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Original article

Identifying the combining ability and genetic components of some rice agronomic traits (*Oryza sativa L.*)

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ABSTRACT

Traditional breeding methods produce high-yielding varieties with blast disease resistance. In this study, twenty-one F1s were evaluated for genotypic variation with seven parents; Analysis of variance showed statistically significant differences at the 0.05 level between all genotypes (crosses and parents). Blast and its constituent characters were also significantly affected by the mean squares of parents versus crosses. On the other hand, all of the F1 characters studied showed extremely high levels of variance in general combining ability (GCA) and specific combining ability (SCA). The best hybrid combinations for grain yield per plant were Sakha101 × Hassawi-1, Giza175 × Sakha103, and Gz9577 × Giza175. Regarding heritability estimates for all traits under consideration, the results revealed that heritability, in general, was high for all characters. Pearson's correlation found 15 correlation coefficients among the characters to be significant ($p < 0.05$). Flag leaf area, grain yield per plant, and milling percentage all had positive and highly significant correlations.

1. Introduction

Rice (*Oryza sativa L.*) is a staple food consumed by many human populations worldwide (Wang et al., 2023). Every year requirement for rice grows in line with the global population. The concern of urbanization calls for increased food production on the planet's limited agricultural land (Fofana et al., 2014; Nalley et al., 2017). Cultivar improvements for farmer-preferred features like grain yield, shatter resistance, tolerance to abiotic and biotic challenges, and consumer preferred features like aroma, color, cook ability, and grain size will serve as the foundation for an increase in rice farming (Uyeh et al., 2021). However, abiotic and biotic factors limit global rice production; abiotic stresses like high and low temperature, drought, low and high soil nutrient content, and salinity; and biotic factors like diseases and pests cause significant losses at various stages of crop growth and development (Suvi et al., 2020; Mujawamariya et al., 2017). Economic losses are incurred due to yield and quality reductions caused by primary rice diseases (Abebrese et al., 2019). To successfully enhance and create new types, it is required to study the genetic behaviour and the genetic background of all the desired attributes of all the genotypes (Patial et al., 2016; Kargbo et al., 2019). Nonetheless, studies on extensive and limited skill set having the capacity to identify the appropriate parents to produce crosses that will produce offspring with the best qualities are vital. When parent plants generate healthy progeny, they have excellent combining capacity. Also, combining abilities aids in defining a gene's pattern that influences the expression of quantitative features, which can be used to discover possibly superior parents and hybrids (Zhang et al., 2015). General combining ability (GCA) assesses additive gene function corresponding to a genotype's average results in a sequence of hybrid compositions. In contrast to GCA, the specific combining ability (SCA) is the efficiency of a parent in a specialized crossing (Anis et al., 2016; El-Malky and Al-Daej, 2018; Yadav et al., 2021; Fahmi et al., 2017). A mutation is a heritable change in the DNA; this frequency was discovered to be more than 1%, called polymorphism (Khan et al., 2015).

Breeders need an in-depth study of the genetic history of the parents, which carries desirable features, to transfer the crop and yield characters and capitalize on the knowledge of GCA of lines and SCA of their test crosses, heterosis, and heterotic orientation (Bhor et al., 2020; Gowayed Salah et al., 2020). The impact of the parents and their hybrid combinations on general and specialized combining abilities can be reliably determined using the half-

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diallel crossing mating design (Griffing, 1956). Creating a new genotype with higher yield and resistance is critical to enhancing the rice breeding program. Therefore, the fundamental purpose of this research is to examine the heritability of blast resistance and other quantitative features, such as general and specialized combining ability and estimates of genetic factors in the F1 generation.

2. Materials and methods

Field studies were undertaken between 2019 and 2020 to explore the magnitude of combining abilities and genetic characteristics.

2.1. Experimental material

Seven rice genotypes were used in this investigation, namely; Giza178, Sakha 101, Gz6903-3–4-2–1, GZ 9577–4-1–1, Hassawi-1, Giza175 and Sakha103. However, the parents included five were resistant to leaf blast infection (Giza178, Gz6903-3–4-2–1, GZ 9577–4-1–1, Giza175 and Sakha103), two were susceptible (Sakha 101 and Hassawi-1). In addition, crosses were made among that genotype through half dialell to produce 21 F_1 crosses which were included as experimental materials in this study.

