RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
57 (6) 2676-2683, 2025
http://doi.org/10.54910/sabrao2025.57.6.40
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

# GENETIC AND PHENOTYPIC CORRELATIONS IN YIELD-RELATED TRAITS OF RICE HYBRIDS USING FACTORIAL HYBRIDIZATION

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## SUMMARY

The particular research aimed to evaluate the performance of 24 rice (*Oryza sativa* L.) genotypes comprising four local (Amber 33, Yasmine , Al-furat , and dajla) and four Egyptian cultivars (Giza 201, Giza 178, Giza 179, and Basmati 1). Completing the 24 were 16 hybrids obtained through the factorial hybridization method held in 2021 and 2022 at the Rice Research Station, Al-Mishkhab, Al-Najaf Al-Ashraf, Iraq. Significant differences were evident among the genotypes (varieties and their hybrids) in all studied traits. The hybrid Giza 201 × Al-furat excelled on traits of 1000-grain weight, biological yield, grain yield per plant, and harvest index (27.60 g, 429.33 g, 234.67 g, and 54.66%, respectively). The hybrid Basmati 1 × Dajla also excelled for biological yield, grain yield, and harvest index (405.33 g, 196.67 g, and 48.55%, respectively). Similarly, the cultivar Al-furat stood out for the above traits (367.67 g, 192.67 g, and 52.41%, respectively).

**Keywords:** Rice (*O. sativa* L.), cultivars, hybrids, genetic parameters

**Key findings:** The rice (*O. sativa* L.) hybrid Giza 201 × Al-furat excelled for the traits of 1000-grain weight, biological yield, grain yield per plant, and harvest index (27.60 g, 429.33 g, 234.67 g, and 54.66%, respectively).

Communicating Editor: Dr. A.N. Farhood

Manuscript received: October 20, 2023; Accepted: August 03, 2025.


**Citation:** Abdhussian HM, Sarheed AF, Musa AKJ (2025). Genetic and phenotypic correlations in yield-related traits of rice hybrids using factorial hybridization. *SABRAO J. Breed. Genet.* 57(6): 2676-2683. http://doi.org/10.54910/sabrao2025.57.6.40.

## INTRODUCTION

Rice (*Oryza sativa* L.) is one of the important and major grain crops in the world. It ranks second after wheat in terms of value. About half of the world's population consumes it. Rice is the main economic resource for hundreds of millions of Asian residents (FAOSTAT, 2021). The world's cultivated rice area is 162 million hectares and produces approximately 756 million tons (FAO*,* 2022). In Iraq, an area of 38,800 ha (388,000 dunums) entailed rice planting, with an annual production of 155,000 tons for the year 2021 (Statistics, 2020). This production requires a boost to meet the continued population growth, especially in the next 30 years, because of an expected population increase of up to 40%. Likewise, raising rice production is essential due to the increasing risk of environmental pressures and the limitation of arable areas (FAO, 2022).

Rice in Iraq comes in second place after the wheat crop for importance and production. It is one of the crucial strategic crops in food security, as the cultivated area of it in 2020 amounted to approximately 40,690 hectares and the total production to 464,200 tons, with an average yield of 1,140.8 kg/1000 $m^2$ (Ministry of Agriculture statistics, 2020). The production rate per hectare in Iraq is small compared with its productivity in Arab countries and other countries worldwide. Although Iraq is one of the countries known for cultivating this crop from ancient times, especially since the environmental conditions in Iraq are suitable for its cultivation (Al-Younis, 1993).

The factorial mating in breeding and improving grain crops is one of the systems that can be dependable in comparing parental cultivars and selecting the best (Al-Taweel *et al*., 2012). The first rice cultivar released in 1966 was IR8. It was a modern, high-yielding rice cultivar at the time. The IR8 underwent several genetic improvements in terms of shortening its growth period and improving its grain quality. Later on, the International Rice Research Institute (IRRI), in the Philippines, released 42 rice cultivars. The yield of IR8 and other early cultivars ranged between nine and 10 t/ha during the years 1969–1970.

