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# COMBINING ABILITY AND HETEROSIS FOR AGRONOMIC AND YIELD TRAITS IN EGYPTIAN TWO-LINE HYBRIDS OF RICE (*Oryza sativa* L.) INVOLVING PHOTO-THERMO SENSITIVE GENIC MALE STERILE LINES

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## ABSTRACT

***Hybrid rice is an important technical innovation in hybrid rice seed production based on photo-thermo-sensitive genic male sterile (PTGMS) lines in rice. The present study was undertaken to investigate the magnitude of genotypic variation, both general and specific combining abilities, and estimate the genetic behavior. The study also aimed to assess the potentiality of heterosis expression for new developed photo-thermo-sensitive genic male sterile lines (PTGMS) and six exotic and novel Egyptian testers of new plant types using line x tester analysis for agronomic and yield traits to get useful information for two line system hybrid rice in Egypt. Highly significant differences for GCA effects among PTGMS lines and testers for all studied traits. Highly significant differences for SCA effects for all the studied traits. PTGMS-78 was the best general combiner among sterile lines followed by PTGMS-38, while the EJGSR 182 was the best general combiner among the restorer lines followed by Sakha Super 303 then Sakha Super 301. The higher GCA effects of parents exhibited stronger and superior heterosis in hybrids. Hereitability estimates in narrow sense ($h^2_n$) were high for all traits studied. Nine and five hybrid rice combinations gave significant and positive estimates of SCA effects for grain yield plant$^{-1}$ and grain yield t/ha$^{-1}$, respectively. The best SCA effects were obtained for the combinations, PTGMS-43xEJGSR-182, PTGMS-23xSakha Super 303, PTGMS-38xSakha Super 303, PTGMS-20xEJGSR -182, PTGMS-78xEJGSR-182 and PTGMS-20xMinghui 63. Among 30 super hybrid combinations, 11 were the most promising with mean performance of grain yield ranging from 14.82 t/ha$^{-1}$ for PTGMS-78 x EJGSR-182 to 14.22 t/ha$^{-1}$ for PTGMS-38 x Sakha Super 303 with superiority to the standard check variety ranging from 36.97% to 31.42%.***

Key words: ***Hybrid Rice, Super Rice, Two-line system, PTGMS, GCA, SCA, Heterosis.***

## INTRODUCTION

Heterosis, or hybrid vigor is a term used to describe the phenomenon in which the performance of an $F_1$ generated by crossing of two genetically different individuals, is superior to that of the better parent (Xiao *et al* 1996 and Yuan 1994).

Two-line hybrid rice has a strong standard heterosis because, their male sterility is mainly controlled by one or two pairs of recessive nuclear genes, it has no relation to cytoplasm, and it is free from the constraining of the definite restoration maintenance relationship, so making full use of parent with good economical characters and general combining ability

(GCA) increasing the breeding opportunity of strong heterosis combinations (Yuan 1994).

Combining ability is a measure of gene action (additive and non-additive). GCA effects represent additive gene action, whereas specific combining ability (SCA) effects represent non-additive gene action. The presence of non-additive genetic variance offers scope for exploration of heterosis (Yadav *et al* 1999 and El-Mowafi *et al* 2005). The parents with good GCA effects can be used to obtain hybrid with strong heterosis and SCA effects (Yan *et al*., 2000). The experience of sterile line breeding showed that Indica hybrid, Japonica hybrid or crossing of Indica and Japonica had a strong correlation between economic traits and grain yield heterosis and combining ability of parents, especially the combining ability of sterile line which is more important (Lu 2000). The rice researchers around the world carried out studies on the combining ability of different kinds of rice (Chen *et al* 1997, El-Mowafi *et al* 2005) and their achievements in this aspect can guide the use of heterosis in rice and selecting of parents in hybridization breeding. To develop super hybrid with higher yield, better grain quality and multi-resistance to diseases is very important, and the key is to breed new PTGMS lines with good combining ability.

The present investigation aimed to estimate the combining ability and heterosis of agronomic traits in five Egyptian Photo-Thermo-sensitive Genic Male Sterility lines with six pollinator lines.

## MATERIALS AND METHODS

Thirty super rice hybrid combinations were produced from the five Egyptian Japonica PTGMS lines PTGMS-20, PTGMS-23, PTGMS-38, PTGMS-43 and PTGMS-78 used as females, crossed with the six super pollinator lines, Minghui 63, Sakha Super 300, Sakha Super 301, Sakha Super 302, Sakha Super 303 and EJGSR182 (Table 1) used as males using Line x Tester mating design. The crosses among PTGMS lines and pollinators were attempted during the year 2021 (through hybrid seed production program in the isolation field). All the hybrids, their parents, Sakha Super 300 also as a check variety were sown on May 25$^{th}$ in experimental field area of Sakha Research Station, Sakha, Kafr El-Sheikh, Egypt. Thirty day old seedlings were transplanted with one seedling hill$^{-1}$ adopting spacing of 20 cm between rows and 20 cm between plants. Each test entry consisted of 14 rows of 10m length. The plots were designed by randomized complete block design (RCBD) with four replications. All recommendations of agronomic practices, weed management and plant protections were applied.

**Table 1. Egyptian Photo-Thermo-sensitive Genic Male Sterile lines (PTGMS) and pollinator lines used to produce hybrid combinations.**

| Genotype | Description | Origin |
|---|---|---|
| **PTGMS lines** | | |
| **PTGMS-20** | **PTGMS** | **Egypt** |
| **PTGMS-23** | **PTGMS** | **Egypt** |
| **PTGMS-38** | **PTGMS** | **Egypt** |
| **PTGMS-43** | **PTGMS** | **Egypt** |
| **PTGMS-78** | **PTGMS** | **Egypt** |
| **Pollinators** | | |
| **Minghui 63** | **Pollinator** | **China** |
| **Sakha Super 300** | **Pollinator** | **Egypt** |
| **Sakha Super 301** | **Pollinator** | **Egypt** |
| **Sakha Super 302** | **Pollinator** | **Egypt** |
| **Sakha Super 303** | **Pollinator** | **Egypt** |
| **EJGSR 182** | **Pollinator** | **Egypt** |

Observations were recorded on ten plants plot$^{-1}$ taken at random from each entry in each replication for days to maturity, plant height (cm), panicle length (cm), spikelets panicle$^{-1}$, panicles palnt$^{-1}$, filled grains panicle$^{1}$, spikelet fertility%, 1000-grain weight (g) and grain yield plant$^{-1}$.

Ten guarded rows (10 $m^2$) were harvested from each entry in each replication to determine grain yield ($t/ha^{-1}$). Data were analyzed according to Steel and Torrie (1980). Combining ability analysis was carried out as suggested by Kembthorne model (1957). Superiority (over the best inbred variety Sakha Super 300) was calculated for the studied traits.

## RESULTS AND DISCUSSION

### Mean performance

Mean performance of 11 parental lines (five PTGMS and six pollinators) and their 30 hybrid rice combinations of line x tester for the studied traits is presented in Table (2).

As revealed in Table (2), the mean performance of the studied traits varied from hybrid combination to another. For days to maturity, the $F_1$ mean values of six hybrid combinations were towards the higher parents (late maturing parents), while one hybrid only tended to the lower parent (early maturing parent). However, the $F_1$ means of the rest (23 hybrids) were intermediate between the two parents involved; some of them were towards the early maturing parents, while others were towards the late maturing parents.

The most desirable mean values towards the earliness were obtained from the PTGMS lines, PTGMS-43 (127.75 days) and PTGMS-20 (129.83 days), restorer lines Sakha Super 303 (117.95 days) and Sakha Super 302 (117.98 days) and the hybrid combinations PTGMS-20 x Sakha Super 303 (123.45 days), PTGMS-23xSakha Super 303 (123.15 days), PTGMS-43xSakha Super 302 (123.98 days) and PTGMS-43xSakha Super 303 (123.23 days).

Complete to over dominance was observed in most of the hybrid combinations towards taller plant height. Average plant height varied from 85.70 to 125.03 cm for female PTGMS lines and male parents and from 105.65 to 141.20 cm for hybrids. Short stature of plant is a desirable trait the female parent PTGMS-23 had minimum mean value of plant height (85.83 cm) while, the male parent Sakha Super 302 had a maximum plant height (125.03 cm).

