO	%	NO	%	NO	%	NO
Yield and its components:								
Panicles plant $^{-1}$ A	-0.62 to 40.35	-	-7.47 to 28.23	-	-17.91 to16.43	-	-24.96 to6.44	-
B	4.98 to 40.35	43	6.37 to 28.23	27	4.56 to16.43	8	4.30 to6.44	2
C	-	-	-7.47 to -5.64	4	-17.91 to5.07	28	-24.96 to-4.42	37
Filled grains panicle^{-1} A	-1.96 to 37.06	-	-19.84 to 29.94	-	-1.88 to45.24	-	0.00 to33.88	-
B	1.28 to 37.06	44	1.84 to29.94	23	8.49 to45.24	44	4.87 to33.88	42
C	-1.96	1	-19.84 to-2.26	18	-1.88	1	-	-
Spikelet fertility% A	-7.14 to 5.45	-	-9.81 to5.14	-	-	-	-	-
B	2.97 to 5.45	3	5.14	1	3.78 to7.34	8	4.12 to6.17	5
C	-7.14 to -2.65	14	-9.81 to-3.68	19	-6.23 to-4.80	2	-7.65 to-3.65	3
1000-grain weight (g) A	-	-	-8.89 to15.82	-	-	-	-10.34 to3.74	-
B	0.27 to 14.89	45	1.55 to15.82	25	-	-	3.74	1
C	-	-	-8.89 to-1.83	20	-15.20 to-1.88	45	-10.34 to-0.51	41
Grain yield t ha^{-1} A	-	-	-	-	-	-	-8.61 to1.45	-
B	34.41 to 58.77	45	17.76 to35.43	45	14.28 to30.45	45	0.15 to1.45	8
C	-	-	-	-	-	-	-8.61 to0.29	33

A: Over all range B: positive significant range C: Negative significant range

Standard variety (G.B. 201) = Giza Basmati 201 , Standard hybrid = EBHR 11

Evaluation of basmati hybrid combinations for heterosis breeding based on mean performance, MP, BP heterosis and superiority over basmati inbred check variety Giza Basmati 201 (SV) and hybrid check (SH) Egyptian Basmati Hybrid 11 (Table 5) would be meaningful from this point of view. Out of 45 basmati hybrid combinations hybrid with a yield advantage of >3.0 t/ha over the highest yielding check variety Giza Basmati 201, ten were considered as promising combinations (Table 6).

Table 5. The best aromatic hybrid combinations and their estimates of mean performance, heterosis over mid parents (MP), over better parent (BP), and superiority over standard variety (SV) and Standard hybrid (SH).

Trait	Hybrid combination	Mean perfm.	MP heterosis	BP heterosis	SV superiorty	SH superiorty
Days to maturity	Sakha basmati 12A x EBR3	127.27	-5.93**	-4.86**	-5.07**	-5.61**
	IR58025A x EBR3	128.97	-5.02**	-3.59**	-3.80**	-4.35**
	Sakha basmati 12A x EBR2	129.30	-4.68**	-3.87**	-3.56**	-4.10**
Plant height (cm)	Sakha basmati 12A x EBR15	103.81	2.74**	12.20**	-10.86**	-7.27**
	Sakha basmati 13A x EBR15	104.01	2.70**	7.23**	-10.69**	-7.09**
	Sakha basmati 12A x EBR3	105.93	2.06**	9.73**	-9.05**	-5.38**
Panicle length (cm)	Sakha basmati 14A x EBR20	30.75	18.77**	6.62**	7.83**	2.33**
	Sakha basmati 14A x EBR3	30.43	18.93**	7.78**	6.71**	1.26**
	Sakha basmati 14A x G.B. 201	30.07	16.85**	5.42**	5.42**	0.04
Spikelet panicle^{-1}	IR58025A x EBR30	308.87	10.20**	-8.82**	45.23**	35.38**
	Sakha basmati 13A x EBR30	305.46	16.96**	-9.83**	43.62**	33.88**
	IR58025A x EBR15	294.79	16.07**	3.01	38.50**	29.21**
Panicles plant^{-1}	Sakha basmati 13A x G.B. 201	26.24	33.58**	16.43**	16.43**	6.44**
	Sakha basmati 12A x EBR3	25.71	40.35**	28.23**	14.10**	4.30**
	Sakha basmati 11A x EBR30	24.70	34.65**	15.49**	9.62**	0.20
Filled grains panicle^{-1}	IR58025A x EBR30	278.50	16.00**	-10.83**	45.24**	33.88**
	Sakha basmati 12A x EBR30	272.22	12.21**	-12.84**	41.97**	30.86**
	IR58025A x EBR15	270.99	16.00**	-0.78**	41.33**	30.27**
Spikelets fertility%	Sakha basmati 14A x EBR25	96.79	5.45**	5.14**	7.34**	6.17**
	Sakha basmati 14A x EBR20	96.65	2.16	-1.06	7.18**	6.01**
	Sakha basmati 14A x EBR15	96.13	1.84	-0.25	5.58**	5.44**
1000-grain weight (g)	Sakha basmati 13A x G.B. 201	29.29	7.56**	-1.88**	-1.88**	3.74**
	IR58025A x G. B. 201	28.26	6.52**	-5.34**	-5.34**	0.08
	Sakha basmati 13A x EBR1	28.25	4.14**	-3.42**	-6.84**	0.00
Grain yield (t ha^{-1})	Sakha basmati 13A x G .B. 201	13.98	46.18**	30.45**	30.45**	1.45**
	Sakha basmati 13A x EBR30	13.91	44.65**	28.51**	29.83**	0.97**
	Sakha basmati 14A x EBR30	13.90	55.37**	28.39**	29.70**	0.87**