2.2. Experimental procedure

To account for the variance in heading date among the parental variety, seven genotypes were sowed 15 days apart on three different dates in the summer of 2019. The parent seedlings were planted in a greenhouse and transplanted onto the experimental field 30 days later, where they were placed 20 cm apart in 5-meter-long rows. In 2019, seven parents participated in a half diallell cross that resulted in 21 offspring. We employed the hot water emasculation and hybridization approaches (Butany, 1961). The parent varieties and the 21 offspring crossings will be evaluated in a three-sample randomized complete block design (RCBD) experiment in 2020.

2.3. Data collection

The IRRI Standard Evaluation System assessed the critical agronomic traits: leaf blast reaction, flag leaf area, number of filled grains per panicle, grain yield per plant (g), milling percentage, and head rice percentage (Rice, 1996). For both seasons of the research, agronomic techniques such as fertilization, irrigation, and weed and pest control were carried out as recommended for rice crops.

2.4. Statistical analysis

Two-way ANOVA analysis was performed using the obtained data for a randomized complete block (Panse and Sukhatme, 1954) and variance analysis for crossing Kempthorne's design (Kempthorne, 1957). Statistical analysis was performed on $p < 0.05$ *and 0.001* (Khan et al., 2019).

3. Results

3.1. Mean performance for quantitative traits

The mean performance of parents and their 21 hybrids for the studied traits is shown in (Table 1). For blast infection, five parents were resistant to leaf blast infection (Giza178, Gz6903-3–4-2–1, Gz9577-4–1-1, Giza175 and Sakha103), while Sakha101 and Hassawi-1 were susceptible. In the cross combination, all the F_1 showed resistance to leaf blast except the cross Sakha101(S) × Hassawi-1 (S) was susceptible, indicating that the two parents carrying recessive genes for resistance. On the other hand, the resistantXresistant and resistantXsusceptible gave resistance in the F_1 generation. This indicated that the resistant trait was dominant. Concerning flag leaf area, the parents Sakha101, Gz6903-3–4-2–1 and Hassawi-1 gave the high value of 40.0, 39.87 and 38.10 cm^2, respectively. While in F1, the best crosses were Sakha101 × Gz6903, Gz69031 × Gz95771, Giza178 × Sakha103, Giza178 × Sakha101, and Gz6903 × Sakha103 gave 48.47, 45.66, 43.62, 43.58 and 43.30, respectively. According to the number of filled grains per panicle, three varieties, Giza178 (133.0), Gz9577-4–1-1(125.6) and Sakha101 (122.3), gave high values, while the best crosses were Sakha101 × Gz6903, Giza178 × Sakha101, Giza178 × Gz6903 and Gz69031 × Gz95771 gave 169.0, 155.6, 145.6 and 143.3, respectively. For grain yield per plant, five parents were heights value grain yield, ranging from 40.43 to 46.49 g (Table 1). On the other hand, sixteen crosses were heights value in grain yield per plant, ranging from 40.20 to 49.70 (Table 1). In milled rice and head rice percentage, three parents, Sakha103, Sakha101 and Gz6903-3–4-2–1, gave high value, while the best crosses were Gz9577 × Giza175 (65.49%) and Gz6903x Giza175 (65.39%).

3.2. Anova analysis

A two-way ANOVA analysis was performed and documented in Table 2 to compare the differences between parents and hybrids for all studied traits. According to the results, selection procedures based on the accumulation of additive effects would effectively improve these traits.

3.3. GCA effects

Table 3 displays estimates of parental GCA effects. The results showed that five rice genotypes, namely; Giza178, Gz6903-3–4-2–1, Gz9577-4–1-1, Giza165 and sakha103, were highly significant negative values for blast resistance (-0.46, −0.23, −0.34, −0.31 and −0.34, respectively) this indicated that these genotypes were the best combiners for blast trait. Also, the significant negative value was desirable for blast resistance, while two varieties, Sakha101 and Hassawi-1, gave positive significance. Concerning the Flag leaf area, two varieties (Sakha101 and Gz6903-3–4-2–1) had significant positive desirable GCA effects proving to be excellent combiners for this trait. This indicated that these varieties are good combiners to transfer this trait and could be used as a donor in the breeding program. The genotypes Sakha101, Gz6903-3–4-2–1 and Gz9577-4–1-1 gave highly significant positive GCA effects for grain yield/plant and milling percentage. These genotypes are suitable donors for these traits.

3.4. SCA effects

Twenty-one rice hybrids were estimates of specific combining ability effects (Table 4). Seven crosses were significantly negative for blast reaction the best combination was Sakha101x Gz9577 and Sakha101x Sakha103. The crosses with significant negative values could be utilized in rice breeding programs to develop new early-duration rice varieties. Regarding flag leaf area, seven hybrid combinations exhibited significant and highly significant positive values of SCA effects. The desirable hybrid combinations were Gz69031 × Gz95771, Giza178 × Sakha103, Giza178 × Gz95771 and Hassawi-1 × Giza175, which gave 7.09, 5.43, 3.22, and Hassawi-1 × Giza175 respectively, indicating that they could be used in a breeding program. Eight rice crosses

Table 1
Mean performance for studied traits in the selected seven parents and their crosses.