**Table 2. Mean performance of parents and their $F_1$ hybrids for studied traits.**

| Genotypes | | Days to maturity | Plant height (cm) | Panicle length (cm) | Spikelets spanicle$^{-1}$ | Panicles plant$^{-1}$ |
|---|---|---|---|---|---|---|
| Lines | PTGMS-20 | 129.83 | 88.70 | 16.95 | 167.05 | 18.25 |
| | PTGMS-23 | 133.40 | 85.83 | 16.75 | 155.58 | 21.13 |
| | PTGMS-38 | 136.50 | 103.03 | 19.90 | 173.45 | 22.83 |
| | PTGMS-43 | 127.75 | 95.63 | 16.80 | 215.70 | 21.80 |
| | PTGMS-78 | 134.98 | 108.20 | 20.28 | 224.58 | 24.25 |
| Testers | Minghui 63 | 133.28 | 122.90 | 32.45 | 310.00 | 17.60 |
| | Sakha Super 300 | 135.98 | 124.63 | 21.80 | 249.68 | 19.58 |
| | Sakha Super 301 | 137.75 | 118.05 | 24.08 | 262.90 | 18.23 |
| | Sakha super 302 | 117.98 | 125.03 | 23.30 | 285.33 | 15.73 |
| | Sakha Super 303 | 117.95 | 106.38 | 17.78 | 323.03 | 15.23 |
| | EJGSR 182 | 125.43 | 109.34 | 19.35 | 298.33 | 17.55 |
| Hybrid combinations | PTGMS-20/Minghui 63 | 135.10 | 134.50 | 29.20 | 419.88 | 17.90 |
| | PTGMS-20/S.S.300 | 130.78 | 111.00 | 23.00 | 296.48 | 21.45 |
| | PTGMS-20/S.S.301 | 133.65 | 110.65 | 24.20 | 329.88 | 19.78 |
| | PTGMS-20/S.S.302 | 124.35 | 114.65 | 22.38 | 319.03 | 17.60 |
| | PTGMS-20/S.S.303 | 123.45 | 108.20 | 18.93 | 351.65 | 17.48 |
| | PTGMS-20/182 | 127.95 | 114.23 | 20.90 | 354.13 | 19.18 |
| | PTGMS-23/Minghui 63 | 136.18 | 135.88 | 27.65 | 415.70 | 19.08 |
| | PTGMS-23/S.S.300 | 134.88 | 107.33 | 23.20 | 308.00 | 21.60 |
| | PTGMS-23/S.S.301 | 135.30 | 106.95 | 24.93 | 348.38 | 21.05 |
| | PTGMS-23/S.S.302 | 124.05 | 113.70 | 25.48 | 325.83 | 19.88 |
| | PTGMS-23/S.S.303 | 123.15 | 105.65 | 20.05 | 366.43 | 19.38 |
| | PTGMS-23/182 | 127.13 | 111.40 | 20.40 | 341.70 | 18.70 |
| | PTGMS-38/Minghui 63 | 138.28 | 141.20 | 31.90 | 417.25 | 19.23 |
| | PTGMS-38/S.S.300 | 137.43 | 125.45 | 23.38 | 318.63 | 22.90 |
| | PTGMS-38/S.S.301 | 139.30 | 120.25 | 25.03 | 341.33 | 21.50 |
| | PTGMS-38/S.S.302 | 124.78 | 124.53 | 24.90 | 332.83 | 19.83 |
| | PTGMS-38/S.S.303 | 126.13 | 109.58 | 19.33 | 366.60 | 19.70 |
| | PTGMS-38/182 | 130.33 | 114.88 | 21.15 | 347.18 | 21.43 |
| | PTGMS-43/Minghui 63 | 133.45 | 135.75 | 32.43 | 358.70 | 19.15 |
| | PTGMS-43/S.S.300 | 131.98 | 124.00 | 25.08 | 285.40 | 22.75 |
| | PTGMS-43/S.S.301 | 135.15 | 121.60 | 27.03 | 348.38 | 22.03 |
| | PTGMS-43/S.S.302 | 123.98 | 123.38 | 27.45 | 351.95 | 18.95 |
| | PTGMS-43/S.S.303 | 123.23 | 107.08 | 20.45 | 369.25 | 18.68 |
| | PTGMS-43/182 | 124.95 | 120.28 | 22.15 | 348.58 | 18.48 |
| | PTGMS-78/Minghui 63 | 134.23 | 140.08 | 30.70 | 400.20 | 19.70 |
| | PTGMS-78/S.S.300 | 134.18 | 129.65 | 25.38 | 312.40 | 25.08 |
| | PTGMS-78/S.S.301 | 136.25 | 126.98 | 27.08 | 353.58 | 23.08 |
| | PTGMS-78/S.S.302 | 126.73 | 132.68 | 27.58 | 307.43 | 21.00 |
| | PTGMS-78/S.S.303 | 125.88 | 109.58 | 22.60 | 375.88 | 19.85 |
| | PTGMS-78/182 | 128.25 | 122.88 | 22.90 | 359.45 | 22.15 |
| LSD 5% | | 0.69 | 1.40 | 0.48 | 5.76 | 0.76 |
| LSD 1% | | 0.98 | 1.99 | 0.68 | 8.21 | 1.08 |

**Table 2. Cont.**

| Genotypes | | Filled grains panicle$^{-1}$ | Spikelet fertiliety% | 1000 grain weight (g) | Grain yield plant$^{-1}$ (g) | Grain yield (t/ha$^{-1}$) |
|---|---|---|---|---|---|---|
| Lines | PTGMS-20 | 160.50 | 96.08 | 26.86 | 40.34 | 6.94 |
| | PTGMS-23 | 150.55 | 96.75 | 26.73 | 46.00 | 7.61 |
| | PTGMS-38 | 167.38 | 96.50 | 28.07 | 49.73 | 8.91 |
| | PTGMS-43 | 204.55 | 94.83 | 26.46 | 45.73 | 8.99 |
| | PTGMS-78 | 211.65 | 94.25 | 29.23 | 54.02 | 9.36 |
| Testers | Minghui 63 | 284.43 | 91.75 | 29.20 | 58.63 | 10.82 |
| | Sakha Super 300 | 239.75 | 96.03 | 28.14 | 67.05 | 11.73 |
| | Sakha Super 301 | 250.73 | 95.38 | 28.84 | 66.63 | 11.86 |
| | Sakha super 302 | 267.40 | 93.73 | 28.90 | 62.54 | 10.96 |
| | Sakha Super 303 | 302.70 | 93.70 | 29.15 | 62.85 | 11.79 |
| | EJGSR 182 | 279.75 | 93.78 | 30.71 | 64.24 | 12.17 |
| Hybrid combinations | PTGMS-20/Minghui 63 | 342.95 | 81.68 | 29.66 | 63.61 | 11.95 |
| | PTGMS-20/S.S.300 | 278.35 | 93.88 | 28.11 | 74.29 | 12.90 |
| | PTGMS-20/S.S.301 | 302.03 | 93.38 | 28.75 | 70.88 | 13.17 |
| | PTGMS-20/S.S.302 | 292.08 | 91.55 | 27.93 | 67.96 | 13.38 |
| | PTGMS-20/S.S.303 | 322.80 | 91.80 | 28.70 | 69.90 | 13.64 |
| | PTGMS-20/182 | 318.83 | 90.03 | 29.29 | 75.68 | 13.78 |
| | PTGMS-23/Minghui 63 | 348.25 | 83.30 | 29.46 | 66.22 | 12.35 |
| | PTGMS-23/S.S.300 | 290.90 | 94.45 | 28.17 | 77.82 | 13.88 |
| | PTGMS-23/S.S.301 | 319.58 | 95.15 | 28.55 | 87.11 | 14.00 |
| | PTGMS-23/S.S.302 | 303.60 | 93.18 | 27.73 | 75.84 | 13.74 |
| | PTGMS-23/S.S.303 | 344.25 | 93.95 | 28.50 | 86.74 | 13.90 |
| | PTGMS-23/182 | 321.48 | 94.08 | 29.59 | 75.41 | 14.12 |
| | PTGMS-38/Minghui 63 | 335.13 | 80.33 | 29.89 | 69.76 | 12.33 |
| | PTGMS-38/S.S.300 | 305.50 | 96.00 | 28.69 | 85.58 | 14.27 |
| | PTGMS-38/S.S.301 | 326.33 | 95.60 | 29.29 | 86.07 | 14.49 |
| | PTGMS-38/S.S.302 | 315.63 | 94.58 | 28.70 | 82.49 | 14.07 |
| | PTGMS-38/S.S.303 | 347.83 | 94.88 | 29.28 | 88.39 | 14.22 |
| | PTGMS-38/182 | 329.65 | 94.95 | 29.56 | 67.87 | 14.24 |
| | PTGMS-43/Minghui 63 | 285.40 | 79.58 | 28.66 | 63.65 | 12.35 |
| | PTGMS-43/S.S.300 | 273.18 | 95.73 | 29.32 | 86.64 | 14.33 |
| | PTGMS-43/S.S.301 | 333.95 | 95.53 | 29.85 | 78.93 | 14.49 |
| | PTGMS-43/S.S.302 | 330.93 | 94.03 | 28.67 | 75.23 | 13.95 |
| | PTGMS-43/S.S.303 | 348.00 | 94.25 | 29.13 | 76.43 | 14.45 |
| | PTGMS-43/182 | 328.98 | 95.13 | 30.11 | 84.00 | 14.65 |
| | PTGMS-78/Minghui 63 | 324.35 | 81.05 | 30.06 | 68.03 | 11.88 |
| | PTGMS-78/S.S.300 | 298.35 | 95.50 | 29.47 | 86.77 | 14.72 |
| | PTGMS-78/S.S.301 | 337.45 | 95.45 | 29.90 | 86.46 | 14.76 |
| | PTGMS-78/S.S.302 | 290.28 | 94.40 | 29.35 | 80.61 | 14.68 |
| | PTGMS-78/S.S.303 | 353.98 | 94.18 | 29.79 | 81.49 | 14.19 |
| | PTGMS-78/182 | 339.23 | 94.38 | 30.07 | 86.80 | 14.82 |
| LSD 5% | | 3.85 | 0.96 | 0.28 | 1.74 | 0.30 |
| LSD 1% | | 5.49 | 1.37 | 0.40 | 2.48 | 0.43 |

The hybrid combinations, PTGMS-23 x Sakha Super 303 (105.65 cm), PTGMS-23 x Sakha Super 301 (106.95 cm) and PTGMS-43 x Sakha Super 303 (107.08 cm) gave the lowest mean values for plant height trait. Complete to over dominance was observed in all or most of hybrids towards longest panicle, highest number of spikelets panicle$^{-1}$**,** the higher number of filled grains panicle$^{-1}$, lower or higher rate of spikelet fertility %, higher grain yield plant$^{-1}$ and grain yield t/ha$^{-1}$.

For panicles plant$^{-1}$, 21 hybrids were intermediate between the two parents involved, while seven hybrids were towards the higher parents and only two hybrid combinations were towards the lower number of panicles plant$^{-1}$. With respect to 1000-grain weight, the $F_1$ mean values of 17 hybrid rice combinations were intermediate between the two parents involved and the rest of 13 hybrids were tended to the higher parents.

The highest mean values of grain yield (t/ha$^{-1}$) were obtained by the Egyptian Japonica super hybrid rice combinations PTGMS-78xEJGSR 182 (14.82 t/ha$^{-1}$), PTGMS-78xSakha Super 301 (14.76 t/ha$^{-1}$) and PTGMS-78xSakha Super 300 (14.72 t/ha$^{-1}$). The lowest values were estimated for the hybrids, PTGMS-78xMinghui 63, PTGMS-20xMinghui 63 and PTGMS-38xMinghui 63 and ranged from 11.88 to 12.33 t/ha$^{-1}$, respectively. The parental lines, EJGSR 182, Sakha Super 301, Sakha Super 303 and Sakha Super 300, manifested the highest mean performance of 12.17, 11.86, 11.79 and 11.73 t/ha, respectively for grain yield t/ha$^{-1}$.

**Analysis of variance**

Analysis of variance (Table 3) revealed highly significant differences among the 41 genotypes (30 hybrids, 5 PTGMS lines and 6 restorer lines) tested for all studied traits. The hybrid rice parental lines and the resulting two line hybrids showed highly significant differences for all traits studied. Parents vs hybrids mean squares revealed that average heterosis was highly significant in all hybrids for all studied traits under investigation. The analysis of variance for combining ability given in Table (3) revealed highly significant differences among the PTGMS and restorer lines.

The analysis of variance for general combining ability (GCA) given in Table (3) revealed highly significant mean squares for both the PTGMS and restorer lines. The highly significant mean squares of specific combining ability (SCA) of lines x testers for all traits, which indicated that both of additive and non-additive gene actions were involved in the control of the expression of these traits. The estimate of variance due to GCA was higher than that due to SCA for all the traits, except filled grains panicle$^{-1}$, indicating the more importance of additive gene action. In case of filled grains panicle$^{-1}$, preponderance of non-additive gene action was recorded by virtue of low GCA/SCA variance ratio.