***, ** significant at 0.05 and 0.01 levels probability, respectively.**

Table 6. The best hybrid combinations for grain yield with their yield advantage, heterosis and the superiority over inbred and hybrid checks.

Hybrid combination	Yield t ha^{-1}	Yield adv. t ha^{-1}		Heterosis and superiority%			
		G.B.201	EBHR11	MP	BP	SV	SH
Sakha Basmati 13A x G.B.201	13.980	3.260	0.200	46.18**	30.45**	30.45**	1.45**
Sakha Basmati 13A x EBR30	13.910	3.190	0.130	44.65**	28.51**	29.83**	0.97**
Sakha Basmati 14A x EBR30	13.900	3.180	0.120	55.37**	28.39**	29.70**	0.87**
Sakha Basmati 12A x EBR30	13.880	3.160	0.100	44.66**	28.20**	29.52**	0.73**
Sakha Basmati 12A x EBR25	13.870	3.150	0.090	45.62**	29.79**	29.42**	0.65**
Sakha Basmati 14A x G .B.201	13.850	3.130	0.070	55.80**	29.27**	29.27**	0.53**
Sakha Basmati 11A x G .B.201	13.800	3.080	0.020	56.40**	28.77**	28.77**	0.15*
Sakha Basmati 13A x EBR3	13.800	3.080	0.020	45.72**	31.05**	28.77**	0.15*
Sakha Basmati 14A x EBR25	13.790	3.070	0.010	55.89**	29.07**	28.71**	0.10
Sakha Basmati 12A x EBR1	13.780	3.060	0.000	47.27**	33.88**	27.71**	0.00
Average (Basmati Hybrids)	13.874	3.154	0.094				
G.B. 201(Giza Basmati 201)	10.720	Basmati Inbred Check					
Sakha Basmati 12A x G.B. 201	13.780	Basmati Hybrid Check					
L.S.D 0.05				0.014	0.019	0.019	0.019
0.01				0.020	0.027	0.027	0.027

***, ** significant at 0.05 and 0.01 probability levels, respectively.**

Among the ten best selected hybrids, mean performance of grain yield t/ha ranged from 13.780 t/ha for Sakha Basmati 12A x EBR1 to 13.980 t/ha for Sakha Basmati 13A x Giza Basmati 201 with an average of 13.874 t/ha. The yield advantage values over the best local inbred and hybrid checks, Giza Basmati 201 and EBHR 11 ranged from (3.060 and 0.00) to (3.260 and 0.20) with an average of 3.154 and 0.094 t/ha, respectively. Superiority over inbred and hybrid checks ranged from 27.71% and 0.00 to 30.45 and 1.45%, respectively. Five of the 10 basmati hybrids are mentioned in Table 2b.

Significant and positive heterotic effect for grain yield in hybrid rice combinations have been reported by Sahai and Chaudhary (1991), El-Mowafi (2001), El-Mowafi *et al* (2005), Rashid *et al* (2007), Vanisree *et al* (2011), Selvaraj *et al* (2011), Lin *et al* (2012), Latha *et al* (2013), Thorat *et al* (2017), Solanke *et al* (2019) and El-Mowafi *et al* (2021).

REFERENCES

Abd Allah, R.M. (2008). Genetical and Morphological studies on Environmental Genetic and Cytoplasmic Male Sterility lines in rice. M.Sc. Thesis, Fac. of Agric., Mansoura Univ., Egypt.