Genotype	*Blast reaction	Flag leaf area(cm)^2	No. of filled grains /panicle	Grain yield/plant	Milling %	Head rice %
Giza178	1.33	34.27	133.0	46.49	68.38	61.25
Sakha101	5.33	40.00	122.3	45.33	71.11	64.27
Gz6903-3–4-2–1	2.00	39.87	120.0	40.43	71.10	64.25
Gz9577-4–1-1	2.00	34.18	125.6	41.40	65.03	60.30
Hassawi-1	4.67	38.10	90.33	30.30	61.31	53.57
Giza175	1.33	31.87	119.6	34.17	68.18	62.59
Sakha103	1.67	35.39	111.3	41.35	72.04	64.65
Giza178x Sakha101	2.33	43.58	155.6	45.20	71.63	64.04
Giza178x Gz6903	1.67	39.38	145.6	48.67	71.75	62.57
Giza178x Gz95771	1.67	41.91	138.0	41.97	71.31	63.53
Giza178x Hassawi-1	1.67	37.87	103.3	45.40	70.83	63.60
Giza178x Giza175	2.00	35.66	162.6	39.37	69.94	63.47
Giza178x Sakha103	1.33	43.62	130.0	42.53	71.56	64.59
Sakha101x Gz6903	2.00	45.66	169.0	49.07	72.74	63.79
Sakha101x Gz9577	1.67	38.92	151.3	49.70	71.62	63.61
Sakha101x Hassawi-1	5.00	40.21	109.6	34.70	70.66	64.53
Sakha101x Giza175	2.33	38.31	139.0	41.57	69.77	64.75
Sakha101x Sakha103	1.67	38.72	110.6	40.23	71.16	63.75
Gz69031x Gz95771	1.33	48.47	143.3	50.23	72.02	62.93
Gz6903x Hassawi-1	2.67	38.82	112.6	40.57	71.34	63.72
Gz6903x Giza175	2.00	36.61	125.3	40.20	71.76	65.39
Gz6903x Sakha103	1.67	43.30	120.6	44.13	71.08	63.99
Gz9577x Hassawi-1	2.00	39.29	102.6	34.53	72.45	64.35
Gz9577x Giza175	1.67	36.86	127.6	43.50	72.48	65.49
Gz9577x Sakha103	2.00	36.33	91.0	33.37	70.66	64.20
Hassawi-1x Giza175	2.00	38.40	92.6	30.57	67.76	64.28
Hassawi-1x Sakha103	2.00	37.43	113.3	40.37	69.65	64.17
Giza175x Sakha103	2.00	35.90	131.3	40.70	71.73	63.60
L.S.D a t 0.05 at 0.01	**0.4**	**1.4**	**10.2**	**2.9**	**3.7**	**3.2**
	0.5	**2.1**	**12.3**	**4.1**	**5.2**	**4.8**

Table 2
Estimates of the mean square of ordinary analysis and combining ability analysis for studied characters.

S.O.V.	D.f.	Blast reaction	Flag leaf area(cm)^2	No. of filled grains/panicle	Grain yield/plant(g)	Milling (%)	Head rice (%)
Replications	2	1.39	2.73	7.18	6.50	2.32	3.73
Genotypes	27	3.29**	39.75**	7.75**	49.80**	4.01**	1.74**
Parents	6	8.27**	29.37**	4.60**	54.93**	4.53**	2.61**
Crosses	20	1.69**	35.28**	9.98**	41.19**	3.93**	1.49**
P.VsC (H)	1	5.43**	196.87**	1.92**	91.14**	2.54**	1.61**
Error	54	0.34	2.25	9.33	1.84	0.18	1.78
GCA	6	3.16**	24.66**	2.76**	44.88**	2.33**	0.67**
SCA	21	0.51**	10.08**	2.53**	8.52**	1.05**	0.56**
Error	54	0.11	0.75	3.11	0.61	0.06	0.59
GCA/SCA ratio	–	6.17	2.44	1.10	5.26	2.21	1.19

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

Table 3
Estimates of GCA effects for studied characters.

