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5. S U M M A R Y

The present investigation was carried out during 2001 and 2002 rice growing seasons at the research farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt.

The main objective was to study :

- 1- The mean heterosis effect as a deviation from both mid-parent and better-parent.
- 2- General and specific combining ability effects.
- 3- Phenotypic correlation coefficients among all possible pairs of the studied characters.

Eight rice varieties namely, Giza 178, Sakha 101, Sakha 103, Sakha 104, Giza 177, IET 1444, Egyptian Yasmin and Pusa Basmati 1 were crossed in all possible combinations excluding reciprocals according to **Griffings (1956)**, Method (2), Model (1).

Twelve characters were investigated and divided into two main groups as follow :

1. **Days to 50% heading and yield and its components**, i.e., no. of days to 50% heading, no. of panicles/plant, no. of filled grains/panicle, 100-grain weight (g), sterility % and grain yield/plant (g).
2. **Shoot and root characters**, i.e., plant height at harvest (cm), panicle length (cm), root length (cm), root volume (ml³), no. of roots/plant and root:shoot ratio. Root characters were measured at maximum tillering stage.

The results obtained in this investigation could be summarized as follow :

1. Days to 50% Heading and Yield and Its Component Characters :

1.1. No. of days to (50%) heading

- A. The mean F_1 values of 14 hybrids were intermediate between their parental lines. Most of them tended towards the latest parent, revealing that lateness was partially dominant over earliness in these crosses. On the other hand, the mean F_1 values of 5 crosses, were earlier than the earliest parent indicating over-dominance of earliness was over-dominant over lateness in these promising crosses.
- B. Highly significant and negative estimates of heterosis were found in 4 crosses as a deviation from mid-parent and maximized in the cross Giza 178 x Egyptian Yasmin and minimized in the cross IET 1444 x Pusa Basmati. In addition, significant negative heterosis percentage as a deviation from better-parent was observed for Giza 178 x IET 1444 cross only.
- C. The GCA mean square was closed to SCA suggesting that additive and non-additive gene effect played an important role in the inheritance of this character. Four genotypes namely IET 1444, Sakha 103, Giza 177 and Giza 178 were found to be a good general combiners for earliness.
- D. Ten cross combinations exhibited significant negative specific combining ability effect for no. of days to 50% heading. Hence it were the best cross combinations for earliness, all of them involved at least one good general combiner.
- E. Number of days to 50% heading was significantly and negatively associated with root length, root volume, no. of roots/ plant and root:shoot ratio .

1.2. Number of panicles/plant

- A. The mean F_1 values of 20 studied crosses carried higher no. of panicles/plant than the better parents. However, some values were lower than the lowest parents in another 7 crosses, suggesting that high no. of panicles/plant character was over-dominant over low number.
- B. Highly significant positive mean heterosis was observed for no. of panicles/plant as a deviation from the mid-parent or better-parent values for 20 and 18 combinations, respectively.
- C. The GCA:SCA ratio was less than unity indicating that the observed genetic variation among F_1 crosses for no. of panicles/plant could slightly be attributed to the non-additive gene action. In addition, Giza 178 followed by Sakha 104, IET 1444 and Egyptian Yasmin were superiors than the other genotypes. Their estimated general combining ability effects were highly significant and positive .
- D. Highly significant positive estimates of specific combining ability effects were recorded in 13 crosses, which varied from 2.05 for Sakha 101 x IET 1444 to 9.65 for Sakha 104 x IET 1444.
- E. Number of panicles/plant was significantly and positively associated with sterility % and grain yield/plant.

1.3. Number of filled grains/panicle

- A. The mean F_1 values of the 5 crosses namely, Giza 178 x IET 1444, Giza 178 x Egyptian Yasmin, Giza 178 x Pusa Basmati 1, Sakha 101 x Sakha 104 and IET 1444 x Egyptian Yasmin recorded higher no. of filled grains/ panicle than the highest parent, suggesting that the high no. of filled grains/ panicle were over-dominance imperious over the low. On the other hand, the mean F_1 values of 7 hybrids were intermediate between their parental

lines. Four of them tended toward the lowest parent indicating that partial dominance was played a remarkable role in the inheritance of such character.