Abdelkhalik, A. F. (2015). Heterosis and combining ability for development of new basmatic hybrid rice. J. Plant Breed. 19(7): 2165-2175, Egypt.

Annadurai, A. and N. Nadarajan (2001). Heterosis for yield and its components traits in rice. Madras Agric. J. 88(1-3): 184-186.

Biswash, R. and M. Haque (2015). Estimation of superior of exotic hybrids of rice over check varieties in Bangladesh. Am. Euras. J. agric. & Environ. Sci., 15(3): 659-663.

El-Mowafi, H. F. and A. A. Abou-Shousha (2003). Combining ability and heterosis analysis of diverse CMS lines in hybrid rice. Tanta University. Journal of Agricultural Research, 29(1): 106-127.

El-Mowafi, H.F., R.M. Abdallah, Samah M. Abdelkhalek and M.H. Mubarak (2018). Combining ability and molecular evaluation for developing new basmati rice hybrids in Egypt. Egypt J. Plant Breed., 22(7):1467-1485.

El-Mowafi, H.F., (2001). Study on heterosis in hybrid rice under Egyptian condition. Egypt. J. Appl. Sci, 16 (2): 52-63.

El-Mowafi, H. F., M. D. AlKahtani, R. M. Abdallah, A. M. Reda, K. A. Attia, M. A. El-ity, H. E. El-Dabaawy, L. A. Husnain, T. K. Al-Ateeq and M. A. EL-Esawi (2021). Combining Ability and Gene Action for Yield Characteristics in Novel

Aromatic Cytoplasmic Male Sterile Hybrid Rice under Water-Stress Conditions. Agriculture, 11 (3): 226.

El-Mowafi, H. F., A. O. Bastawisi, M. I. Abo-Youssef and **F. U. Zaman (2005).** Exploitation of rice heterosis under Egyptian conditions. Egypt. J. Agric. Res. 83(5A): 143- 166.

El-Mowafi, H.F., W. Abd El-Hadi and S. Soltan (2018). Superiority for Agronomic and Yield Traits in Hybrid Rice Under Normal and Saline Conditions. Journal of Agricultural Chemistry Biotechnology, 9 (1): 43-50.

GonyaNayak, P., S. R. Ch and S. Vanisree (2016). Heterosis and gene action studies involving aromatic lines for grain quality traits in rice. International Journal of Life Sciences, 4 (4): 517-528.

Jarwar, A. D., Q. D. D. Cruz and G.S. Junejo (2013). Heterosis of some yield and its related characters in aromatic rice *(Oryza saliva* L.) varieties and their F1 hybrids under lowland and upland environments. Pak. J. Agric. Agril. Engg. Vet. Sci.29(1): 13-23.

Kempthorne, O. (1957). An introduction to genetic statistics. John Wiley and Sons Inc., New York, 458-471.

Kumar, S., S. Kumar, N. Pratap and D. K. Dwivedi (2012). Estimation of heterosis for grain yield attributing traits in rice *(Oryza sativa*, L.). Plant Archives, 12(1): 159-164.

Latha, S., D. Sharma and G.S. Sanghera (2013). Combining ability and heterosis for grain yield and its component traits in rice *(Oryza sativa* L.). Notulae Scientia Biologicae, 5(1): 90-97.

Lin, J. R., S. X. Wei and W. M. Guo (2012). Biological characteristics and heterosis utilization of four indica japonica intermediate type restorer lines with wide compatibility. China National Rice Research Institute (CNRRI), 26(6): 656-662.

Mahrous, Z. S., (2022). Inheritance of Photo-Thermo sensitive Genic Male Sterility in hybrid Rice under Egyptian condition. MS.c.thesis, Fac. of Agric., Tanta Univ.

Mather, K. (1949). Biometrical genetics. 3rd. Ed. Cambridge Univ. Press, London, N.Y. 158 pp.

Mather, K. and **J. L. Jinks (1982).** Biometrical Genetics. 2nd Ed. Chapman & Hall, London, pp. 382 pp.

Neelam, S., M. Ramesha, T. D. Reddy and A. Sankar (2009). Study of heterosis by utilizing male sterility-restoration system in rice (*Oryza sativa* L.). J. Rice Res, 2 (2): 93-98.

Panse, V.G. and P.V. Sukhatme (1954). Statistical Methods for Agricultural Workers. Indian Council of Agric. Res., New Delhi, 227 p.

Patil, S. R., R. D. Vashi, P. P. Patil, S. S. Patil and P. G. Varpe (2012). Heterosis for yield and its components in rice *(Oryza sativa*, L.). Agricultural Science Digest., 32(2), 111-117.

