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Genetical Studies on Salinity and Drought Tolerance in Rice

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5- SUMMARY

The presented study was carried out at the Genetic Department, Faculty of Agriculture, Kafrelsheikh University, Egypt. In addition, Rice Research and Training Center (RRTC) facilities at El-Sirw Agriculture Research Station Experimental Farm, Damietta Governorate, Egypt, during 2014 and 2015 rice growing seasons. This study involved eight rice varieties, i.e., Sakha102, Sakha104, Sakha105, Sakha106, Giza178, A22, IRAT170, and WAB56-125 beside their F_1 crosses and F_2 generations. The parents and their F_1 were evaluated under the three environments; i.e., normal, salinity and drought conditions. Seventeen traits; i.e., plant height, tillers plant^{-1}, straw weight plant^{-1}, panicle length and days to heading for vegetative traits; total chlorophyll content, proline content, sodium content, potassium content and Na^+/K^+ ratio for physiological traits and panicles plant^{-1}, spikelets sterility percentage, 100-grain weight, panicle weight, filled grains panicle^{-1}, harvest index (HI %) and grain yield plant^{-1} for yield traits. The 28 F_2 populations were evaluated for eight traits involved; plant height, panicle length, panicles plant^{-1}, 100-grain weight, panicle weight, filled grains panicle^{-1}, spikelets sterility percentage and grain yield plant^{-1}. Randomized Complete Block Design with three replications was used and the data were analyzed according to **Griffing, 1956** method 2, model 1 and **Hayman, 1954.**

The objectives of this investigation were to:

1. Evaluate the performance of some rice genotypes under the three environments; i.e., normal, salinity and drought conditions.
2. Estimate the combining ability, heterosis and heritability for the studied traits under different three conditions.

3. Estimate the correlation coefficient between the studied traits under different three conditions.
4. Study the genetic diversity among the parents by using eight SSR markers linked to some salinity and / or drought tolerance.
5. Study inbreeding depression, genetic variability, heritability and genetic advance for F_2 hybrid populations.

The obtained results could be summarized as follows:

1) **<u>Results for germination and seedling</u>**: The results indicated that the genetic variation exists among rice cultivars in terms of early seedling under salt and drought stresses condition, where under sever salt stress, A22 followed by WAB56-125 cultivar were the most tolerant cultivar which can be suggested for cultivation under salt stress condition. Furthermore, Sakha104 followed by IRAT170 were the best genotypes under high drought stress for most traits. The most desirable parents under control (non-stressed) were, Giza178 for germination energy percentage (GE %) and final germination percent (FGP %); Sakha104 for shoot length and root length; IRAT170 for seedling fresh weight and shoot fresh weight and Sakha105 for root fresh weight.

2) **<u>The ordinary analysis of variance</u>**: The results indicated highly significant differences among genotypes, parents, crosses, parents *vs.* crosses under the three environments (normal, salinity and drought conditions).

3) **<u>The most desirable mean values for mean performances</u>:** The most desirable parents and hybrids **under normal condition** were Sakha105 and Sakha105 × Sakha106 for plant height; Giza178 and

Sakha102 × Giza178 for tillers plant^{-1}; WAB56-125 and Giza178 × WAB56-125 for straw weight plant^{-1}; IRAT170 and Sakha102 × A22 for panicle length; Sakha102 and Sakha102 × Sakha106 for days to heading; A22 and Sakha102 × Giza178 for total chlorophyll content and harvest index; Giza178 and Sakha105 × Giza178 for proline content; Giza178 and Sakha104 × WAB56-125 for Na^+/K^+ ratio and sodium content; Giza178 and Sakha102 × Giza178 for potassium content; Giza178 and A22 × WAB56-125 for panicles plant^{-1}; Sakha105 and Sakha102 × IRAT170 for 100-grain weight; IRAT170 and A22 × IRAT170 for panicle weight; Giza178 and Giza178 × A22 for filled grains panicls^{-1}; Sakha105 and A22 × WAB56-125 for sterility percentage and Giza178 and Sakha105 × A22 for grain yield plant^{-1}.