- B. Significant or highly significant positive heterosis effects were estimated as a deviation from mid-parent for 4 crosses, and maximized in cross, Giza 178 x IET 1444 and minimized in cross, Sakha 103 x Pusa Basmati 1. Moreover, 3 other crosses namely, Giza 178 x IET 1444, Giza 178 x Egyptian Yasmin and Giza 178 x Pusa Basmati 1 exhibited significant positive heterosis as a deviation from better-parent.
- C. The calculated ratio of general combining ability to specific combining ability variances were close to unity indicating that both additive and non-additive gene effects played a fundamental role in the inheritance of this character. The estimates of general combining ability effects revealed that among the 8 genotypes, the four genotypes Sakha 101, Giza 178, Sakha 103 and IET 1444 were found to be good general combiners for no. of filled grains/panicle
- D. Ten crosses exhibited significant positive estimates of specific combining ability effects. Their estimates ranged between 17.14 and 30.74 for Giza 178 x Egyptian Yasmin and Giza 178 x Sakha 101 crosses, respectively.
- E. Number of filled grains/panicle was positive significant phenotypically correlated with 100-grain weight and grain yield/plant. However, it was negative significantly associated with sterility % .

1.4. Hundred-grain weight (g)

- A. The mean F_1 values of 9 crosses were intermediate between their parental lines, four of them tended towards the light grained parent. While the other 5 crosses, tended towards the heavy grains parent. These results revealed that partial dominance was important in the inheritance of the present character. Meanwhile, the F_1 mean values of 15 crosses carried heavier grains than the heaviest grained parent indicating the importance of over-dominance in the inheritance of such character.
- B. Highly significant positive estimates of heterosis were found in 18 crosses as a deviation from mid-parent and 12 crosses when measured as a deviation from better-parent. The best crosses which showed significant positive heterosis were Giza 178 x Pusa Basmati 1, Giza 178 x Giza 177 and Giza 178 x Sakha 101.
- C. The GCA/SCA ratio was less than unity suggesting the preponderance of non-additive gene effects in the expression of 100-grain weight. Four genotypes namely, Sakha 101, Sakha 104, Egyptian Yasmin and IET 1444 exhibited significant positive estimates of general combining ability effects, indicating that these genotypes were the best combiners and it might be utilized as a parent in hybridization programme for improving these character.
- D. Significant positive estimates of specific combining ability effects were detected for 7 crosses, their estimates ranged between 0.23 and 0.62 for Giza 177 x Pusa Basmati 1 and Sakha 101 x IET 1444, respectively.
- E. 100-grain weight was positively and significantly correlated with grain yield/plant .

1.5. Sterility percentage

- A. The mean F_1 values of 4 crosses, Giza 178 x IET 1444, Giza 178 x Egyptian Yasmin, Sakha 101 x Sakha 103 and Sakha 101 x Sakha 104 were lower than the lowest parent.
- B. High significant negative estimates of heterosis were estimated as a deviation from mid-parent for 5 crosses and maximized in the cross Sakha 101 x Sakha 104 and minimized in the cross, Giza 178 x Pusa Basmati 1. In addition, 4 crosses namely, Giza 178 x IET 1444, Giza 178 x Egyptian Yasmin, Sakha 101 x Sakha 103 and Sakha 101 x Sakha 104 showed high significant negative heterosis as a deviation from better-parent.
- C. The relative estimates of specific combining ability was lower than the estimates of general combining ability, revealing preponderance of non-additive gene action in the expression of this character. However, 5 genotypes namely, Sakha 101, Sakha 103, Giza 178, IET 1444 and Sakha 104 exhibited highly significant estimates in negative directions of general combining ability effects indicating that these varieties were good general combiners for lowering sterility % .
- D. Significant negative estimates of specific combining ability were observed for 11 crosses, all of them at least involved one of the best general combiners.
- E. Sterility % was positively and significantly correlated with root:shoot ratio.

1.6. Grain yield/plant (g)

- A. The mean F_1 values of 21 crosses were higher than the highest parent suggesting that over-dominance played an important role in the inheritance of grain yield/plant.