Priyanka, K., H. K. Jaiswal and S. A. Waza (2014). Combining ability and heterosis for yield, its components and some grain quality parameters in rice (*Oryza sativa* L.). J. Appl. & Nat. Sci., 6(2): 495-506.

Rashid, M., A. A. Cheema and M. Ashraf (2007). Line x tester analysis in basmatic rice. Pak. J. Bot., 39(6): 2035-2042.

Reddy, M. R., C. S. Raju, D. Sravani, T. D. Reddy and G. N. Reddy (2012). Heterosis for yield and kernel size in aromatic rice *(Oryza sativa* L.). India. Annals of Biological Research, 3(6): 2662-2666.

Sahai, V. and R. Chaudhary (1991). A study of commercial exploitation of heterosis in rice. Oryza, 28: 27-30.

Sanghera, **G. S. and W. Hussain** (2012). Heterosis and combining ability estimates using line x tester analysis to develop rice hybrids for temperate conditions. Not. Sci. Biol., 4(3): 131- 142.

Selvaraj, C. K., P. Nagarajan, K. Thiyagarajan, M. Bharathi and R. Rabindran (2011). Studies on heterosis and combining ability of well known last resistant nee genotypes with high yielding varieties of rice (*Oryza sativa* L.). Inter. J. Plant Breeding and Genetics, 5(2): 111-129.

Sha, X.Y. and S.D. Linscombe (2003). Specially rice for Louisiana. Louisiana Agric . 46 (3): 8.

Solanke, A. C., P. B. Patel and P. K. Patel (2019). Study of heterosis and inbreeding depression in F2 generation of aromatic rice. The Pharma Innovation Journal, 8 (8): 10-15.

Thorat, B., R. Kunkerkar and T. Bagkar (2017). Studies on heterosis for yield and its contributing traits in hybrid rice (*Oryza sativa* L.). International Journal of Chemical Studies, 5 (5): 7-12.

Vanisree, S., C. S. Raju, P. N. Reddy, M. Sreedhar and L. Krishna (2011). Heterosis and gene effects for grain yield and physiological traits in rice (*Oryza saliva,* L.). J. Res. ANGRAU, 39(4): 1-5.

Veeresha, B. A., Hanamaratti, N. G. and P. M. Salimatb (2015). Heterosis and combining ability studies for yield and productivity traits in rice: a review. International J. of Current Agricultural Res., 4(5): 120-125.

Vennila, S., Y. Anbuselvam and K. Palaniraja (2011). Heterosis studies for yield and its components in rice (*Oryza sativa,* L.). International J. of Recent Scientific Res., 2(9): 261- 262.

قوة الهجين فى المحصول والصفات المرتبطة به فى الأرز العطري فى مصر

عمرو محمد رضا، السيد فاروق على عرفات، سماح منير عبد الخالق، رزق محمد عبد الله،
عادل عطيه حديفة و حمدى فتوح الموافى

تم إنتاج خمسة وأربعون توليفة أرز هجين عطرية باستخدام خمسة سلالات عقم ذكرى وراثي سيتوبلازمي وتسعة آباء معيدة لخصوبة السلالة العقيمة عطرية بإتباع تصميم تزاوج السلالة × الكشاف . وتهدف الدراسة إلى اكتشاف أفضل التراكيب الوراثية من الأرز الهجين العطري فيما يتعلق بتفوقها على متوسط الأبوين وأفضل الأبوين والصنف المقارن البسمتي جيزة بسمتى ٢٠١ والهجين المقارن البسمتي (هجين مصرى بسمتى ١١) لتسع صفات حقلية ومحصولية وتعتبر الهجن التى تتميز بأفضيلة محصولية متفوقة على صنف وهجين الاختبار أو المقارنة هجن واعدة ، من بين خمسة وأربعون توليفة أرز هجين عطرى تم تقييمها كانت عشرة هجن منها واعدة للغاية بمتوسط أداء محصول حبوب مرتفع يتراوح من ١٣,٧٧ طن/هكتار للهجين. Sakha Basmati 13 A x EBR2 إلى ١٣,٩٨ طن/هكتار للهجين Sakha Basmati 13 A x Giza Basmati 201 بمتوسط عام للهجن العطرية المتفوقة محصولياً ١٣,٨٧٤ طن/هكتار بأفضلية محصولية تتراوح من ٣,٠٦٠ طن/هكتار إلى ٣٢٦٠ طن/هكتار بتفوق من ٢٧,٧١ إلى ٣٠,٤٥% .

المجلة المصرية لتربية النبات ٢٧(٣): ٣٤٣- ٣٨٢ (٢٠٢٣)