Meanwhile, under salinity condition the best genotypes were Sakha105 and Sakha106 × IRAT170 for plant height; Giza178, Sakha104 × A22 and Giza178 × WAB56-125 for tillers plant^{-1}; Giza178 and A22 × WAB56-125 for straw weight plant^{-1}; WAB56-125 and IRAT170 × WAB56-125 for panicle length; Sakha102 and Sakha102 × Sakha106 for days to heading; Giza178 and Giza178 × A22 for total chlorophyll content and filled grains panicls^{-1}; Giza178 and Sakha106 × Giza178 for proline content; Giza178 and Sakha104 × Giza178 for Na^+/K^+ ratio, harvest index and grain yield plant^{-1}; Giza178 and Sakha102 × WAB56-125 for sodium content and panicle weight; Giza178 and Giza178 × WAB56-125 for potassium content and sterility percentage; Giza178 and Sakha104 × A22 for panicles plant^{-1} and IRAT170 and Sakha105 × Sakha106 for 100-grain weight**.**

Furthermore, under drought condition the best genotypes were Sakha105, Sakha104 × Sakha105 and Sakha105 × Sakha106 for plant height; Giza178 and Sakha104 × A22 for tillers plant^{-1}; Giza178 and A22 × WAB56-125 for straw weight plant^{-1} and potassium content; Giza178 and Giza178 × WAB56-125 for panicle length, filled grains panicls^{-1}, sterility percentage and grain yield plant^{-1}; Sakha106 and Sakha102 × Sakha106 for days to heading; WAB56-125 and Giza178 × A22 for total chlorophyll content; WAB56-125 and A22 × WAB56-125 for proline content; Giza178 and Sakha102 × Giza178 for Na^+/K^+ ratio and panicles plant^{-1}; Giza178 and Sakha104 × Giza178 for sodium content; Sakha105 and Sakha105 × IRAT170 for 100-grain weight; IRAT170 and Sakha104 × IRAT170 for panicle weight and Giza178 and Giza178 × IRAT170 for harvest index.

4) **<u>For salinity and drought tolerance index:</u>** Salinity and drought indices decreased for all the studied traits except for days to heading, proline content, sodium content, Na^+/K^+ ratio and spikelets sterility percentage. The most desirable parents were Giza178, WAB56-125 and A22 the best genotypes for salinity and drought indices followed by Sakha104 for salinity index and IRAT170 for drought index. While, the most desirable hybrids were Sakha102 × WAB56-125, IRAT170 × WAB56-125, Sakha104 × WAB56-125, Sakha104 × A22 and Sakha104 × Giza178 for **salinity index** in most traits.

Furthermore, the most desirable hybrids for **drought index** were IRAT170 × WAB56-125 and Giza178 × IRAT170 for tillers plant^{-1}, straw weight plant^{-1}, panicle length, panicles plant^{-1}, spikelets sterility, 100-grain weght, filled grains panicle^{-1}, harvest index and grain yield plant^{-1}; Giza178 × A22 for chlorophyll content and days to heading; Sakha106 × A22 and Sakha106 × Giza178 for sodium content and Na^+/K^+ ratio and Sakha104 × WAB56-125 for proline content.

5) **<u>For general combining ability (GCA):</u>** The best combiners under three studied conditions were Sakha105 and Sakha106 for plant height;

Giza178 and A22 for tillers plant^{-1} and straw weight plant^{-1}; Giza178, WAB56-125 and A22 for panicle length; Sakha102 and Sakha106 for days to heading; Giza178, WAB56-125 and A22 for total chlorophyll content, proline content, sodium content, potassium content, Na^+/K^+ ratio and panicles plant^{-1}; IRAT170 and Sakha105 for 100-grain weight; IRAT170 under normal and drought, Giza178, A22 and WAB56-125 for panicle weight; Giza178, WAB56-125 and A22 for filled grains panicle^{-1}; Giza178 for spikelets sterility and Giza178, WAB56-125 and A22 for harvest index and grain yield plant^{-1}.