Genotype	Blast reaction	Flag leaf area(cm)^2	No. of filled grains/panicle	Grain yield/Plant (g)	Milling %	Head rice %
Giza178	−0.46**	−0.06	0.50	−0.26	−0.06	−0.58*
Sakha101	0.92**	1.59**	−0.65	2.65**	0.17*	0.17
Gz6903-3–4-2–1	−0.23*	2.32**	−0.13	2.73**	0.51**	−0.07
Gz9577-4–1-1	−0.34**	−0.11	0.50	0.59*	0.48**	0.13
Hassawi-1	0.80**	−0.32	0.57	−0.89**	−0.33**	0.03
Giza175	−0.31**	−2.85**	−0.76	−3.56**	−0.94**	0.07
Sakha103	−0.38**	−0.56	−0.02	−1.25**	0.18*	0.23
L.S.D at 5%	0.22	0.57	1.15	0.51	0.16	0.50
L.S.D at 1%	0.30	0.77	1.54	0.68	0.21	0.67

showed substantial positive values of SCA effects for grain yield per plant. The desirable hybrid combinations were Sakha101 × Hassawi-1, Giza175 × Sakha103 and Gz9577 × Giza175, which gave 5.18, 4.58 and 3.31, respectively. In milling rice percentage, six crosses were highly significant values of (SCA) effects and positive values. However, the best crosses were Gz9577x Giza175(1.97), Giza175 × Sakha103 (1.56), Gz9577 × Hassawi-1 (1.25) and Gz6903 × Giza175(1.21). The present finding was also supported by documented studies (El-Malky and Al-Daej, 2018; Fahmi et al., 2017).

Table 4
Estimates of SCA effects for studied characters.

Genotype	Blast reaction	Flag leaf area	Panicle length	No. of filled grains/panicle	Grain yield/plant	Milling %	Head rice %
Giza178x Sakha101	−0.36	2.97**	1.25**	−2.52	−1.02	0.47*	0.57
Giza178x Gz6903	0.26	−2.05*	−1.22**	−2.10	2.36**	0.20	−0.65
Giza178x Gz95771	0.39	3.22**	1.19**	1.52	1.50*	−0.20	0.09
Giza178x Hassawi-1	−0.90**	−0.59	−1.09**	0.77	−0.28	0.23	0.27
Giza178x Giza175	0.68*	0.05	−2.55**	1.61	0.13	0.03	0.10
Giza178x Sakha103	0.10	5.43**	−1.85**	−0.89	0.70	0.39	1.04
Sakha101x Gz6903	−0.95**	2.38**	0.59	−1.48	−0.52	0.94**	−0.26
Sakha101x Gz9577	−1.15**	−1.63*	−0.34	0.15	2.52**	−0.14	−0.67
Sakha101x Hassawi-1	0.89**	−0.10	−0.28	0.40	5.18**	−0.19	0.36
Sakha101x Giza175	−0.53	0.84	0.65*	−0.77	−0.94	−0.39	0.54
Sakha101x Sakha103	−1.11**	−1.32	0.25	0.07	0.13	−0.27	−0.64
Gz69031x Gz95771	−0.20	7.09**	0.60	1.57	2.96**	−0.12	−1.08
Gz6903x Hassawi-1	−0.15	−2.31**	0.36	−0.18	1.96**	0.10	−0.17
Gz6903x Giza175	0.43	−1.68*	1.59**	0.98	−2.40**	1.21**	1.44*
Gz6903x Sakha103	0.18	2.43**	1.26**	−0.52	−1.06	−0.74**	−0.13
Gz9577x Hassawi-1	−0.70*	0.89	1.23**	0.11	1.33	1.25**	0.22
Gz9577x Giza175	0.22	1.30	0.30	−3.39*	3.31**	1.97**	1.32
Gz9577x Sakha103	0.64*	−1.81*	0.83**	−0.89	−3.42**	−1.12**	−0.15
Hassawi-1x Giza175	−0.74*	3.08**	−0.85**	1.52	2.04**	−1.84**	0.22
Hassawi-1x Sakha103	−0.65*	−0.47	1.25**	1.36	−0.76	−1.22**	−0.07
Giza175x Sakha103	0.60	0.84	1.48**	0.86	4.58**	1.56**	−0.69
L.S.D at 5%	**0.61**	**1.55**	**0.62**	**3.16**	**1.40**	**0.44**	**1.38**
at 1%	**0.81**	**2.10**	**0.83**	**4.23**	**1.88**	**0.59**	**1.85**

3.5. Estimates of genetic parameters

Characteristics' additive and dominant genetic contributions and heritabilities were calculated (Table 5). Since the additive variance was more significant than the non-additive variance or dominance for all qualities, this supported the idea that additive gene activity predominated in determining early character traits. Estimates of heritability for all attributes showed that heredity was high for all characters except for spikelet fertility and head rice percentage. Blast reaction, flag leaf area, panicle length, filled grain count per panicle, yield per plant, and milling percentage were respectively 86.51, 94.10, 95.35, 84.66, 95.43, and 95.39.