In plant breeding, it provides us with useful estimates in determining the components of a complex trait such as yield. However, it does not provide accurate information about the relative importance of direct and indirect effects of each trait on yield. Therefore, the use of path coefficient analysis will help partition the genetic correlation coefficient between the dependent variable (yield) and the independent variables. The wheat traits incurred studies for direct and indirect effects to derive the selection evidence to guide the plant breeders in selection and hybridization programs (Taha, 2007).

Moreover, studying the genetic parameters of traits, such as the heritability ratio, reveals the relative importance of genetic variation on total phenotypic variation, and thus, the utilization of appropriate breeding methods is essential. The method of factorial mating proposed by the two scientists, Comstock and Robinson (1948 and 1952), is one of the methods of hybridization between strains or cultivars through which the best strains and genetic structures served as parents.(AL-Burki,2021).consequently, determining the best hybrids results from them. The most vital goals of this study comprise studying the phenotypic, genetic, and environmental correlations between the studied traits to determine those most closely linked to the outcome phenotypically, genetically, and environmentally, and estimating the path coefficient.(Idris,2012)

## MATERIALS AND METHODS

### Plant material and procedure

The presented research on rice commenced in 2021 and 2022 at the Rice Research Station, Al-Mishkhab, Al-Najaf Al-Ashraf, Iraq (located at a latitude of 31.48 North and longitude of 44.29 East, with an altitude of 70 m above sea level). Eight genetic compositions of rice used include four local cultivars (Amber 33, Yasmine, Al-Furat, and Degla), obtained from the rice research station in Al-Mishkhab. The other four were Egyptian cultivars (Giza 201, Giza 178, Giza 179, and Basmati 1), which came from the Arab Organization for Agricultural Development, Egypt.

Plowing the field soil with two perpendicular plows employed a rotary plow at a depth of 30 cm. Then, its smoothening used disc harrows, with the soil leveled by a leveling machine. Afterward, dividing the field into plots consisted of a panel length of 3 m and a width of 1 m. Thus, the area of the experimental unit reached 3 $m^2$. The experimental soil received fertilizer treatments with $P_2O_5$ superphosphate fertilizer (150 kg/ha). It had a one-time addition before planting, with the planting done manually on lines at a distance of 10 cm between one line and another. Meanwhile, sowing occurred with a seed rate of 35 kg per 1000 $m^2$. The addition of nitrogen fertilization was in batches. For the purpose of combating weeds, Isol pesticide application had a spray rate of 50-100 g per 100 l of water after planting, using 100 l containers to combat weeds growing with rice. Additionally, manual weeding took place whenever necessary, and the manual harvesting of experimental units proceeded when the plants reached physiological maturity.

Eight rice genotypes introduced into a crossbreeding program employed the factorial mating design proposed by researchers Comstock and Robinson (1948 and 1952) (Table 1). The pure strains that entered succeeded in dividing into two groups. The first four were the local rice cultivars used as female parents (Amber 33, Yasmine, Al-furat, and Dajla). The second group of the four male genotypes was Egyptian cultivars (Giza 201, Giza 178, Giza 179, and Basmati 1). The number of hybrids produced should be the sum of 4 × 4 = 16 hybrids. The hybrid has the symbol of two numbers representing its parents. The first number represents the mother, and the second number represents the father. For example, the hybrid 1 × 6 symbolizes strain number 6, which is Giza 178, representing the father of this hybrid, and strain number 1, which is Amber 33, represents the mother of this hybrid. The following table shows the method of multiplication to obtain 16 hybrids.

**Implementation of the experiment**

Before plantation, the physical and chemical properties of the experimental field soil entailed assessment (Table 2). The eight genotypes incurred planting in the first year of 2021 at the rice research station in Al-Mishkhab, affiliated with the General Authority for Agricultural Research, Ministry of Agriculture. The control of pollination continued by taking random samples within the experimental units before the flowering stage and placing them in 7-kg pits, three of each cultivar. Their transfer to the canopy near the experimental field happened in carrying out the hybridization process between the local and Egyptian cultivars. This included removing the anthers from the mothers using forceps prepared for this purpose, as well as using a magnifying glass to facilitate the process of removing the anthers. Pollen grains' transfer proceeded from the fathers to the maternal lines, with the male and female inflorescences covered with Poehlmen leaf bags after.