**Table 3. Analysis of variance and mean square from line x tester analysis for studied traits.**

| SOV | df | Days to maturity | Plant height (cm) | Panicle length (cm) | Spikelets panicle$^{-1}$ | Panicles plant$^{-1}$ |
|---|---|---|---|---|---|---|
| Replications | 3 | 0.76 | 0.836 | 0.07 | 51.907 | 0.374 |
| Treatments | 40 | 130.51** | 650.97** | 70.19** | 16063.64** | 18.77** |
| Parents | 10 | 200.33** | 774.33** | 85.29** | 14205.74** | 33.67** |
| Crosses | 29 | 110.85** | 466.77** | 52.18** | 4609.44** | 13.17** |
| Par.vs.crosses | 1 | 2.42** | 4759.13** | 441.31** | 366814.35** | 32.00** |
| Lines | 4 | 57.93** | 731.64** | 40.38** | 465.08** | 28.03** |
| Testers | 5 | 572.51** | 1882.42** | 256.27** | 22527.04** | 46.27** |
| Linesxtesters | 20 | 6.01** | 59.88** | 3.52** | 958.91** | 1.93** |
| Residual | 120 | 0.35 | 1.42 | 0.17 | 24.09 | 0.42 |
| CV% | | 0.45 | 1.02 | 1.73 | 1.53 | 3.22 |
| **SOV** | **df** | **Filled grains panicle$^{-1}$** | **Spikelet fertility%** | **1000 grain weight (g)** | **Grain yield plant$^{-1}$ (g)** | **Grain yield t/ha$^{-1}$** |
| Replications | 3 | 18.89 | 0.263 | 0.06 | 3.765 | 0.032 |
| Treatments | 40 | 10976.64** | 84.91** | 3.45** | 641.83** | 16.49** |
| Parents | 10 | 11473.76** | 9.27** | 6.71** | 357.46** | 13.428** |
| Crosses | 29 | 2069.97** | 105.63** | 1.81** | 253.83** | 3.01** |
| Par.vs.crosses | 1 | 264298.76** | 240.32** | 18.18** | 14737.38** | 437.91** |
| Lines | 4 | 1092.09** | 21.69** | 4.91** | 450.38** | 4.04** |
| Testers | 5 | 7192.37** | 577.28** | 4.47** | 715.60** | 12.89** |
| Linesxtesters | 20 | 984.95** | 4.50** | 0.53** | 99.08** | 0.34** |
| Residual | 120 | 10.77 | 0.67 | 0.06 | 2.21 | 0.07 |
| CV% | | 1.11 | 0.88 | 0.82 | 2.07 | 2.01 |

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

The information on the magnitude of general and specific combining ability for different agronomic and yield traits helps in understanding the gene action which is important for planning an effective hybrid rice breeding programe in Egypt. The superiority of parents has to be assessed bassed on GCA of female and male parents and its ability to produce specific combining hybrids. Additive and non-additive gene in the parent, estimated through combining ability analysis, is useful in determining the possibility for commercial exploitation of heterosis (Ram *et al*., 1998, Ganesan and Rangaswamy,1998, El-Mowafi *et al* 2012, El-Mowafi *et al* (2021a) and El-Mowafi *et al* (2021b).

**General combining ability (GCA) effects**

Significant differences of GCA effects were observed among the Egyptian PTGMS lines for the studied traits (Table 4). The PTGMS-78 was the best combiner for panicle length, panicles plant$^{-1}$, 1000-grain weight, grain yield plant$^{-1}$ and grain yield t/ha$^{-1}$and good combiner for spikelets panicle$^{-1}$, filled grains panicle$^{-1}$, spikelet fertility %, PTGMS-38 was best combiner for spikelets panicle$^{-1}$, filled grains panicle$^{-1}$, spikelet fertility% and good combiner for panicles plant$^{-1}$, 1000-grain weight, grain yield plant$^{-1}$and grain yield t/ha$^{-1}$. PTGMS-43 was the best combiner for days to maturity (earliness) and good combiner for spikelet fertility %, 1000-grain weight and grain yield t/ha$^{-1}$.

Among the testers or male parents (Table 4), Sakha Super 300 was the best general combiner for spikelet fertility% and grain yield plant$^{-1}$ and good combiner for short stature plant, panicles plant$^{-1}$ and grain yield t/ha$^{-1}$. Sakha Super 301 wad good combiner for short stature plant (plant height), panicle length, filled grains panicle$^{-1}$, spikelet fertility%, 1000-grain weight, grain yield plant$^{-1}$, grain yield t/ha$^{-1}$ and the best combiner for panicles plant$^{-1}$. Sakha Super 302 was good combiner for days to maturity, panicle length, spikelet fertility% and grain yield t/ha$^{-1}$. Sakha Super 303 was the best combiner for earliness, short stature plant and filled grains panicle$^{-1}$ and good combiner for spikelets panicle$^{-1}$, spikelet fertility%, grain yield plant$^{-1}$ and grain yield t/ha$^{-1}$.

**Table 4. General combining ability effects for each line and tester for studied traits.**

| Genotypes | Days to maturity | Plant height (cm) | Panicle length (cm) | Spikelets panicle$^{-1}$ | Panicles plant$^{-1}$ |
|---|---|---|---|---|---|
| **Lines** | | | | | |
| PTGMS-20 | -1.13** | -4.59** | -1.46** | -3.90** | -1.39** |
| PTGMS-23 | -0.23* | -6.65** | -0.94** | 1.94** | -0.34 |
| PTGMS-38 | 2.36** | 2.52** | -0.28* | 4.90** | 0.48 |
| PTGMS-43 | -1.56** | 1.88** | 1.20** | -5.36** | -0.28 |
| PTGMS-78 | 0.57** | 6.84** | 1.48** | 2.42** | 1.53** |
| SE (gi) | 0.12 | 0.24 | 0.08 | 1.00 | 0.13 |
| LSD 5% | 0.20 | 0.40 | 0.22 | 0.08 | 0.50 |
| LSD 1% | 0.28 | 0.58 | 0.31 | 0.12 | 0.72 |
| **Testers** | | | | | |
| Minghui | 5.10** | 17.35** | 5.82** | 53.28** | -1.27** |
| Sakha Super 300 | 3.50** | -0.65** | -0.55** | -44.89** | 2.47** |
| Sakha Super 301 | 5.58** | -2.85** | 1.09** | -4.76** | 1.20** |
| Sakha super 302 | -5.57** | 1.66** | 1.00** | -21.66** | -0.83** |
| Sakha Super 303 | -5.98** | -12.12** | -4.29** | 16.89** | -1.27** |
| EJGSR 182 | -2.63** | -3.40** | -3.06** | 1.14** | -0.30 |
| SE (gi) | 0.13 | 0.27 | 0.09 | 1.10 | 0.14 |
| LSD 5% | 0.22 | 0.44 | 0.24 | 0.09 | 0.55 |
| LSD 1% | 0.31 | 0.63 | 0.34 | 0.13 | 0.79 |
| **Genotypes** | **Filled grains panicle$^{-1}$** | **Spikelet fertility%** | **1000 grain weight (g)** | **Grain yield plant$^{-1}$ (g)** | **Grain yield t/ ha$^{-1}$** |
| **Lines** | | | | | |
| PTGMS-20 | -10.14** | -1.68** | -0.40 | -7.17** | -0.65** |
| PTGMS-23 | 1.70** | 0.29 | -0.47 | 0.64** | -0.13** |
| PTGMS-38 | 7.04** | 0.66 | 0.09 | 2.47** | 0.15** |
| PTGMS-43 | -2.90** | 0.31 | 0.15 | -0.08 | 0.25** |
| PTGMS-78 | 4.30** | 0.43 | 0.63 | 4.14** | 0.39** |
| SE (gi) | 0.67 | 0.17 | 0.05 | 0.30 | 0.05 |
| LSD 5% | 0.28 | 1.11 | 1.66 | 0.14 | 0.09 |
| LSD 1% | 0.39 | 1.58 | 2.37 | 0.20 | 0.12 |
| **Testers** | | | | | |
| Minghui | 7.58** | -10.88** | 0.40 | -11.30** | -1.62** |
| Sakha Super 300 | -30.38** | 3.05** | -0.39 | 4.66** | 0.23** |
| Sakha Super 301 | 4.23** | 2.96** | 0.13 | 4.34** | 0.40** |
| Sakha super 302 | -13.14** | 1.48* | -0.66 | -1.13** | 0.17** |
| Sakha Super 303 | 23.73** | 1.75** | -0.06 | 3.04** | 0.29** |
| EJGSR 182 | 7.99** | 1.65* | 0.59 | 0.40** | 0.53** |
| SE (gi) | 0.73 | 0.18 | 0.05 | 0.33 | 0.06 |
| LSD 5% | 0.30 | 1.22 | 1.82 | 0.15 | 0.10 |
| LSD 1% | 0.43 | 1.74 | 2.59 | 0.22 | 0.14 |

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

EJGSR 182 was the best combiner for 1000-grain weight and grain yield t/ha$^{-1}$ and good combiner fo days to maturity, plant height, spikelets paniclet$^{-1}$, filled grains panicle$^{-1}$, spikelet fertility% and grain yield plant$^{-1}$. Finally, Minghui 63 was the best combiner for panicle length and spikelets panicle$^{-1}$ and good combiner for filled grains panicle$^{-1}$ and 1000-grain weight.

**Evaluation of the parents**

According to the ranking numbers of the GCA proposed by Wang (1981) and El-Mowafi *et al* (2005), the data in Table (5) showed that the female lines, PTGMS-78, PTGMS-38 and PTGMS-43 and also the male parents, EJGSR-182,Sakha Super 303 and Sakha Super 301 were the best general combiners.