- B. Twenty two and 20 crosses showed highly significant positive heterosis as a deviation from both mid-parent and better-parent, respectively. The best crosses which showed the highest heterosis estimates were Sakha 103 x IET 1444, Sakha 101 x IET 1444 and Giza 177 x Pusa Basmati 1.
- C. The calculated ratio of general to specific combining abilities were close to unity indicating that both additive and non-additive gene action might played an important role in the inheritance of grain yield/plant. Moreover, 4 genotypes, namely Giza 178, Sakha 101, IET 1444 and Sakha 103 were exhibited highly significant positive estimates of general combining ability effects indicating that these genotypes were the best general combiners under the present study.
- D. Highly significant positive estimates of specific combining ability effects were illustrated for 15 crosses. The high values were estimated in the cross, Sakha 101 x IET 1444 followed by Sakha 103 x IET 1444 and Sakha 103 x Egyptian Yasmin.
- E. Grain yield/plant was significant or highly significant and positively correlated with plant height, panicle length, no. of panicles/plant, no. of filled grains/ panicle, 100-grain weight, root length, root volume, no. of roots/plant and root:shoot ratio.

2. Shoot and Root Characters :

2.1. *Plant height at harvest (cm)*

- A. The mean F_1 values of most crosses were found to be taller than the tallest parent suggesting over-dominance of tallness dominant over shortness in such crosses. On the other hand, the F_1 mean values of 3 crosses were intermediate between their parental lines. Most of them tended towards the tallest parent, revealing that tallness was partially dominant over shortness in these crosses.

- B. Significant negative heterosis percentage was estimated as a deviation from mid-parent for the cross Sakha 103 x Sakha 104. Moreover, insignificant negative mean heterosis as a deviation from better-parent were estimated in the same cross .
- C. The ratio between general and specific combining ability variances revealed preponderance of non-additive gene effects in the inheritance of this character. The genotypes, Sakha 101, Sakha 103, Giza 178 and Egyptian Yasmin were good general combiners for plant height. Their GCA effects were highly significant negative.
- D. The estimates of specific combining ability effects were significant and negative in 8 crosses. The high estimates were detected for Sakha 103 x Sakha 104 cross, followed by Giza 178 x Egyptian Yasmin and Sakha 101 x Sakha 104.
- E. Plant height was positive and significantly correlated with panicle length, no. of panicles/plant , root length, root:shoot ratio and grain yield/plant.

2.2. Panicle length (cm)

- A. The mean F_1 values of Giza 178 x Egyptian Yasmin and Sakha 103 x Pusa Basmati 1 crosses were lower than the shortest parent revealing that the short panicle length was over-dominancy imperious over the longest panicle in these two crosses. However, 19 crosses had longer than the longest parent detecting that the longest panicle was over-dominancy lordly over the short in these crosses.
- B. Highly significant positive estimates of heterosis were estimated for panicle length, as a deviation from mid-parent in 20 crosses. The highest positive estimates were computed for the crosses,

Sakha 103 x Egyptian Yasmine and Sakha 103 x IET 1444. However, heterosis estimates as a deviation from better-parent were highly significant positive in 15 crosses, and negative in 8 crosses. The highest positive estimates were detected in Sakha 103 x Giza 177 and Sakha 103 x Egyptian Yasmin crosses.

- C. The ratio between general and specific combining abilities was more than unity indicating that the additive gene effects played an important role in the inheritance of this character. Three genotypes namely, Egyptian Yasmin, IET 1444 and Pusa Basmati 1 showed significant positive estimates of general combining ability effects indicating that these genotypes were good combiners for improving this character.
- D. The estimates of specific combining ability effects were highly significant positive for 13 crosses, their estimates were maximized in crosses, Giza 178 x Sakha 101, Sakha 103 x Giza 177, Giza 178 x Sakha 101, Sakha 101 x Egyptian Yasmin and Sakha 103 x Giza 177 which appeared to be the best specific combinations for panicle length under this investigation.
- E. Panicle length was significantly and positively correlated with each of no. of filled grains/panicle, sterility % and grain yield/plant .

2.3. *Root length (cm) at maximum tillering stage*

- A. The mean F_1 values of 9 genotypes were moderate between their parents. Five crosses namely, Giza 178 x Sakha 101, Giza 178 x Sakha 103, Giza 178 x Pusa Basmati 1, Giza 177 x IET 1444 and IET 1444 x Pusa Basmati 1 were inclined to the longest root parent. On the contrary, the root length of 9 crosses were longer than the longest parent indicating that both short and tall root length were partially dominant or over-dominant over each other according to the cross itself.