**Table 1.** Multiplication method and hybrid symbol.

| No. | Genotype | Symbol | No. | Genotype | Symbol |
|---|---|---|---|---|---|
| *1* | ♂ ) Giza 201×Amber 33(♀ | 1×5 | *9* | ♂ ) Giza 201×Al-furat♀( | 3×5 |
| *2* | ♂ ) Giza 178×Amber 33(♀ | 1×6 | *10* | ♂ ) Giza 178×Al-furat(♀ | 3×6 |
| *3* | ♂ ) Giza 179×Amber 33(♀ | 1×7 | *11* | ♂ ) Giza 179×Al-furat(♀ | 3×7 |
| *4* | ♂ ) Basmati× Amber 33(♀ | 1×8 | *12* | ♂ ) Basmati× Al-furat(♀ | 3×8 |
| *5* | ♂ ) Giza 201×Yasmine(♀ | 2×5 | *13* | ♂ ) Giza 201×dajla(♀ | 4×5 |
| *6* | ♂ ) Giza 178×Yasmine(♀ | 2×6 | *14* | ♂ ) Giza 178×dajla(♀ | 4×6 |
| *7* | ♂ ) Giza 179×Yasmine(♀ | 2×7 | *15* | ♂ ) Giza 179×dajla(♀ | 4×7 |
| *8* | ♂ ) Basmati× Yasmine(♀ | 2×8 | *16* | ♂ ) Basmati× dajla(♀ | 4×8 |

**Table 2.** Physical and chemical traits of the experimental field soil.

| Traits | | Agricultural season 2022 | Units | |
|---|---|---|---|---|
| Soil texture components | Sand | *23.09* | $g.kg^{-1}$ | Silty clay mixture |
| | Silt | *41.27* | $g.kg^{-1}$ | |
| | Clay | *35.64* | $g.kg^{-1}$ | |
| Nitrogen | | *24.25* | Ppm | |
| Phosphorus | | *15.31* | Ppm | |
| Potassium | | *175.12* | Ppm | |
| EC electrical conductivity | | *3.24* | $Ds.m^{-1}$ | |
| pH | | *7.47* | --- | |

**Experimental design**

In the second year, 2022, the seeds of the parents and hybrids (16 individual hybrids + eight parents) underwent planting according to a completely randomized block design with three replicates. The experimental unit included three replicates. After preparing the field soil in terms of plowing, smoothing, and dividing, repeating the leveling included water to ensure the success of seedling growth. Movable is an important process in the Stahl method. According to the planting dates on June 21, the seeds of all varieties entailed placement in cloth bags inside containers filled with clear water for a period of 48 h. Changing the water transpired every 12 h to ensure the abundance of dissolved oxygen for the seed embryos. After this process, the packaging of seeds comprised placing them in jute bags and covering them for 24 h for the purpose of stimulating germination (the appearance of the root and the petiole). Afterward, the prepared plastic dishes with dimensions of 28 cm × 58 cm × 3 cm filled with fine soil and moistened to the point of saturation received the scattering of seeds from all varieties.

Then the placement process proceeded, with the dishes placed on top of each other and each dish covered. The plates for planting were empty plates before stacking these plates well on top of each other after covering them with a jute bag soaked in water to maintain permanent moisture for the seeds. They remained in this state for five days. Then, moving the plates to the nursery ensued to obtain better growth of the seedlings. Placing the plates next to each other, they got covered with a light cloth to prevent damage to the seedlings from birds, rodents, and direct sunlight. The nursery attained watering twice a day, with the water being drained, while keeping the nursery moist to help the roots of the seedlings grow in the dishes. The dishes remained in the nursery until their planting in the permanent field. The nursery was near the experiment site for ease of transportation and to avoid harm to the seedlings. Then the seedlings' transfer to the permanent field occurred when they were 25 days old, planting one seedling per hole. The distance between one hole and another was 25 cm, and between one line and another was 25 cm.