**Table 5. Rank of parents for general combining ability effects.**

| Genotypes | MDG | Ht (cm) | Pnl (cm) | Sp/ Pn | Pn/ P | FG/ Pn | Sp/ F% | GW (g) | YldH (g) | GYTH | Total | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lines** | | | | | | | | | | | | |
| PTGMS-20 | 2 | 2 | 5 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 42 | 5 |
| PTGMS-23 | 3 | 1 | 4 | 3 | 4 | 3 | 4 | 5 | 3 | 4 | 34 | 4 |
| PTGMS-38 | 5 | 4 | 3 | 1 | 2 | 1 | 1 | 3 | 2 | 3 | 25 | 2 |
| PTGMS-43 | 1 | 3 | 2 | 5 | 3 | 4 | 3 | 2 | 4 | 2 | 29 | 3 |
| PTGMS-78 | 4 | 5 | 1 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 20 | 1 |
| **Testers** | | | | | | | | | | | | |
| Minghui | 5 | 6 | 1 | 1 | 6 | 3 | 6 | 6 | 6 | 6 | 42 | 5 |
| Sakha Super 300 | 4 | 4 | 4 | 6 | 2 | 6 | 1 | 1 | 1 | 4 | 37 | 4 |
| Sakha Super 301 | 6 | 3 | 2 | 4 | 1 | 4 | 2 | 2 | 2 | 2 | 29 | 3 |
| Sakha Super 302 | 2 | 5 | 3 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 45 | 6 |
| Sakha Super 303 | 1 | 1 | 6 | 2 | 5 | 1 | 3 | 3 | 3 | 3 | 29 | 2 |
| EJGSR 182 | 3 | 2 | 5 | 3 | 3 | 2 | 4 | 4 | 4 | 1 | 28 | 1 |

**MDG (days) = Days to maturity, Ht (cm) = Plant height, Pnl (cm) = Panicle length, Sp/Pn = Spikelets panicle$^{-1}$, Pn/P = Panicles plant$^{-1}$, FG/Pn = Filled grains panicle$^{-1}$, Sp/F% = Spikelet fertility%, GW (g) = 1000 grain weight, Yld = Grain yield plant$^{-1}$, YldH (t/ha$^{-1}$) = Grain yield t/ha$^{-1}$.**

**Specific combining ability (SCA) effects**

The data of the SCA effects given in Table (6) indicated that there are some superior combinations that could be suseful in local super breeding program to get good recombinants. For days to maturity and plant height, eight and 11 hybrid rice combinations showed significant SCA effects in the desired direction for the two traits, respectively. For panicle length, nine hybrid rice combinations had superior SCA effects, 11 hybrids for spikelets panicle$^{-1}$, seven hybrids for panicles plant$^{-1}$, three hybrids for spikelet fertility%, eight for 1000-grain weight, nine for grain yield plant$^{-1}$ and five hybrids for grain yield t/ha$^{-1}$.

The SCA expresses the non-additive effects of genes. The results presented in Table (6) indicated that the traits depend not only on the GCA but also on the SCA, revealing that the cross combination PTGMS-43 x EJGSR182 (H x H) excelled others with significantly higher SCA effects for days to maturity, filled grains panicle$^{-1}$, spikelet fertility%, 1000-grain weight, and grain yield plant$^{-1}$. PTGMS-23 x Sakha Super 303 (L x H) for days to maturity, panicle length, panicles plant$^{-1}$ and grain yield plant$^{-1}$, PTGMS-38 x Sakha Super 303 (H x H) for days to maturity and grain yield plant$^{-1}$, PTGMS-20 x EJGSR 182 (L x H) for panicle length, spikelets panicle$^{-1}$, panicles plant$^{-1}$, and grain yield plant$^{-1}$, PTGMS-78 x EJGSR 182 (H x H) for panicles plant$^{-1}$, filled grains panicle $^{-1}$ and grain yield plant$^{-1}$. PTGMS-20xMighui 63 (L x L) Indica Japonica hybrid showed highly significant SCA effects for spikelets panicle$^{-1}$, filled grains panicle$^{-1}$, spikelet fertility%, 1000-grain weight, grain yield plant$^{-1}$ and grain yield t/ha$^{-1}$.

This study demonstrated that the majority of the hybrid combinations, showed significant SCA effects, which involved good and poor GCA, indicating additive x dominance type of gene interaction involved in the expression of traits. However, some combinations such as PTGMS-20 x Minghui 63 for grain yield plant$^{-1}$ and grain yield t/ha$^{-1}$ and PTGMS-23 x Minghui 63 for grain yield t/ha$^{-1}$ involving low x low GCA showed high SCA effects, suggesting that epistatic gene action, might be due to genetic diversity in the form of heterozygous loci.

**Table 6. Specific combining ability effects for super hybrid rice combinations for studied traits.**

| Hybrids | Days to maturity | Plant height (cm) | Panicle length (cm) | Spikelets panicle$^{-1}$ | Panicles plant$^{-1}$ |
|---|---|---|---|---|---|
| PTGMS-20/Minghui 63 | 0.79** | 1.61** | 0.28 | 21.43** | 0.28 |
| PTGMS-20/S.S.300 | -1.94** | -3.89** | 0.45* | -3.81 | 0.08 |
| PTGMS-20/S.S.301 | -1.15** | -2.04** | 0.01 | -10.53** | -0.32 |
| PTGMS-20/S.S.302 | 0.71** | -2.54** | -1.72** | -4.49* | -0.46 |
| PTGMS-20/S.S.303 | 0.22 | 4.78** | 0.11 | -10.41** | -0.15 |
| PTGMS-20/EJGSR-182 | 1.36** | 2.09** | 0.86** | 7.82** | 0.58* |
| PTGMS-23/Minghui 63 | 0.96** | 5.04** | -1.78** | 11.42** | 0.40 |
| PTGMS-23/S.S.300 | 1.26** | -5.51** | 0.14 | 1.88 | -0.82** |
| PTGMS-23/S.S.301 | -0.40 | -3.69** | 0.22 | 2.13 | -0.10 |
| PTGMS-23/S.S.302 | -0.49* | -1.44** | 0.86** | -3.52 | 0.76** |
| PTGMS-23/S.S.303 | -0.98** | 4.28** | 0.72** | -1.47 | 0.70* |
| PTGMS-23/EJGSR-182 | -0.36 | 1.32* | -0.16 | -10.44** | -0.95** |
| PTGMS-38/Minghui 63 | 0.47 | 1.20* | 1.81** | 10.01** | -0.26 |
| PTGMS-38/S.S.300 | 1.22** | 3.45** | -0.35* | 9.55** | -0.33 |
| PTGMS-38/S.S.301 | 1.01** | 0.45 | -0.35* | -7.88** | -0.46 |
| PTGMS-38/S.S.302 | -2.36** | 0.22 | -0.38* | 0.52 | -0.10 |
| PTGMS-38/S.S.303 | -0.60* | -0.96 | -0.67** | -4.26* | 0.21 |
| PTGMS-38/EJGSR-182 | 0.25 | -4.37** | -0.07 | -7.93** | 0.96** |
| PTGMS-43/Minghui 63 | -0.44 | -3.61** | 0.85** | -38.29** | 0.42 |
| PTGMS-43/S.S.300 | -0.31 | 2.63** | -0.13 | -13.42** | 0.27 |
| PTGMS-43/S.S.301 | 0.78** | 2.43** | 0.17 | 9.43** | 0.82** |
| PTGMS-43/S.S.302 | 0.76** | -0.29 | 0.69** | 29.90** | -0.22 |
| PTGMS-43/S.S.303 | 0.42 | -2.82** | -1.02** | 8.65** | -0.06 |
| PTGMS-43/EJGSR-182 | -1.21** | 1.66** | -0.55** | 3.73 | -1.23** |
| PTGMS-78/Minghui 63 | -1.79** | -4.25** | -1.15** | -4.57* | -0.84** |
| PTGMS-78/S.S.300 | -0.24 | 3.32** | -0.11 | 5.80** | 0.80** |
| PTGMS-78/S.S.301 | -0.25 | 2.85** | -0.05 | 6.85** | 0.07 |
| PTGMS-78/S.S.302 | 1.38** | 4.05** | 0.54** | -22.41** | 0.03 |
| PTGMS-78/S.S.303 | 0.94** | -5.28** | 0.85** | 7.50** | -0.69* |
| PTGMS-78/EJGSR-182 | -0.04 | -0.70 | -0.08 | 6.83 | 0.64* |
| SE (Sij) | 0.29 | 0.60 | 0.20 | 2.45 | 0.32 |
| LSD 5% | 0.49 | 0.99 | 0.34 | 4.07 | 0.53 |
| LSD 1% | 0.69 | 1.41 | 0.48 | 5.80 | 0.76 |

**Table 6. Cont.**

| Hybrids | Filled grains panicle$^{-1}$ | Spikelet fertility% | 1000 grain weight (g) | Grain yield plant$^{-1}$ (g) | Grain yield t/ ha$^{-1}$ |
|---|---|---|---|---|---|
| PTGMS-20/Minghui 63 | 25.87** | 2.17** | 0.51** | 4.53** | 0.43** |
| PTGMS-20/S.S.300 | -0.77 | 0.45 | -0.24* | -0.76 | -0.47** |
| PTGMS-20/S.S.301 | -11.71** | 0.04 | -0.12 | -3.84** | -0.36** |
| PTGMS-20/S.S.302 | -4.29** | -0.32 | -0.14 | -1.30* | 0.07 |
| PTGMS-20/S.S.303 | -10.44** | -0.33 | 0.02 | -3.52** | 0.21* |
| PTGMS-20/EJGSR-182 | 1.33 | -2.01** | -0.03 | 4.90** | 0.11 |
| PTGMS-23/Minghui 63 | 19.33** | 1.83** | 0.39** | -0.67 | 0.30** |
| PTGMS-23/S.S.300 | -0.06 | -0.95* | -0.11 | -5.03** | -0.02 |
| PTGMS-23/S.S.301 | -5.99** | -0.16 | -0.24* | 4.59** | -0.06 |
| PTGMS-23/S.S.302 | -4.60** | -0.66 | -0.27* | -1.22 | -0.09 |
| PTGMS-23/S.S.303 | -0.82 | -0.15 | -0.11 | 5.51** | -0.06 |
| PTGMS-23/EJGSR-182 | -7.86** | 0.08 | 0.34** | -3.17** | -0.08 |
| PTGMS-38/Minghui 63 | 0.87 | -1.52** | 0.25* | 1.03 | 0.02 |
| PTGMS-38/S.S.300 | 9.21** | 0.23 | -0.16 | 0.89 | 0.10 |
| PTGMS-38/S.S.301 | -4.58** | -0.08 | -0.07 | 1.71* | 0.16 |
| PTGMS-38/S.S.302 | 2.09 | 0.37 | 0.13 | 3.59** | -0.04 |
| PTGMS-38/S.S.303 | -2.58 | 0.41 | 0.11 | 5.33** | -0.01 |
| PTGMS-38/EJGSR-182 | -5.02** | 0.58 | -0.26* | -12.56** | -0.23* |
| PTGMS-43/Minghui 63 | -38.91** | -1.92** | -1.03** | -2.53** | -0.07 |
| PTGMS-43/S.S.300 | -13.18** | 0.31 | 0.42** | 4.50** | 0.07 |
| PTGMS-43/S.S.301 | 12.99** | 0.20 | 0.44** | -2.89** | 0.06 |
| PTGMS-43/S.S.302 | 27.33** | 0.17 | 0.04 | -1.12 | -0.27* |
| PTGMS-43/S.S.303 | 7.53** | 0.13 | -0.10 | -4.09** | 0.12 |
| PTGMS-43/EJGSR-182 | 4.25** | 1.11** | 0.24* | 6.12** | 0.08 |
| PTGMS-78/Minghui 63 | -7.16** | -0.56 | -0.11 | -2.36** | -0.68** |
| PTGMS-78/S.S.300 | 4.80** | -0.04 | 0.09 | 0.41 | 0.32** |
| PTGMS-78/S.S.301 | 9.29** | 0.00 | 0.00 | 0.43 | 0.19 |
| PTGMS-78/S.S.302 | -20.52** | 0.43 | 0.24* | 0.05 | 0.33** |
| PTGMS-78/S.S.303 | 6.31** | -0.06 | 0.08 | -3.24** | -0.28* |
| PTGMS-78/EJGSR-182 | 7.30** | 0.24 | -0.29** | 4.71** | 0.12 |
| SE (Sij) | 1.64 | 0.41 | 0.12 | 0.74 | 0.13 |
| LSD 5% | 2.72 | 0.68 | 0.20 | 1.23 | 0.21 |
| LSD 1% | 3.88 | 0.97 | 0.28 | 1.76 | 0.30 |