6) **<u>For specific combining ability (SCA) effects:</u>** The most desirable hybrids **under normal condition** were A22 × WAB56-125 for plant height; Sakha102 × Giza178 for tillers plant^{-1}, total chlorophyll content, potassium content and panicles plant^{-1}; Sakha105 × A22 for straw weight plant^{-1}; Sakha102 × A22 for panicle length and spikelets sterility percentage; Sakha102 × Sakha104 for days to heading; Sakha105 × Giza178 for proline content; Sakha104 × WAB56-125 for Na^+/K^+ ratio and sodium content; A22 × IRAT170 for 100-grain weight and panicle weight; Giza178 × A22 for filled grains panicle^{-1} and Sakha105 × WAB56-125 for harvest index and grain yield plant^{-1}.

Whereas, under salinity condition the highest estimates were obtained by A22 × WAB56-125 for plant height; Sakha102 × WAB56-125 for tillers plant^{-1}, Na^+/K^+ ratio, sodium content and panicle weight; Sakha102 × A22 for straw weight plant^{-1} and panicle length; Giza178 × A22 for days to heading; Sakha102 × Giza178 for total chlorophyll content; Sakha106 × Giza178 for proline content; Giza178 × WAB56-125 for potassium content and filled grains panicle^{-1}; Sakha104 × A22 for panicles plant^{-1}; IRAT170 × WAB56-125 for 100-grain weight; Sakha106

× WAB56-125 for spikelets sterility percentage and Sakha104 × Giza178 for harvest index and grain yield plant^{-1}.

Furthermore, under drought condition the highest estimates were obtained by Giza178 × A22 for plant height; Sakha102 × Giza178 for tillers plant^{-1}; Sakha102 × A22 for straw weight plant^{-1}; Sakha104 × IRAT170 for panicle length; Giza178 × IRAT170 for days to heading; Sakha106 × A22 for total chlorophyll content; Sakha106 × Giza178 for proline content; Sakha102 × WAB56-125 for Na^+/K^+ ratio and sodium content; Sakha102 × IRAT170 for potassium content; Sakha105 × A22 for panicles plant^{-1}, harvest index and grain yield plant^{-1}; A22× IRAT170 for 100-grain weight; Sakha102 × Sakha104 for panicle weight; Giza178 × WAB56-125 for filled grains panicle^{-1} and Sakha106 × WAB56-125 for spikelets sterility percentage.

7) <u>For heterosis over the mid-parent (HM.P.%):</u> The most desirable hybrids **under normal condition** were, Sakha105 × Sakha106 for plant height; Sakha102 × A22 for tillers plant^{-1}, straw weight plant^{-1}, panicle length, panicles plant^{-1} and spikelets sterility percentage; Giza178 × IRAT170 for days to heading; Sakha102 × Giza178 for total chlorophyll content and potassium content; Sakha105 × Giza178 for proline content; Sakha104 × WAB56-125 for Na^+/K^+ ratio and sodium content; A22 × IRAT170 for 100-grain weight and panicle weight; Giza178 × A22 for filled grains panicle^{-1}; Sakha105 × WAB56-125 for harvest index and Sakha105 × A22 for grain yield plant^{-1}.

Whereas, under salinity condition the highest heterosis over mid-parent estimates were obtained by Sakha106 × IRAT170 for plant height; Sakha106 × A22 for tillers plant^{-1}, panicle length and potassium content; Sakha102 × A22 for straw weight plant^{-1}; Giza178 × A22 for days to heading; Sakha102 × Giza178 for total chlorophyll content; Sakha106 ×

Giza178 for proline content; Sakha102 × WAB56-125 for Na^+/K^+ ratio, panicle weight, harvest index and grain yield plant^{-1}; Sakha104 × Giza178 for sodium content; Sakha105 × A22 for panicles plant^{-1}; IRAT170 × WAB56-125 for 100-grain weight; Giza178 × WAB56-125 for filled grains panicle^{-1} and Sakha106 × WAB56-125 for spikelets sterility percentage.

Furthermore, under drought condition the highest heterosis over mid-parents estimates were obtained by Sakha105 × Sakha106 for plant height; Sakha102 × A22 for tillers plant^{-1} and straw weight plant^{-1}; Sakha105 × A22 for panicle length, potassium content, panicles plant^{-1}, harvest index and grain yield plant^{-1}; Giza178 × IRAT170 for days to heading; Sakha106 × A22 for total chlorophyll content and proline content; Sakha102 × Giza178 for Na^+/K^+ ratio and sodium content; A22 × IRAT170 for 100-grain weight; Sakha102 × Sakha104 for panicle weight; A22 × WAB56-125 for filled grains panicle^{-1} and Sakha106 × WAB56-125 for spikelets sterility percentage.