The field's watering started using the traditional irrigation method to irrigate the rice crop continuously after manual transplanting. The uprooting of the bush happened three times manually. The first weeding took place 10 days after planting, while the second was 15 days from the first weeding, and the third after 15 days from the second weeding. The experiment received fertilizer treatment with the compound fertilizer (18-18-0) NP at 400 kg $ha^{-1}$ mixed with the soil. As for the urea fertilizer, adding N (46%) occurred in two equal batches—the first, 10 days after planting at 140 kg $ha^{-1}$ for each batch, while the second was a month after the first batch, continuing irrigation operations until the plants reached the physiological maturity stage (Al-Hassani and Al-Maadidi, 2017).

Ten plants taken from each experimental unit were random before starting to take measurements, and researchers considered not taking peripheral plants. All measurements of traits proceeded on the individual plant, as the replicate includes 24 genetic compositions; thus, the number of experimental units will reach 72. Soil and crop service operations continued, as follows. In the first year, the following chart showed the distribution of transactions in the experiment field for studied traits, with the data recorded on the total number of grains and 1000-grain weight, straw weight (g plant$^{-1}$), and biological yield (g plant$^{-1}$). For grain yield (g plant$^{-1}$), two guarded lines entailed harvest from each treatment. The plants bore manual threshing, with data formulated with 14% humidity. The harvest index calculation used the method as follows:

Harvest index = (grain weight/biological yield weight) ×100 (Shweta&Singh,2020)

**Statistical analysis**

Data for the genotypes (parents and hybrids) and for the studied traits underwent analysis according to a completely randomized block design using the analysis of variance method. Meanwhile, using the least significant difference of 0.05, diagnosed statistical differences between the arithmetic means of the coefficients (Steel and Torrie, 1980).

**Genetic analysis**

The hybrid data analysis was according to the method of the global mating system proposed by the scientists, Comstock and Robinson (1948 and 1952) and the fixed model (Table 3).

For the purpose of conducting genetic studies, according to this system, the equation of the mathematical model is: (Palaniswamy&Gomez,1971).

$$y_{ijk} = \mu + M_i + F_j + MF_{ij} + R_k + e_{ijk} \begin{bmatrix} i = 1,2,3,4 \\ j = 1,2,.,6 \\ k = 1,2,3 \end{bmatrix}$$

Where $y_{ijk}$ = the value of viewing is due to genotype $ij$ in the sector $k$ ;

$\mu$ = the general average of the trait;

$M_i$ = the parents influence $(i)$ ;

$F_j$ = female influence $(j)$ ;

$MFij$ = effect of male and female interference;

$R_k$ = sector influence $k$ ; and

$e_{ijk}$ = the value of the experimental error of the genotype $ij$ located in the sector $k$ .

**RESULTS AND DISCUSSION**

The genotypes revealed significant differences for the number of grains trait (Table 4). The H9 hybrid Giza 201 × A-furat excelled as the best parent, while the H1 hybrid gave the lowest number of seeds (164.83 grains plant$^{-1}$). As for the varieties, the A-furat cultivar stood out by giving the highest number of seeds. It reached 283.90 grains plant$^{-1}$, while the Amber 33 cultivar gave the lowest number of grains at 140.23 grains plant$^{-1}$. Meanwhile, for the weight of 1000 grains, the H9 hybrid (Giza 201) and the H2 hybrid (Giza 201) outshone others. As for the varieties, the Furat cultivar excelled by giving the supreme straw weight of 175 grains plant$^{-1}$, while the lowest straw weight from the cultivar Giza 179 was 51.67 grains plant$^{-1}$.

As for the biological yield characteristic, the H16 hybrid Basmati × Dajla excelled by giving the highest biological yield of 405.33 grains plant $^{-1}$. Meanwhile, the lowest biological yield resulted from the H13 hybrid (Giza 179-1) for the said yield trait. The hybrid H9 Giza 201 × A-furat was excellent by giving the maximum grain yield of 234.67 grains plant$^{-1}$, while the hybrid H1 Giza 178 × Amber 33 gave the lowest grain yield of 35.33 grains plant$^{-1}$. As for the varieties, the cultivar A-furat was superior. It provided the highest grain yield of 192.67 grains plant$^{-1}$, while the cultivar Giza 179 gave the lowest grain yield of 28.33 grains plant$^{-1}$. As for the harvest index trait, the hybrid H1 Giza 178 × Amber 33 reached 27.04%. Of the varieties, the Al-Furat cultivar outperformed by giving the highest harvest index of 52.41%, while the Amber 33 cultivar gave the lowest value (25.65%).