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

Yan *et al* (2000) reported that if the parents have lower GCA, but higher SCA cannot lead to strong heterosis of the hybrids. According to the GCA effects of their parents, the combining forms of these combinations were high x high, low x low, high x low and high x medium, indicating the genetic complexity of the trait. This situation was also found in other traits. It implied that there was no necessary relationship between GCA and SCA effects. The results we in accordance with results reported by El-Mowafi *et al* (2005)

**Estimates of genetic parameters and heritability**

The estimates of genetic parameters for ten studied traits are presented in Table (7). The results indicated that the additive genetic variance ($\sigma^2A$) and relative importance of GCA for all traits studied were greater than dominance variance ($\sigma^2D$) and relative importance of SCA%. The importance of the additive gene action for the inheritance of these traits is in agreement with the findings reported by El-Mowafi *et al* (2005), Shrivastava *et al* (2015) and Reda *et al* (2023).

Concerning heritability estimates in broad sense heritability ($h^2_b$) %, the results in Table (7) indicated that the heritability values were high for all agronomic and yield traits and ranged between 89.717% for 1000-grain weight to 98.930% for days to maturity. However, heritability estimates in marrow sense ($h^2_n$) % were high for most of traits studied, days to maturity (94.53%), plant height (88.13%), panicle length (93.38%), spikelets panicle$^{-1}$ (80.40%), panicles plant$^{-1}$ (80.63%), filled grains panicle$^{-1}$ (55.31%), spikelet fertility% (94.74%), 1000-grain weight (68.51%), grain yield plant$^{-1}$ (65.24%) and grain yield t/ha$^{-1}$ (91.91%). These results are in general agreement with those reported by El-Mowafi *et al* (2018),

The results explain why GCA was superior to SCA and the additive gene action was greater than non-additive for all traits studied.

**Heterosis and superiority percentage**

The three important genetic factors affecting heterosis are: (i) the genetic diversity of the parents, where the heterotic effects increased with the increase of the genetic divergence in traits, and also with respect to geographical origin of parents; (ii) the genetic base of the parents and, (iii) the wider adaptability of the parents.

**Table 7. Genetic parameters of studied traits.**

| Parameter | Days to maturity | Plant height (cm) | Panicle length (cm) | Spikelets panicle$^{-1}$ | Panicles plant$^{-1}$ |
|---|---|---|---|---|---|
| Additive variance ($\sigma^2$ A) | 30.488 | 119.117 | 14.174 | 1057.830 | 3.305 |
| Dominance variance ($\sigma^2$ D) | 1.417 | 14.615 | 0.838 | 233.705 | 0.379 |
| Environmental variance ($\sigma^2$ E) | 0.345 | 1.422 | 0.167 | 24.094 | 0.415 |
| Genotypic variance ($\sigma^2$ G) | 31.905 | 133.732 | 15.011 | 1291.534 | 3.683 |
| Phenotypic variance ($\sigma^2$ P) | 32.250 | 135.154 | 15.178 | 1315.628 | 4.098 |
| Broad sense heritability ( $h^2b$) % | 98.930 | 98.948 | 98.900 | 98.169 | 89.873 |
| Narrow sense heritability ($h^2n$) % | 94.538 | 88.134 | 93.382 | 80.405 | 80.637 |
| Relative importance of gca%* | 95.560 | 89.071 | 94.421 | 81.905 | 89.723 |
| Relative importance of sca%** | 4.440 | 10.929 | 5.579 | 18.095 | 10.277 |
| **Parameter** | **Filled grains panicle$^{-1}$** | **Spikelet fertility%** | **1000-grain weight$^{-1}$ (g)** | **Grain yield plant$^{-1}$ (g)** | **Grain yield t/ha$^{-1}$** |
| Additive variance ($\sigma^2$ A) | 314.835 | 29.355 | 0.380 | 45.463 | 0.781 |
| Dominance variance ($\sigma^2$ D) | 243.544 | 0.958 | 0.118 | 24.218 | 0.069 |
| Environmental variance ($\sigma^2$ E) | 10.773 | 0.670 | 0.057 | 2.209 | 0.066 |
| Genotypic variance ($\sigma^2$ G) | 558.379 | 30.313 | 0.497 | 69.682 | 0.850 |
| Phenotypic variance ($\sigma^2$ P) | 569.152 | 30.983 | 0.554 | 71.891 | 0.916 |
| Broad sense heritability ( $h^2b$)% | 98.107 | 97.838 | 89.717 | 96.927 | 92.797 |
| Narrow sense heritability ($h^2n$)% | 55.317 | 94.746 | 68.519 | 63.240 | 85.293 |
| Relative importance of gca%* | 56.384 | 96.840 | 76.372 | 65.244 | 91.914 |
| Relative importance of sca%** | 43.616 | 3.160 | 23.628 | 34.756 | 8.086 |

***, ** Relative importance gca = $\sigma^2$ A / $\sigma^2$ G x 100 and Relative importance sca = $\sigma^2$ D / $\sigma^2$ G x 100, respectively**

High positive values of heterosis would be of interest for all studied traits, except for days to maturity and plant height, where negative values would be useful. The superiority over the best standard variety is especially important because the hybrid to be released is expected to outperform the existing superior local variety or hybrid.

**Days to maturity**

The negative estimates of heterosis for days to maturity are performed to develop earliness super rice hybrids. Results in Table 8 showed that ten hybrids indicated desirable significant and highly significant negative heterosis over mid parents (MP). The best estimates were recorded for the hybrid combinations PTGMS-38 x Sakha Super 303 (-2.01%), PTGMS-38 x Sakha Super 302 (-1.93%) and PTGMS-20 x Sakha Super 300 (-1.60%). However, results in Table (8) revealed that significant heterosis effects were found as deviation from the better-parent (BP) value for one hybrid combination namely PTGMS-78xSakha Super 300 (-0.59%).

Evaluation based on the superiority (over check cultivar Sakha Super 300) indicated that 17 hybrids recorded significant and negative values. The hybrids, PTGMS-23 x Sakha Super 303 (-7.60%), PTGMS-43 x Sakha Super 303 (-7.54%), and PTGMS-20 x Sakha Super 303 (-7.38%) showed the earliest maturity with highly significant negative superiority over check cultivar Sakha Super 300, These findings revealed that we can get earliness in new super rice hybrids which is in agreement with results of El-Mowafi (2001).

**Plant height (cm)**

Results in Table (8) reported that all the hybrid rice combinations (30 hybrids) had highly significant and positive heterosis for plant height trait over the mid-parents and better parent. Such estimates ranged from 2.00% in the hybrid PTGMS-23 x Sakha Super 300 to 30.20% in the super hybrid combination PTGMS-23 x Minghui 63 for mid-parents and ranged from 3.01% in the hybrid PTGMS-78 x Sakha Super 303 to 58.31% in the hybrid, PTGMS-23 x Minghui 63 for BP heterosis.

Data in Table (8) indicated that 16 hybrid combinations exhibited desirable negative and highly significant superiority over check cultivar Sakha Super 300 values towards short stature plant. Similar results were reported by Abdallah (2008), El-Mowafi *et al* (2012), Hadifa (2021) and Reda *et al* (2023).

**Table 8. Estimates of mid- parent heterosis (MP)%, better-parent heterosis (BP)%, and superiority to the standard variety (SV)% for days to maturity and plant height traits.**

| Genotypes | Days to maturity (day) | | | Plant height (cm) | | |
|---|---|---|---|---|---|---|
| | MP% | BP% | SV% | MP% | BP% | SV% |
| PTGMS-20/Minghui | 2.69** | 4.06** | 1.37** | 27.13** | 51.63** | 9.44** |
| PTGMS-20/Sakha Super300 | -1.60** | 0.73* | -1.88** | 4.06** | 25.14** | -9.68** |
| PTGMS-20/Sakha Super301 | -0.10 | 2.94** | 0.28 | 7.04** | 24.75** | -9.97** |
| PTGMS-20/Sakha Super302 | 0.36 | 5.40** | -6.70** | 7.28** | 29.26** | -6.71** |
| PTGMS-20/Sakha Super303 | -0.36 | 4.66** | -7.38** | 10.93** | 21.98** | -11.96** |
| PTGMS-20/EJGSR182 | 0.25 | 2.01** | -4.00** | 15.36** | 28.78** | -7.05** |
| PTGMS-23/Minghui | 2.13** | 2.18** | 2.18** | 30.20** | 58.31** | 10.56** |
| PTGMS-23/Sakha Super300 | 0.14 | 1.11** | 1.20** | 2.00** | 25.05** | -12.67** |
| PTGMS-23/Sakha Super301 | -0.20 | 1.42** | 1.52** | 4.91** | 24.61** | -12.98** |
| PTGMS-23/Sakha Super302 | -1.30** | 5.14** | -6.93** | 7.84** | 32.47** | -7.49** |
| PTGMS-23/Sakha Super303 | -2.01** | 4.41** | -7.60** | 9.93** | 23.09** | -14.04** |
| PTGMS-23/EJGSR182 | -1.77** | 1.36** | -4.61** | 14.16** | 29.79** | -9.36** |
| PTGMS-38/Minghui | 2.51** | 3.75** | 3.75** | 24.99** | 37.05** | 14.89** |
| PTGMS-38/Sakha Super300 | 0.87** | 1.07** | 3.11** | 10.21** | 21.76** | 2.07** |
| PTGMS-38/Sakha Super301 | 1.59** | 2.05** | 4.52** | 8.78** | 16.71** | -2.16** |
| PTGMS-38/Sakha Super302 | -1.93** | 5.76** | -6.38** | 9.21** | 20.87** | 1.33* |
| PTGMS-38/Sakha Super303 | -0.86** | 6.94** | -5.36** | 4.66** | 6.36** | -10.84** |
| PTGMS-38/EJGSR182 | -0.48* | 3.91** | -2.21** | 8.19** | 11.50** | -6.53** |
| PTGMS-43/Minghui | 2.25** | 4.46** | 0.13 | 24.24** | 41.95** | 10.46** |
| PTGMS-43/Sakha Super300 | 0.09 | 3.31** | -0.98** | 12.59** | 29.67** | 0.90 |
| PTGMS-43/Sakha Super301 | 1.81** | 5.79** | 1.40** | 13.82** | 27.16** | -1.06 |
| PTGMS-43/Sakha Super302 | 0.91** | 5.09** | -6.98** | 11.83** | 29.02** | 0.39 |
| PTGMS-43/Sakha Super303 | 0.31 | 4.48** | -7.54** | 6.01** | 11.97** | -12.87** |
| PTGMS-43/EJGSR182 | -1.30** | -0.38 | -6.25** | 17.36** | 25.78** | -2.13** |
| PTGMS-78/Minghui | 0.07 | 0.71* | 0.71* | 21.23** | 29.46** | 13.98** |
| PTGMS-78/Sakha Super300 | -0.96** | -0.59* | 0.68* | 11.37** | 19.82** | 5.49** |
| PTGMS-78/Sakha Super301 | -0.08 | 0.94** | 2.23** | 12.25** | 17.36** | 3.32** |
| PTGMS-78/Sakha Super302 | 0.20 | 7.42** | -4.91** | 13.78** | 22.62** | 7.96** |
| PTGMS-78/Sakha Super303 | -0.46 | 6.72** | -5.55** | 2.13** | 3.01** | -10.84** |
| PTGMS-78/EJGSR182 | -1.50** | 2.25** | -3.77** | 12.97** | 13.57** | -0.02 |
| LSD 5 % | 0.60 | 0.69 | 0.69 | 1.21 | 1.40 | 1.40 |
| LSD 1% | 0.85 | 0.98 | 0.98 | 1.73 | 1.99 | 1.99 |