3.6. Correlation and coefficient between studied traits

Table 6 defines the correlation and coefficient established between the six studied characteristics in this study. A strong statistical association was performed between flag leaf area, grain yield per plant and milling percentage.

Table 5
Estimation of additive genetic variance (σ^2A), dominance genetic variance (σ^2D), environmental variance (σ^2E) and heritability in broad for studied traits.

Traits	σ^2A	σ^2D	σ^2E	h^2_b %
Blast reaction	**0.34**	**0.40**	**0.34**	**86.51**
Flag leaf area	**2.65**	**9.32**	**2.25**	**94.10**
Panicle length	**0.45**	**2.00**	**0.36**	**95.35**
No. of filled grains/panicle	**−0.04**	**−0.58**	**9.33**	**84.66**
Grain yield/plant	**4.92**	**7.91**	**1.84**	**95.43**
Milling %	**0.25**	**0.99**	**0.18**	**95.39**

4. Discussion

Traditional breeding for improved yield traits and significant resistance remains a substantial objective in rice breeding programs. Therefore, the most cost-effective and practical method of eliminating these pests is the development of new rice varieties that are both high yielding and resistant to blast (Breseghello and Coelho, 2013). The unfavourable weather has a significant impact on food security and agricultural productivity. The output of main crops has decreased as temperatures have risen across the planet. Therefore, a study with a half dialell mating design and seven parents was done to learn more about the level of combining capacity for several agronomic features and their associations with grain yield. The selected features are crucial for increasing rice yields (Kargbo et al., 2019; Bhor et al., 2020).

For this reason, agricultural research institutions have undertaken breeding programmes to improve agricultural cultivars to overcome these environmental stresses. Useful genetic resources are a powerful instrument for the development and high yield of crops like rice (Nalley et al., 2017; Uyeh et al., 2021). This study focused on selecting seven rice cultivars from two types (Indica-Japonica and Japonica) and origins (Egypt and Saudi Arabia) to determine which cultivars qualify as different genetic sources qualify as a distinct genetic source be recommended for use by plant breeders. Significant differences between parental lines were found in the mean squares of the ordinary analysis of variance by

Table 6
Estimates of correlation coefficient for Paris of studied traits.

Characters	Flag leaf area	Blast reaction	No. of filled grains/panicle	Grain yield/plant	Milling%	Head rice %
Flag leaf area	1.00					
Blast reaction	0.045	1.00				
Spikelet fertility	−0.034	−0.008	1.00			
Grain yield/plant	0.687**	0.117	0.008	1.00		
Milling%	0.435*	−0.004	−0.204	0.543**	1.00	
Head rice %	0.013	0.205	−0.224	−0.043	0.203	1.00

half diallel of crosses for all traits (Tiwari et al., 2019; Adjah et al., 2020; Mosleth et al., 2020). In addition, there was a high level of significance between the mean performance of the parents and their F1 hybrid for all traits examined, showing that different rice genotypes have different genetic potential. Positive GCA effects would benefit most studied traits, including grain yield/plant. Generally, the estimates of the overall GCA status of parents indicated the genotypes, namely; Giza178, Gz6903-3–4-2–1, Gz9577-4–1-1, Sakah103 and Giza175 Hassawi-1 were highly significant negative value for the blast; this indicated that these genotypes were the best combiners for this trait.

On the other hand, Sakha101 and Hassawi-1 were susceptible to blasts, and the best crosses were Sakha101x Gz9577 and Sakha101x Sakha103. While, Sakha101 × Hassawi-1, Giza175 × Sakha103 and Gz9577 × Giza175 for grain yield per plant (Gowayed Salah et al., 2020; Breseghello and Coelho, 2013). Estimates of genetic component variance revealed that all traits studied were governed by non-additive variance or dominance. All heritability estimates were high, indicating a paternal influence on these traits (El-Malky and Al-Daej, 2018; Mosleth et al., 2020; Saidaiah et al., 2010).

5. Conclusion

This study concludes that understanding the correlations between these quantitative attributes was essential for the breeder to improve complex quantitative features like resistance, for which direct selection is inefficient. Using Pearson's correlation analysis, this study discovered that the thirteen quantitative qualities under investigation were not all highly correlated. All three correlation coefficients were statistically significant. A positive correlation was found between flag leaf area, grain yield per plant, and milling percentage.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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