**Table 3.** Rice genotypes mean performance for growth and yield traits in rice.

| Genotypes | Number of total grains | 1000-grain weight (g) | Biological yield (g plant$^{-1}$) | Harvest index (%) | Grain yield (g plant$^{-1}$) |
|---|---|---|---|---|---|
| H 1 | 164.83 | 22.25 | 130.67 | 35.33 | 27.04 |
| H 2 | 259.63 | 20.80 | 215.00 | 103.33 | 47.79 |
| H 3 | 205.53 | 21.01 | 183.33 | 72.33 | 39.47 |
| H 4 | 263.17 | 22.43 | 330.33 | 148.67 | 45.01 |
| H 5 | 224.30 | 22.35 | 233.00 | 107.67 | 46.21 |
| H 6 | 236.47 | 21.45 | 352.67 | 169.67 | 48.10 |
| H 7 | 227.43 | 22.40 | 209.00 | 98.33 | 47.12 |
| H 8 | 188.00 | 21.27 | 190.67 | 86.00 | 45.07 |
| H 9 | 294.10 | 27.60 | 429.33 | 234.67 | 54.66 |
| H 10 | 217.80 | 24.07 | 207.33 | 98.67 | 47.58 |
| H 11 | 251.57 | 21.99 | 341.67 | 161.33 | 47.22 |
| H 12 | 194.37 | 24.03 | 151.00 | 55.33 | 36.65 |
| H 13 | 189.10 | 24.55 | 122.00 | 39.33 | 32.23 |
| H 14 | 254.27 | 23.79 | 241.33 | 111.67 | 46.27 |
| H 15 | 246.00 | 22.61 | 192.00 | 87.67 | 45.66 |
| H 16 | 293.70 | 20.57 | 405.33 | 196.67 | 48.55 |
| *178*G | 188.20 | 19.47 | 146.00 | 49.00 | 33.58 |
| *179*G | 156.13 | 25.82 | 80.00 | 28.33 | 35.39 |
| *201*G | 244.10 | 23.98 | 157.33 | 76.00 | 48.28 |
| B | 202.63 | 20.09 | 140.67 | 45.00 | 31.99 |
| Y | 205.73 | 18.46 | 171.67 | 68.67 | 40.01 |
| F | 283.90 | 23.78 | 367.67 | 192.67 | 52.41 |
| D | 246.60 | 24.21 | 148.67 | 55.00 | 37.02 |
| *33*A | 140.23 | 21.44 | 162.33 | 41.67 | 25.65 |
| LSD | 13.219 | 1.257 | 11.884 | 6.068 | 2.216 |

**Table 4.** Genetic correlation values for the studied traits in rice.

| Traits | Number of total grains | 1000-grain weight (g) | Straw | Biological yield (g plant$^{-1}$) | Harvest index (%) | Grain yield (g plant$^{-1}$) |
|---|---|---|---|---|---|---|
| Number of total grains | 1 | | | | | |
| 1000-grain weight (g) | 0.191 | 1 | | | | |
| Straw | 0.715 | -0.012 | 1 | | | |
| Biological yield (g plant$^{-1}$) | 0.806 | 0.109 | 0.975 | 1 | | |
| Harvest index (%) | 0.851 | 0.241 | 0.601 | 0.745 | 1 | |
| Grain yield (g plant$^{-1}$) | 0.846 | 0.194 | 0.928 | 0.987 | 0.826 | 1 |

**Estimating genetic, environmental, and phenotypic correlations**

The genetic correlation values for the studied traits indicated the yield as positively and significantly correlated with the traits, total grain number, grain weight, straw weight, biological yield, and harvest index, with values reaching 0.84, 0.19 g, 0.92 g, 0.98 g, and 0.82%, respectively (Table 3). The weight of 1000 grains also revealed a positive correlation with the trait of the total number of grains, with correlation values reaching 0.19. Likewise, the total grain number also displayed a positive correlation with the traits. Positive values indicate the possibility of improving yield through the trait that shows a high moral correlation, serving as evidence of selection for plant breeders.(Shankar, 2023).