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

**Panicle length**

Results in Table (9) revealed that all 30 hybrids were significant or highly significant and positive desirable for mid-parents heterosis ranging from 2.59% in the hybrid PTGMS-38xSakha Super 303 to 36.91% in the super hybrid combination PTGMS-43 x Sakha Super 302. Data in Table (8) revealed that 22 hybrids showed desirable significant or highly significant and positive heterosis over better-parent. The highest values were recorded for the hybrid combinations PTGMS-78 x Sakha Super 302 (18.35%), PTGMS-43 x Sakha Super 302 (17.81%) and PTGMS-78 x Sakha Super 300 (16.40%). As evident from Table (9), the 30 hybrids showed negative (undesirable) superiority over check cultivar Sakha Super 300 and ranged from -0.08 for PTGMS-43xMighui 63 to -41.68% for PTGMS-20xSakha Super 303. These results are in general agreement with those reported by El-Mowafi (2001), Singh *et al* (2002) and El-Mowafi *et al* (2021a).

**Spikelets panicle$^{-1}$**

Results in Table (9) indicated that all hybrid rice combinations scored highly significant and positive (desirable) for both of the mid-parent and better-parent and ranged from 20.58% for PTGMS-78 x Sakha Super 302 to 78.57% for PTGMS-23 x Minghui 63 and from 7.75% for PTGMS-78 x Sakha Super 302 to 35.44% for PTGMS-20 x Minghui 63, respectively. The estimates of positive superiority over check cultivar Sakha Super 300 were highly significant in 25 hybrid rice combinations for spikelets panicle$^{-1}$ trait. The highest estimates were exhibited by PTGMS-20 x Minghui 63 (35.44%), PTGMS-38 x Minghui 63 (34.60%) and PTGMS-23 x Minghui 63 (34.10%). These results are in agreement with the findings of Patil *et al* (2012), Abdallah (2013), Hadifa (2021) and Mahrous (2022).

**Panicles plant$^{-1}$**

Data in Table (10) showed that 18 hybrids showed significant or highly significant and positive MP heterosis estimates and ranged from 3.55% in the hybrid PTGMS-38 x Sakha Super 303 to 14.43% in the hybrid, PTGMS-78 x Sakha Super 300. For BP heterosis, data showed that five hybrids tested had significant or highly significant and positive (desirable) which ranged from 3.40% to 9.58% for the hybrids PTGMS-78 x Sakha Super 300 and PTGMS-20 x Minghui 63, respectively.

**Table 9. Estimates of mid-parent heterosis (MP)%, better-parent heterosis (BP)%, and superiority to the standard variety (SV)% for panicle length and spikelets panicle$^{-1}$ traits.**

| Genotypes | Panicle length (cm) | | | Spikelets panicle$^{-1}$ | | |
|---|---|---|---|---|---|---|
| | MP% | BP% | SV% | MP% | BP% | SV% |
| PTGMS-20/Minghui | 18.22** | -10.02** | -10.02** | 76.03** | 35.44** | 35.44** |
| PTGMS-20/Sakha Super300 | 18.71** | 5.50** | -29.12** | 42.29** | 18.74** | -4.36** |
| PTGMS-20/Sakha Super301 | 17.98** | 0.52 | -25.42** | 53.45** | 25.48** | 6.41** |
| PTGMS-20/Sakha Super302 | 11.18** | -3.97** | -31.05** | 41.04** | 11.81** | 2.91** |
| PTGMS-20/Sakha Super303 | 9.00** | 6.47** | -41.68** | 43.51** | 8.86** | 13.44** |
| PTGMS-20/EJGSR182 | 15.15** | 8.01** | -35.59** | 52.19** | 18.70** | 14.23** |
| PTGMS-23/Minghui | 12.40** | -14.79** | -14.79** | 78.57** | 34.10** | 34.10** |
| PTGMS-23/Sakha Super300 | 20.36** | 6.42** | -28.51** | 52.00** | 23.36** | -0.65 |
| PTGMS-23/Sakha Super301 | 22.11** | 3.53** | -23.19** | 66.50** | 32.51** | 12.38** |
| PTGMS-23/Sakha Super302 | 27.22** | 9.33** | -21.49** | 47.80** | 14.19** | 5.10** |
| PTGMS-23/Sakha Super303 | 16.15** | 12.80** | -38.21** | 53.12** | 13.44** | 18.20** |
| PTGMS-23/EJGSR182 | 13.02** | 5.43** | -37.13** | 50.56** | 14.54** | 10.23** |
| PTGMS-38/Minghui | 21.87** | -1.69* | -1.69* | 72.61** | 34.60** | 34.60** |
| PTGMS-38/Sakha Super300 | 12.11** | 7.22** | -27.97** | 50.61** | 27.62** | 2.78** |
| PTGMS-38/Sakha Super301 | 13.81** | 3.95** | -22.88** | 56.45** | 29.83** | 10.10** |
| PTGMS-38/Sakha Super302 | 15.28** | 6.87** | -23.27** | 45.09** | 16.65** | 7.36** |
| PTGMS-38/Sakha Super303 | 2.59* | -2.89** | -40.45** | 47.68** | 13.49** | 18.26** |
| PTGMS-38/EJGSR182 | 7.77** | 6.28** | -34.82** | 47.18** | 16.37** | 11.99** |
| PTGMS-43/Minghui | 31.68** | -0.08 | -0.08 | 36.47** | 15.71** | 15.71** |
| PTGMS-43/Sakha Super300 | 29.92** | 15.02** | -22.73** | 22.65** | 14.31** | -7.94** |
| PTGMS-43/Sakha Super301 | 32.23** | 12.25** | -16.72** | 45.58** | 32.51** | 12.38** |
| PTGMS-43/Sakha Super302 | 36.91** | 17.81** | -15.41** | 40.49** | 23.35** | 13.53** |
| PTGMS-43/Sakha Super303 | 18.29** | 15.05** | -36.98** | 37.08** | 14.31** | 19.11** |
| PTGMS-43/EJGSR182 | 22.54** | 14.47** | -31.74** | 35.63** | 16.84** | 12.44** |
| PTGMS-78/Minghui | 16.45** | -5.39** | -5.39** | 49.73** | 29.10** | 29.10** |
| PTGMS-78/Sakha Super300 | 20.62** | 16.40** | -21.80** | 31.74** | 25.12** | 0.77 |
| PTGMS-78/Sakha Super301 | 22.10** | 12.46** | -16.56** | 45.06** | 34.49** | 14.06** |
| PTGMS-78/Sakha Super302 | 26.56** | 18.35** | -15.02** | 20.58** | 7.75** | -0.83 |
| PTGMS-78/Sakha Super303 | 18.79** | 11.47** | -30.35** | 37.28** | 16.36** | 21.25** |
| PTGMS-78/EJGSR182 | 15.58** | 12.95** | -29.43** | 37.48** | 20.49** | 15.95** |
| LSD 5 % | 0.42 | 0.48 | 0.48 | 4.99 | 5.76 | 5.76 |
| LSD 1% | 0.59 | 0.68 | 0.68 | 7.11 | 8.21 | 8.21 |

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

Results for panicles plant$^{-1}$ (Table 10) indicated that out of the thirty super hybrid rice combinations as many as 26 recorded highly significant and positive superiority over the check variety Sakha Super 300. The highest values were detected for the hybrid combinations, PTGMS-78 x Sakha Super 300 (42.47%), PTGMS-78 x Sakha Super 301 (31.11%) and PTGMS-38 x Sakha Super 300 (30.11%). These findings for panicles plant$^{-1}$ are in agreement with those reported by Abd Allah (2008), Abd Allah (2013), Hadifa (2021) and Mahrous (2022).

**Filled grains panicle$^{-1}$**

Highly significant and positive values of heterosis over mid-parent (MP), better-parent (BP) and superiority to the standard variety (SV) for 30, 29 and 27 super hybrid combinations for filled grains panicle$^{-1}$. The highest MP heterosis effects were 60.12%, 59.28% and 56.10% for the hybrids, PTGMS-23 x Minghui 63, PTGMS-23 x Sakha Super 301 and PTGMS-38 x Sakha Super 301, respectively. Moreover, the highest BP heterosis effects were 34.59%, 33.19% and 30.15% for the hybrid combinations, PTGMS-78xSakha Super 301, PTGMS-43 x Sakha Super 301, PTGMS-38 x Sakha Super 301. Data in Table (10) revealed that 27 hybrids showed highly significant and positive SV% over the check cultivar Sakha Super 300. The superiority for filled grains panicle$^{-1}$ ranged from 2.69% for PTGMS-20 x Sakha Super 302 to 24.45% for PTGMS-78 x Sakha Super 303. These results are in agreement with those reported by Singh *et al* (2002), El-Diasty *et al* (2008), Hadifa (2021).