8) <u>For heterosis over the better parent (HB.P.%):</u> The most desirable hybrids **under normal condition** were Sakha106 × IRAT170 for plant height; Sakha102 × A22 for tillers plant^{-1}, panicle length and panicles plant^{-1}; Sakha104 × A22 for straw weight plant^{-1}; Sakha102 × Sakha104 for days to heading; Sakha102 × Giza178 for total chlorophyll content and Na^+/K^+ ratio; Sakha102 × Sakha106 for proline content and 100-grain weight; Sakha104 × WAB56-125 for sodium content; A22 × WAB56-125 for potassium content and spikelets sterility percentage; Sakha105 × A22 for panicles plant^{-1}; Sakha106 × A22 for panicle weight; Giza178 × A22 for filled grains panicle^{-1} and Sakha105 × WAB56-125 for harvest index and grain yield plant^{-1}.

Whereas, under salinity condition the highest heterosis over better parents estimates were obtained by Sakha106 × IRAT170 for plant height; Sakha105 × IRAT170 for tillers plant^{-1} and panicles plant^{-1}; A22 × WAB56-125 for straw weight plant^{-1} and proline content; Sakha102 × A22 for panicle length; Sakha102 × Sakha104 for days to heading; Sakha105 × WAB56-125 for total chlorophyll content; Sakha105 × A22 for Na^+/K^+ ratio and sodium content; Giza178 × WAB56-125 for potassium content, filled grains panicle^{-1} and spikelets sterility percentage; Sakha105 × Sakha106 for 100-grain weight; Sakha104 × IRAT170 for panicle weight and harvest index and Sakha104 × WAB56-125 for grain yield plant^{-1}.

Furthermore, under drought condition the highest heterosis over better parents estimates were obtained by Sakha104 × Sakha105 for plant height; Sakha104 × A22 for tillers plant^{-1}; A22 × IRAT170 for straw weight plant^{-1}; Sakha102 × A22 for panicle length and panicles plant^{-1}; Giza178 × IRAT170 for days to heading; Sakha106 × A22 for total chlorophyll content and proline content; Sakha102 × Giza178 Na^+/K^+ ratio, sodium content and spikelets sterility percentage; A22 × WAB56-125 for potassium content and filled grains panicle^{-1}; Sakha105 × A22 for panicles plant^{-1} and grain yield plant^{-1}; Sakha102 × Sakha104 for 100-grain weight and panicle weight and Sakha102 × IRAT170 for harvest index. These hybrid combinations could be utilizing to enhancing the above traits in breeding program.

9) **<u>For potence ratio:</u>** Over-dominance was detected in some crosses for all traits. In these crosses, the values of potence ratio exceeded the unity, indicating the existence of over-dominance in the inheritance of these traits. The value of potence ratio was less than unity in some crosses for all traits, indicating the presence of partial dominance for these traits.

However, the values of potence ratio ranged from less to more than unity in most crosses for most studied traits, indicating partial to over-dominance for these traits.

10) <u>The phenotypic correlation for grain yield plant^{-1}</u>: It was highly significant positive correlated with each of plant height, tillers plant^{-1}, straw weight plant^{-1}, panicle length, proline content, potassium content, panicles plant^{-1}, panicle weight, filled grains panicle^{-1}, days to heading, total chlorophyll and harvest index under normal, salinity and drought conditions. On the other hand, highly significant negative correlation was obtained for Na^+/K^+ ratio, Na^+ content and 100-grain weight under the three conditions, while the grain yield was highly significant negative correlation for spikelets sterility percentage under salinity and drought conditions.