- B. Seven crosses had significant and highly significant positive mean heterosis as a deviation from better-parent. Furthermore, 11 crosses showed highly significant and positive useful heterosis as a deviation from mid-parent. The best crosses which exhibited high positive heterosis were Giza 178 x Sakha 104, Sakha 104 x IET 1444 and IET 1444 x Egyptian Yasmin.
- C. General combining ability variance was greater than that of specific combining ability variance and their estimated ratio were more than unity demonstrating the preponderance of additive gene action in the inheritance of root length. Furthermore, highly significant positive estimates of general combining ability effects were exhibited for only 3 genotypes namely, Giza 178, IET 1444 and Sakha 104.
- D. Six crosses displayed highly significant positive estimates of specific combining ability effects, their computed values ranged between 3.10 and 7.35 for Giza 178 x IET 1444 and IET 1444 x Egyptian Yasmin.
- E. Root length was positive and significant or highly significant phenotypically associated with root volume, no. of roots/plant, root:shoot ratio and grain yield/plant.

2.4. *Root volume (cm³) at maximum tillering stage*

- A. The mean F_1 values of 6 hybrids were intermediate between their parental lines. Three of them namely Giza 178 x IET 1444, Sakha 104 x IET 1444 and Giza 177 x Pusa Basmati 1 were prone to highest root volume parent. On the other side, the F_1 mean values of 23 cross were either lower or higher root volume than the lowest or highest parent, respectively.

- B. Highly significant positive heterosis were measured as a deviation from mid-parent in 15 crosses. The highest positive percentages were estimated for the crosses Sakha 101 x Pusa Basmati 1, Egyptian Yasmin x Pusa Basmati 1 and Giza 178 x Pusa Basmati 1. Similar estimates were measured as a deviation from better-parent in 11 crosses. These estimates were maximized in the crosses, Egyptian Yasmin x Pusa Basmati 1, Sakha 101 x Pusa Basmati 1 and Giza 178 x Sakha 101.
- C. The estimated ratio of GCA/SCA was greater than unity. Nevertheless, additive gene effect played an important role in the inheritance of this character. In addition, highly significant positive estimates of general combining ability effect were obtained for 4 genotypes, namely, Giza 178, IET 1444, Pusa Basmati 1 and Sakha 101 .
- D. Highly significant positive estimates of specific combining ability effects were obtained for 13 hybrids. Their estimates were maximized in Giza 178 x Sakha 103 and minimized in Giza 177 x Egyptian Yasmin crosses.
- E. Root volume was positive and significantly associated with number of roots/plant, root:shoot ratio and grain yield/plant.

2.5. Number of roots/plant at maximum tillering stage

- A. The mean F_1 mean values of 14 crosses were found to be higher than the highest parent. Their estimated values were maximized in Giza 178 x IET 1444, but it were minimized in Sakha 103 x IET 1444, suggesting that high rooting ability was over-dominancey lordly over low rooting ability. Meanwhile, the mean F_1 values of 7 crosses were moderate between their parental lines, one of them, Giza 178 x Pusa Basmati 1, Sakha 101 x Egyptian Yasmin and Egyptian Yasmin x Pusa Basmati 1 crosses tended

towards the highest rooting ability parent indicating that partial dominance was important in the inheritance of such character in these mentioned crosses.

- B. Highly significant positive heterosis values as a deviation from both mid-parent and better-parent were estimated in the crosses IET 1444 x Pusa Basmati 1, Giza 178 x IET 1444 and Giza 178 x Sakha 104 which exhibited the maximum values of heterosis.
- C. General combining ability to specific combining ability ratio was larger than unity indicating the preponderance of additive gene effect in the inheritance of no. of roots/plant. Furthermore, highly significant positive estimates of general combining ability effects were exhibited for IET 1444 and Giza 178 genotypes.
- D. Eight crosses exhibited highly significant positive estimates of specific combining ability effects, their estimated values were varied from 51.33 to 160.19 in Sakha 101 x Pusa basmati 1 and Giza 178 x Sakha 104 crosses, respectively.
- E. Number of roots/plant was significantly and positively correlated with root:shoot ratio and grain yield/plant.