**Spikelet fertility%**

Non significant and positive MP and BP heterosis estimates for spikelet fertility% trait were recorded for eight and five hybrid combinations respectively, while the rest of hybrids had undesirable non-significant or highly significant heterosis. The superiority over the check cultivar Sakha Super 300 was highly significant and positive for 22 hybrids and ranged from 1.55% in the hybrid, PTGMS23 x Sakha Super 302 to 4.63% in the hybrid PTGMS-38xSakha Super 300. The reports of Banumathy *et al* (2003), Abd Allah (2008), El-Mowafi *et al* (2012), Thorat *et al* (2017), El-Mowafi *et al* (2018) and Mahrous (2022) also revealed high level of negative and positive heterosis for spikelet fertility% trait.

**Table 10. Estimates of mid-parent heterosis (MP)%, better-parent heterosis (BP)% and superiority to the standard variety (SV)% for panicles plant$^{-1}$ and filled grains panicle$^{-1}$ traits.**

| Genotypes | Panicles plant$^{-1}$ | | | Filled grains panicle$^{-1}$ | | |
|---|---|---|---|---|---|---|
| | MP % | BP % | SV % | MP % | BP % | SV % |
| PTGMS-20/Minghui | -0.14 | -1.92 | 1.70 | 54.16** | 20.58** | 20.58** |
| PTGMS-20/Sakha Super300 | 13.42** | 9.58** | 21.88** | 39.09** | 16.10** | -2.14** |
| PTGMS-20/Sakha Super301 | 8.43* | 8.36** | 12.36** | 46.89** | 20.46** | 6.19** |
| PTGMS-20/Sakha Super302 | 3.61 | -3.56 | 0.00 | 36.52** | 9.23** | 2.69** |
| PTGMS-20/Sakha Super303 | 4.41* | -4.25* | -0.71 | 39.38** | 6.64** | 13.49** |
| PTGMS-20/EJGSR182 | 7.12** | 5.07* | 8.95** | 44.84** | 13.97** | 12.09** |
| PTGMS-23/Minghui | -1.48 | -9.70** | 8.38** | 60.12** | 22.44** | 22.44** |
| PTGMS-23/Sakha Super300 | 6.14** | 2.25 | 22.73** | 49.06** | 21.33** | 2.28** |
| PTGMS-23/Sakha Super301 | 6.99** | -0.36 | 19.60** | 59.28** | 27.46** | 12.36** |
| PTGMS-23/Sakha Super302 | 7.87** | -5.92** | 12.93** | 45.28** | 13.54** | 6.74** |
| PTGMS-23/Sakha Super303 | 6.60** | -8.28** | 10.09** | 51.90** | 13.73** | 21.03** |
| PTGMS-23/EJGSR182 | -3.30 | -11.48** | 6.25** | 49.42** | 14.92** | 13.03** |
| PTGMS-38/Minghui | -4.89** | -15.77** | 9.23** | 48.35** | 17.83** | 17.83** |
| PTGMS-38/Sakha Super300 | 8.02** | 0.33 | 30.11** | 50.08** | 27.42** | 7.41** |
| PTGMS-38/Sakha Super301 | 4.75** | -5.81** | 22.16** | 56.10** | 30.15** | 14.73** |
| PTGMS-38/Sakha Super302 | 2.85 | -13.14** | 12.64** | 45.19** | 18.03** | 10.97** |
| PTGMS-38/Sakha Super303 | 3.55* | -13.69** | 11.93** | 47.99** | 14.91** | 22.29** |
| PTGMS-38/EJGSR182 | 6.13** | -6.13** | 21.73** | 47.45** | 17.84** | 15.90** |
| PTGMS-43/Minghui | -2.79 | -12.16** | 8.81** | 16.73** | 0.34 | 0.34 |
| PTGMS-43/Sakha Super300 | 9.97** | 4.36* | 29.26** | 22.97** | 13.94** | -3.96** |
| PTGMS-43/Sakha Super301 | 10.06** | 1.03 | 25.14** | 46.70** | 33.19** | 17.41** |
| PTGMS-43/Sakha Super302 | 1.00 | -13.07** | 7.67** | 40.24** | 23.76** | 16.35** |
| PTGMS-43/Sakha Super303 | 0.88 | -14.33** | 6.11** | 37.21** | 14.97** | 22.35** |
| PTGMS-43/EJGSR182 | -6.10** | -15.25** | 4.97 | 35.86** | 17.60** | 15.66** |
| PTGMS-78/Minghui | -5.85** | -18.76** | 11.93** | 30.77** | 14.04** | 14.04** |
| PTGMS-78/Sakha Super300 | 14.43** | 3.40* | 42.47** | 32.19** | 24.44** | 4.90** |
| PTGMS-78/Sakha Super301 | 8.65** | -4.85** | 31.11** | 45.96** | 34.59** | 18.64** |
| PTGMS-78/Sakha Super302 | 5.07** | -13.40** | 19.32** | 21.19** | 8.55** | 2.06** |
| PTGMS-78/Sakha Super303 | 0.57 | -18.14** | 12.78** | 37.64** | 16.94** | 24.45** |
| PTGMS-78/EJGSR182 | 5.98** | -8.66** | 25.85** | 38.06** | 21.26** | 19.27** |
| LSD 5 % | 0.65 | 0.76 | 0.76 | 3.34 | 3.85 | 3.85 |
| LSD 1% | 0.93 | 1.08 | 1.08 | 4.75 | 5.49 | 5.49 |

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

**1000-grain weight**

Twenty five hybrid rice combinations showed significant or highly significant and positive heterosis (desirable) over mid-parents for 1000-grain weight trait and ranged from 0.98% for PTGMS-78 x Sakha Super 302 to 7.98% for PTGMS-43 x Sakha Super 301. The result in Table (11) indicated that nine hybrids had highly significant and positive estimates of BP heterosis and ranged from 1.56% for PTGMS-20 x Minghui 63 and PTGMS-38 x Sakha Super 301 to 4.20% for PTGMS-43 x Sakha Super 300. Significant or highly significant and positive superiority over the check cultivar (SV%) Sakha Super 300. Moreover, significant and positive (desirable) superiority values were found for ten hybrids. These estimates ranged from 1.22% to 3.12% for the hybrids, PTGMS-38 x EJGSR-182 and PTGMS-43 x EJGSR-182, respectively. Significant superiority for 1000-grain weight trait was also detected by Rahimi *et al* (2010), Borah *et al* (2017) and El-Mowafi *et al* (2021) b.

**Grain yield plant$^{-1}$**

Data in Table (12), indicated that highly significant heterosis values for all thirty super hybrid rice combinations studied over mid-parents (MP), better-parents (BP) and superiority to the standard variety Sakha Super 300. The highest values for MP heterosis were detected for the hybrids, PTGMS-23 x Sakha Super 303 (59.38%), PTGMS-38 x Sakha Super 303 (57.03%) and PTGMS-23 x Sakha Super 301 (54.69%). However, desirable heterosis over BP was ranged from 8.50% for PTGMS-20 x Minghui 63 to 40.63 % for PTGMS-38 x Sakha Super 303.

Superiority% to the check cultivar Sakha Super 300 was highly significant and positive (desirable) for all 30 combinations tested. The highest estimate (50.78%) was obtained for the hybrid PTGMS-38xSakha Super 303, followed by 48.59% for PTGMS-23xSakha Super 301, 48.06% for PTGMS-78xEJGSR-182 then 48.0% for PTGMS-78xSakha Super 300. Positive values of heterosis effects for grain yield traits were previously reported by Attia (2001), Kumar and Singh (2002), Abd Allah (2008), Abd Allah (2013), El-Mowafi *et al* (2018), El-Mowafi *et al* (2021b) and Mahrous (2022).

**Table 11. Estimates of mid-parent heterosis (MP%), better-parent heterosis (BP%), and superiority to the standard variety (SV%) for spikelet fertility% and 1000- grain weight traits.**

| Genotypes | Spikelet fertility% | | | 1000 grain weight ( g) | | |
|---|---|---|---|---|---|---|
| | MP% | BP% | SV% | MP% | BP% | SV% |
| PTGMS-20/Minghui | -13.03** | -14.99** | -10.98* | 5.80** | 1.56** | 1.56** |
| PTGMS-20/Sakha Super300 | -2.26** | -2.29** | 2.32** | 2.23** | -0.09 | -3.73** |
| PTGMS-20/Sakha Super301 | -2.45** | -2.81** | 1.77** | 3.22** | -0.31 | -1.56** |
| PTGMS-20/Sakha Super302 | -3.53** | -4.71** | -0.22 | 0.19 | -3.34** | -4.34** |
| PTGMS-20/Sakha Super303 | -3.25** | -4.45** | 0.05 | 2.46** | -1.57** | -1.73** |
| PTGMS-20/EJGSR182 | -5.16** | -6.30** | -1.88** | 1.77** | -4.60** | 0.32 |
| PTGMS-23/Minghui | -11.62** | -13.90** | -9.21** | 5.34** | 0.87 | 0.87 |
| PTGMS-23/Sakha Super300 | -2.01** | -2.38** | 2.94** | 2.68** | 0.11 | -3.54** |
| PTGMS-23/Sakha Super301 | -0.95* | -1.65** | 3.71** | 2.75** | -1.01* | -2.24** |
| PTGMS-23/Sakha Super302 | -2.17** | -3.70** | 1.55** | -0.28 | -4.03** | -5.03** |
| PTGMS-23/Sakha Super303 | -1.34** | -2.89** | 2.40** | 1.99** | -2.26** | -2.41** |
| PTGMS-23/EJGSR182 | -1.25** | -2.76** | 2.53** | 3.06** | -3.62** | 1.34* |
| PTGMS-38/Minghui | -14.66** | -16.76** | -12.45** | 4.37** | 2.35** | 2.35** |
| PTGMS-38/Sakha Super300 | -0.27 | -0.52 | 4.63** | 2.08** | 1.95** | -1.76** |
| PTGMS-38/Sakha Super301 | -0.35 | -0.93 | 4.20** | 2.93** | 1.56** | 0.29 |
| PTGMS-38/Sakha Super302 | -0.57 | -1.99** | 3.08** | 0.76 | -0.69 | -1.72** |
| PTGMS-38/Sakha Super303 | -0.24 | -1.68** | 3.41** | 2.33** | 0.42 | 0.26 |
| PTGMS-38/EJGSR182 | -0.20 | -1.61** | 3.49** | 0.58 | -3.75** | 1.22* |
| PTGMS-43/Minghui | -14.70** | -16.08** | -13.27** | 2.99** | -1.85** | -1.85** |
| PTGMS-43/Sakha Super300 | 0.31 | -0.31 | 4.33** | 7.40** | 4.20** | 0.40 |
| PTGMS-43/Sakha Super301 | 0.45 | 0.16 | 4.11** | 7.98** | 3.53** | 2.23** |
| PTGMS-43/Sakha Super302 | -0.27 | -0.84 | 2.48** | 3.58** | -0.80 | -1.82** |
| PTGMS-43/Sakha Super303 | -0.01 | -0.61 | 2.72** | 4.77** | -0.08 | -0.24 |
| PTGMS-43/EJGSR182 | 0.87 | 0.32 | 3.68** | 5.35** | -1.94** | 3.12** |
| PTGMS-78/Minghui | -12.85** | -14.01** | -11.66** | 2.90** | 2.95** | 2.95** |
| PTGMS-78/Sakha Super300 | 0.38 | -0.55 | 4.09** | 2.75** | 0.82 | 0.93 |
| PTGMS-78/Sakha Super301 | 0.67 | 0.08 | 4.03** | 2.97** | 2.27** | 2.38** |
| PTGMS-78/Sakha Super302 | 0.44 | 0.16 | 2.89** | 0.98* | 0.40 | 0.51 |
| PTGMS-78/Sakha Super303 | 0.21 | -0.08 | 2.64** | 2.03** | 1.89** | 2.00** |
| PTGMS-78/EJGSR182 | 0.39 | 0.13 | 2.86** | 0.35 | -2.06** | 2.99** |
| LSD 5 % | 0.83 | 0.96 | 0.96 | 0.24 | 0.28 | 0.28 |
| LSD 1% | 1.18 | 1.37 | 1.37 | 0.35 | 0.40 | 0.40 |