11) <u>The results of Hayman approach:</u>

- Significant or highly significant positive values of additive **(D)** under the three conditions for all traits studied except plant height under the three conditions, grain yield plant^{-1}, harvest index, chlorophyll content, Na^+ content and spikelets sterility percentage under normal condition and panicle length under drought condition.
- The dominance component **H_1 and H_2** were highly significant for all traits. These results had that dominance effects were relatively more important than additive in the inheritance of these traits. The magnitude of H_1 was more than H_2 in all traits, indicating that at most loci the positive and negative alleles were in equal proportion.
- Heritability in broad sense **(h^2_b)** estimates was highly for all studied traits, indicating that most of phenotypic variability in all traits was due to genetic variation.

12) Molecular evaluation:

- The eight SSR markers were polymorphic and produced 29 alleles. The number of alleles per locus generated by each marker varied from 2 to 5 alleles with an average of 3.63 alleles per locus.
- The genetic similarity among the eight rice varieties was ranging from 0 to 79%. The highest similarity 79% and shortest genetic distance were scored between Sakha102 with each of Sakha104 and Sakha106; these three parental varieties are Japonica rice. The lowest genetic similarity (0%) and longest genetic distance were found between WAB56-125 and Sakha105. These results were substantiated by the fact that these two genotypes have different origin and fixed their difference in the ability of drought and salt tolerance.
- The results indicated the ability of SSR markers to detect and to identify the allelic diversity and genetic variation among the studied rice genotypes. In addition, RM223 marker elucidated the possibility to use it in MAS for salinity and drought tolerance in the studied rice genotypes according to different alleles.

13) The results of F_2 had the following:

- The highest desirable **mean values** were obtained from the crosses **under normal condition** were Sakha102 × Sakha105 for plant height; Sakha105× Giza178 for panicle length; A22 × WAB56-125 for panicles plant^{-1}, filled grains panicle^{-1}, spikelets sterility percentage and grain yield plant^{-1}; Sakha102 × Sakha104 for 100-grain weight; Sakha105 × A22 panicle weight. Meanwhile, **under salinity condition** the best crosses were Sakha106 × IRAT170 for plant height; Sakha104 × WAB56-125 for panicle length; Sakha104 × A22 for panicles plant^{-1}; Sakha105 × Sakha106 for 100-grain weight; Sakha105 × A22 panicle weight; Giza178 × A22 for filled grains panicle^{-1} and spikelets sterility percentage; Sakha104 × Giza178 for grain yield plant^{-1}. Furthermore, **under drought condition** the best crosses were Sakha105 × Sakha106 for plant height; Sakha105 × A22 for panicle length; Giza178 × WAB56-125 panicles plant^{-1}, filled grains panicle^{-1} and spikelets sterility percentage;; Sakha102 × Sakha105 for 100-grain weight; Sakha104 × IRAT170 for panicle weight and Giza178 × IRAT170 for grain yield plant^{-1}.

- The most desirable **inbreeding depression (I.d.)** in F_2: **under normal condition** were found for the crosses, Sakha102 × IRAT170 for plant height; Sakha106 × WAB56-125 for panicle length and panicles plant^{-1}; Sakha104 × Giza178 for 100-grain weight; Giza178 × IRAT170 for panicle weight; A22 × WAB56-125 for filled grains panicle^{-1}; A22 × IRAT170 for spikelets sterility percentage and Giza178 × IRAT170 for grain yield plant^{-1}.
- **Moreover**, the most desirable inbreeding depression (I.d.) **under salinity condition** were Sakha105 × Sakha106 for plant height; Sakha104 × WAB56-125 for panicle length; Sakha102 × A22 for panicles plant^{-1}; Sakha102 × Giza178 for 100-grain weight and spikelets sterility percentage; A22 × WAB56-125 for panicle weight; Giza178 × A22 for filled grains panicle^{-1} and Giza178 × IRAT170 for grain yield plant^{-1}.
- Furthermore, the most desirable inbreeding depression (I.d.) **under drought condition** were Sakha106 × A22 for plant height; Sakha104 × WAB56-125 for panicle length and filled grains panicle^{-1}; Giza178 × A22 for panicles plant^{-1}; Sakha104 × IRAT170 for 100-grain weight and spikelets sterility percentage; Sakha104 × Giza178 for panicle weight and Sakha102 × A22 for grain yield plant^{-1}.