2.6. *Root:Shoot ratio at maximum tillering stage*

- A. The mean F_1 values of 15 crosses were higher than the highest parent. The highest estimated ratio were observed for Giza 178 x Sakha 101 and Egyptian Yasmin x Pusa Basmati 1, indicating the preponderance of over-dominance in the inheritance of the present character. The mean F_1 values of 6 crosses were intermediate between their parents, most of them tended towards the highest parent, indicating that partial dominance might played a remarkable role in the inheritance of root:shoot ratio.

- B. Highly significant positive estimates of heterosis were found for 16 crosses as a deviation from mid-parent. Same trend was observed for another 13 crosses when it measured as a deviation from better-parent. The best crosses which showed significant positive heterosis percentage were Giza 178 x Sakha 101, IET 1444 x Pusa Basmati 1 and IET 1444 x Egyptian Yasmin.
- C. The estimated ratio between general and specific combining ability variances were greater than unity, suggesting the distinguished of additive gene action in the inheritance of such character. Moreover, highly significant positive estimates of general combining ability effects were denoted for the genotypes, Giza 178, Sakha 101, Egyptian Yasmin and Pusa Basmati 1.
- D. Highly significant positive estimates of specific combining ability effects exhibited for 17 hybrids. Their estimated values were ranged between 0.04 and 0.57 for Giza 178 x Egyptian Yasmin and Egyptian Yasmin x Pusa Basmati 1 crosses, respectively.
- E. Root:shoot ratio character was positively and highly significantly correlated with grain yield/plant.

Briefly,

The results revealed that Giza 178, IET 1444 and Sakha 101 rice genotypes were the best general combiners for most of the studied traits, hence, it must be utilized in any breeding program for improving most of the studied traits.

However, the results also exhibited that Giza 178 x Sakha 104, Giza 177 x Egyptian Yasmin, Giza 178 x Sakha 103, Giza 178 x Sakha 101 and Giza 178 x IET 1444 were the best specific cross

combinations, which can be used for improving most of the studied traits including plant height/plant, their respective specific combining ability effects were high for most of the studied traits.

Hence, the Egyptian rice breeders might concentrate on these combinations for improving most of the studied traits in their breeding program.

6. CONCLUSION

Highly significant and positive estimates of heterosis were obtained in crosses Sakha 103 x IET 1444, Sakha 101 x Egyptian Yasmin and Giza 177 x Pusa Basmati 1 for the most studied traits when it was measured as a deviation from mid-parent and better parent. On the contrary, significant and negative estimates of heterosis were desirable in the crosses Giza 178 x Egyptian Yasmin and Sakha 101 x Sakha 104 for no. of days to 50% heading and sterility % traits when it measured as a deviation from mid-parent and better parent.

Highly significant and positive estimates of heterosis were detected in most studied crosses as a deviation from mid-parent and better-parent for most of the shoot and root characters.

The Egyptian rice variety Giza 178 was the best general combiner for grain yield and most of its components, beside all root characters, while Sakha 101 was the best general combiner for most root characters except root length and no. of roots/plant.

The exotic rice variety, IET 1444 was the best general combiner for grain yield and all the studied characters except root:shoot ratio. The results also revealed that the exotic rice variety, Pusa Basmati 1 was good general combiner for panicle length, root volume and root:shoot ratio characters. Egyptian Yasmin rice variety was poor general combiner for most of root characters; and some agronomic characters. The rice variety, Giza 177, was good general combiner for earliness, whereas, it was poor combiner for other remaining characters.

Giza 178 x Sakha 104, followed by Giza 177 x Egyptian Yasmin, Giza 178 x Sakha 103, Giza 178 x Sakha 101 and Giza 178 x IET 1444 crosses were the best cross combinations for most of the studied characters including grain yield/plant.

Grain yield/plant was significantly or highly significantly and positively correlated with nine characters, these characters were plant height, panicle length, no. of panicles/plant, no. of filled grains/panicle, 100-grain weight, root length, root volume, no. of roots/plant and root:shoot ratio. Moreover, low positive estimates of phenotypic correlation coefficients were recorded between grain yield/plant and each of no. of days to 50% heading and sterility %.