In general, one can say that genetic correlation describes the degree of connection of multiple genes that control a certain quantitative trait from multiple genes. This, in turn, controls another quantitative trait, describing the multiple effects of multiple genes on the two traits. Thus, genetic

**Table 5**. Environmental correlation values for the studied traits in rice.

| Traits | Number of total grains | 1000-grain weight (g) | Straw | Biological yield (g plant$^{-1}$) | Harvest index (%) | Grain yield (g plant$^{-1}$) |
|---|---|---|---|---|---|---|
| Number of total grains | 1 | | | | | |
| 1000-grain weight (g) | 0.101 | 1 | | | | |
| Straw | 0.715 | -0.012 | 1 | | | |
| Biological yield (g plant$^{-1}$) | 0.806 | 0.109 | 0.975 | 1 | | |
| Harvest index (%) | 0.851 | 0.241 | 0.601 | 0.745 | 1 | |
| Grain yield (g plant$^{-1}$) | 0.846 | 0.28 | 0.20 | 0.66 | 0.56 | 1 |

**Table 6.** Phenotypic correlation values for the studied traits in rice.

| Traits | Number of total grains | 1000-grain weight (g) | Straw | Biological yield (g plant$^{-1}$) | Harvest index (%) | Grain yield (g plant$^{-1}$) |
|---|---|---|---|---|---|---|
| Number of total grains | 1 | | | | | |
| 1000-grain weight (g) | 0.183 | 1 | | | | |
| Straw | 0.697 | -0.012 | 1 | | | |
| Biological yield (g plant$^{-1}$) | 0.789 | 0.105 | 0.973 | 1 | | |
| Harvest index (%) | 0.822 | 0.229 | 0.575 | 0.730 | 1 | |
| Grain yield (g plant$^{-1}$) | 0.828 | 0.187 | 0.920 | 0.986 | 0.818 | 1 |

improvement of one of the two traits will lead to improving the other trait if the genetic correlation was positive. Overall, significant positive genetic correlation indicates that genetic systems synergistically influence both linked traits, and selecting for either trait will affect the other in the same direction. Significant positive phenotypic correlation implies that an increase in one trait leads to an increase in the other. These results are consistent with findings stated by both Chen *et al.* (2019) and Cui *et al.* (2020).

According to environmental correlation, the grain yield showed a positive and significant correlation with the traits, viz., 1000-grain weight, straw weight, biological yield, and harvest index, and their correlation values reached 0.28 g, 0.20 g, 0.66 g, and 0.56%, respectively (Table 5). The trait also indicated an association with the weight of 1000 grains, and a significant correlation with the characteristic (total number of grains) gave values of 0.10, respectively (Saleem *et al.,* 2010; Huang *et al.,* 2012). As per phenotypic correlation, the grain yield had a positive and remarkable correlation with the traits, viz., the total number of grains, straw weight, biological yield, and harvest index, with phenotypic correlation values of 0.82 g, 0.92 g, 0.98 g, and 0.81%, respectively (Table 6). Similarly, the said trait expressed an association with the 1000-grain weight.(Khattab, 2020).

The results of the same table showed the values of the phenotypic variance were higher than the values of the genetic variance for the studied traits. This was evident in giving the coefficient of phenotypic variation as higher levels than the coefficient of genetic variation. The difference between the coefficient of phenotypic and genetic variance for these structures was small, as the values were close to each other, and this indicates that genetic variance contributes mainly to the phenotypic variance of these genotypes (Alam*et al.,* 2004; EL-Degwy, 2013).

## CONCLUSIONS

The rice (*O. sativa* L.) hybrid Giza 201 × Al-furat showed the best performance and excelled for the traits of 1000-grain weight, biological yield, grain yield per plant, and harvest index, followed by the hybrid Basmati 1 x Dajla.

## REFERENCES


Alam MF, Khan MR, Nuruzzaman M, Parvez S, Swaraz AM, AlamI, Ahsan N (2004). Genetic bases of heterosis and inbreeding depression in rice (*Oryza sativa* L.). *J. Zhejiang Univ. Sci.* 5(4): 406–411.