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

**Table 12. Estimates of mid-parent heterosis (MP%), better-parents (BP%) and superiority to the standard variety (SV%) for grain yield plant$^{-1}$ and grain yield (t/ha$^{-1}$) traits.**

| Genotypes | Grain yield plant$^{-1}$ | | | Grain yield (t/ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | MP% | BP% | SV% | MP% | BP% | SV% |
| PTGMS-20/Minghui | 28.55** | 8.50** | 8.50** | 34.57** | 10.44** | 10.44** |
| PTGMS-20/Sakha Super300 | 38.35** | 10.79** | 26.71** | 38.19** | 9.97** | 19.22** |
| PTGMS-20/Sakha Super301 | 32.52** | 6.37** | 20.90** | 40.11** | 11.05** | 21.72** |
| PTGMS-20/Sakha Super302 | 32.11** | 8.65** | 15.91** | 49.50** | 22.08** | 23.66** |
| PTGMS-20/Sakha Super303 | 35.48** | 11.21** | 19.23** | 45.65** | 15.69** | 26.06** |
| PTGMS-20/EJGSR182 | 44.74** | 17.81** | 29.09** | 44.22** | 13.23** | 27.36** |
| PTGMS-23/Minghui | 26.58** | 12.95** | 12.95** | 34.02** | 14.14** | 14.14** |
| PTGMS-23/Sakha Super300 | 37.68** | 16.06** | 32.75** | 43.54** | 18.33** | 28.28** |
| PTGMS-23/Sakha Super301 | 54.69** | 30.74** | 48.59** | 43.81** | 18.04** | 29.39** |
| PTGMS-23/Sakha Super302 | 39.74** | 21.26** | 29.36** | 47.98** | 25.36** | 26.99** |
| PTGMS-23/Sakha Super303 | 59.38** | 38.01** | 47.96** | 43.30** | 17.90** | 28.47** |
| PTGMS-23/EJGSR182 | 36.82** | 17.40** | 28.64** | 42.77** | 16.02** | 30.50** |
| PTGMS-38/Minghui | 28.76** | 18.99** | 18.99** | 24.99** | 13.96** | 13.96** |
| PTGMS-38/Sakha Super300 | 46.56** | 27.62** | 45.97** | 38.28** | 21.65** | 31.89** |
| PTGMS-38/Sakha Super301 | 47.94** | 29.17** | 46.82** | 39.53** | 22.18** | 33.92** |
| PTGMS-38/Sakha Super302 | 46.94** | 31.89** | 40.70** | 41.62** | 28.38** | 30.04** |
| PTGMS-38/Sakha Super303 | 57.03** | 40.63** | 50.78** | 37.39** | 20.61** | 31.42** |
| PTGMS-38/EJGSR182 | 19.10** | 5.65** | 15.76** | 35.10** | 17.01** | 31.61** |
| PTGMS-43/Minghui | 21.99** | 8.58** | 8.58** | 24.68** | 14.14** | 14.14** |
| PTGMS-43/Sakha Super300 | 53.64** | 29.21** | 47.78** | 38.32** | 22.17** | 32.44** |
| PTGMS-43/Sakha Super301 | 40.48** | 18.45** | 34.63** | 38.99** | 22.18** | 33.92** |
| PTGMS-43/Sakha Super302 | 38.97** | 20.29** | 28.33** | 39.85** | 27.28** | 28.93** |
| PTGMS-43/Sakha Super303 | 40.77** | 21.60** | 30.37** | 39.08** | 22.56** | 33.55** |
| PTGMS-43/EJGSR182 | 52.77** | 30.76** | 43.28** | 38.47** | 20.38** | 35.40** |
| PTGMS-78/Minghui | 20.80** | 16.05** | 16.05** | 17.74** | 9.80** | 9.80** |
| PTGMS-78/Sakha Super300 | 43.34** | 29.40** | 48.00** | 39.59** | 25.49** | 36.04** |
| PTGMS-78/Sakha Super301 | 43.32** | 29.75** | 47.48** | 39.11** | 24.45** | 36.41** |
| PTGMS-78/Sakha Super302 | 38.32** | 28.89** | 37.50** | 44.49** | 33.94** | 35.67** |
| PTGMS-78/Sakha Super303 | 39.46** | 29.65** | 39.00** | 34.18** | 20.36** | 31.15** |
| PTGMS-78/EJGSR182 | 46.80** | 35.12** | 48.06** | 37.67** | 21.77** | 36.97** |
| LSD 5 % | 1.51 | 1.74 | 1.74 | 0.26 | 0.30 | 0.30 |
| LSD 1% | 2.15 | 2.48 | 2.48 | 0.37 | 0.43 | 0.43 |

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

**Grain yield t/ha$^{-1}$**

Results in Table (12) revealed that all hybrid rice combinations scored highly significant and positive desirable MP heterosis in grain yield t/ha$^{-1}$ ranging from 17.74% for the hybrid PTGMS-78 x Minghui 63 to 49.50% for PTGMS-20 x Sakha Super 302.

In case of heterosis over BP, all hybrid rice combinations also recorded desired highly significant and positive values. The highest positive estimates were determined for PTGMS-78 x Sakha Super 302 (33.94%), PTGMS-38 x Sakha Super 302 (28.38%) and PTGMS-78 x Sakha Super 300 (25.49%).

The estimates of superiority (SV)% over the check cultivar Sakha Super 300 were highly significant in all 30 hybrids for grain yield t/ha$^{-1}$ (Table 12). The highest estimates of superiority (SV)% over the check cultivar were recorded for the hybrid combinations, PTGMS-78 x EJGSR-182 (38.97%), PTGMS-78 x Sakha Super 301 (36.41%), PTGMS-78xSakha Super 300 (36.04%), PTGMS-78 x Sakha Super 302 (35.67%) and PTGMS-43 x EJGSR-182 (35.40%). El-Mowafi *et al* (2018) and Reda *et al* (2023) agreed with the present findings.

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## القدرة علي الائتلاف وقوة الهجين للصفات الحقلية والمحصول لهجن الأرز المصرية نظام السلالتين الناتجة من سلالات العقم الذكري الوراثي الحساسة للفترة الضوئية ودرجة الحرارة .

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***يعتبر إنتاج الأرز الهجين بنظام السلالتين ابتكارا تقنيا هام في مجال إنتاج تقاوي الأرز الهجين بإستخدام سلالات العقم الذكري الوراثي الحساسة للفترة الضوئية ودرجة الحرارة. أجريت هذه الدراسة لتقدير تباينات وتأثيرات القدرة العامة والخاصة علي الإئتلاف ، تقدير نوع فعل الجين وكذلك تقدير قوة الهجين بين السلالات المطورة الجديدة العقيمة وراثيا نتيجة الحساسية للفترة الضوئية ودرجة الحرارة والسلالات المعيدة للخصوبة من التراكيب الوراثية الحديثة بإستخدام نظام السلالة x الكشاف للصفات الزراعية والمحصولية للحصول علي معلومات مفيدة للمربى عن انتاج هجن بنظام السلالتين في مصر. اظهرت النتائج فروق معنوية عالية في تأثيرات القدرة العامة علي الإئتلاف GCA بين سلالات العقم PTGMS لجميع الصفات تحت الدراسة. وكذلك وجود فروق معنوية عالية في تأثيرات القدرة الخاصة علي الإئتلاف SCA لجميع الصفات تحت الدراسة. كما تم تحديد خصائص السلالات العقيمة PTGMS من خلال تأثيرات القدرة العامة GCA والخاصة SCA لكل من***

السلالات العقيمة والسلالات المعيدة للخصوبة وقد كانت القدرة العامة علي الإئتلاف أكثر تأثيرا. وقد كانت السلالة العقيمة PTGMS-78 أفضل السلالات العقيمة من حيث تأثيرات القدرة العامة علي الإئتلاف بين جميع السلالات العقيمة ويليها في ذلك السلالة PTGMS-38 بينما كانت السلالة EJGSR-182 هي الأفضل بين السلالات المعيدة للخصوبة يليها سخا سوبر **303** ثم سخا سوبر **301**، وقد أظهرت تأثيرات القدرة العامة علي الإئتلاف GCA العالية للآباء قوة هجين عالية في الهجن. وقد كانت تقديرات كفاءة التوريث بالمعني الضيق ($h^2_n$) عالية بالنسبة لجميع الصفات المدروسة وقد أعطت تسع وخمس تراكيب هجينية تقديرات إيجابية بشكل ملحوظ لتأثيرات SCA لصفة محصول النبات الفردي ومحصول الحبوب (طن/هكتار) ، علي التوالي. وتم الحصول علي أفضل التقديرات من خلال الهجن

***PTGMS-43xEJGSR-182, PTGMS-23xSakha Super 303, PTGMS-38xSakha Super 303, PTGMS-20xEJGSR -182, PTGMS-78xEJGSR-182 P, TGMS-20xMinghui 63.***

***ومن بين 30 تركيب هجين سوبر كان هناك 11 تركيب هجيني واعد مع متوسط أداء محصولي تراوح بين 14.82 طن/هكتار للهجين PTGMS-78xEJGSR-182 الي 14.22 طن/هكتار للهجين PTGMS-38xSakha Super 303 مع تفوق على الصنف القياسي تراوح من 36.97% الي 31.42%.***

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