AL-Burki FR, Abdulhussein MH, Sarheed AF (2021). Season Response of Bread Wheat Cultivars (Triticum aestivum L.) to Different Planting Dates under Samawa Desert Condition. IOP Conf. Ser.: Earth Environ. Sci.

Al-Hassani LNH, Al-Maadidi AD (2017). The effect of irrigation periods and organic fertilization on the growth and yield of two varieties of rice under the rice intensification system (SRT). *Iraqi J. Agric. Sci*. 48(3): 823–840.

Al-Taweel MS, Ahmed A, Ahmed M (2012). Factorial taxation in wheat. *Al-Rafidain Agric. J.* 8(1): 58–69.

Al-Younis AAA (1993). Production and improvement of field crops: Part One. Cereal crops and legume crops. Ministry of Higher Education and Scientific Research, University of Baghdad, College of Agriculture. 178 pp.

Central Bureau of Statistics (2021). Crop and vegetable production for the year 2021. Directorate of Agricultural Statistics. The Ministry of Planning, Baghdad, Iraq.

Chen J, Zhou H, Xie W, Xia D, Gao G, Zhang Q, Wang G, Lian X, Xiao J, He Y (2019). Genome-wide association analyses reveal the genetic basis of combining ability in rice. *Plant Biotechnol. J.* 17(11): 2211–2222.

Comstock RE, Robinson HF (1948). The components of genetic variance in populations of biparental progenies and their use in estimating the average degree of dominance. *Biometics* 4: 254–266.

Cui Y, Li R, Zhang F, Zhu T, Zhang Q, Ali J, Xu S (2020). Hybrid breeding of rice via genomic selection. *Plant Biotechnol. J*. 18(1): 57–67.

El-Degwy IS (2013). Genetic analysis of some cytoplasmic male sterile and suggested restorer rice lines. *Egyptian J. Agron*. 35(1): 93–114.

FAO (2022). Food and Agriculture Organization of the United Nations. *Quarterly Bull. Stat.* 11(3/4).

FAOSTAT (2021). Grain Production Worldwide by Type. Food and Agriculture Organization of the United Nations. Available at: https://www.statista.com/statistics/263977.

Huang X, Zhao Y, Wei X, Li C, Wang A, Zhao Q, Han B (2012). Genome-wide association study of flowering time and grain yield traits in a worldwide collection of rice germplasm. *Nat. Genet*. 44: 32–39.

Idris AE, Justin FJ, Dagash YM, Abual AI (2012). Genetic variability and inter relationship between yield and yield components in some rice genotypes. *J. Exp. Agric*. 2(2): 233–239.

Khattab MN (2020). Analysis of correlation coefficients and genotypic and phenotypic pathways for yield and some of its components in some genotypes of sweet corn (*Zea mays* L. saccharata). *Syrian J. Agric. Res.* 7(2): 164–177.

Palaniswamy KM, Gomez KA (1971). Length-width method for estimating leaf area of rice. *Agron. J.* 66: 430–433.

Saleem MY, Mirza JI, Haq MA (2010). Combining ability analysis for yield and related traits in basmati rice (*Oryza sativa* L.). *Pak. J. Bot*. 42(1): 627–637.

Shankar RS, Priya PB, Bhardru D, Vanisri S (2023). Assessment of genetic variation and character association among yield and yield attributing traits in sweet corn (*Zea mays* L. saccharata) inbred lines. *Int. J. Environ. Climate Change* 13(10): 1146–1154.

Shweta UN, Singh HC (2020). Genetic analysis of sweet corn inbred lines and hybrids. *J. Pharmacogn. Phytochem.* 9(5): 920–924.

Statistics from the Ministry of Agriculture (2020). Crop production statistics in Iraq. Ministry of Agriculture. Republic of Iraq.

Steel RG, Torrie JH (1980). Principles and Procedures of Statistics. McGraw Hill Book Company, Inc. USA. 485 pp.

Taha GA (2007). Adopting the selection guide technique to improve traits of grain yield and its components in coarse wheat. *Kirkuk Uni. J. – Sci. Studies* 2(3): 52–66.