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Adaptation and Selection of Early Maturing and High-Yielding Production of Some Exotic Rice Genotypes Under Egyptian Conditions

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EIGHTEEN introduced rice genotypes along with two local cultivars were evaluated in two successive seasons of 2020 and 2021 at the Experimental Farm of Sakha Agricultural Research station, Sakha, Kafr El-Sheikh, Egypt for grain yield and associated agronomic characters. Analysis of variance showed very highly significant differences among rice genotypes for all growth parameters assessed. Grain yield for most of studied rice genotypes was higher than check cultivars and AFR0280, AFR278-2-2 and AFR278-8 which had an average yield of 14.26, 14.03 and 14.00 (t/ha), respectively under both seasons. Genotypic variance was observed greater than environmental variance. The phenotypic coefficient of variation (PCV) was close to the genotypic coefficient variation (GCV), this indicating the influence of genetic factors on the expression of the characters studied. High broad-sense heritability (>85%) observed for all studied characters, this suggests that these traits are inherited by additive gene action and can be enhanced through direct selection. Grain yield was positively and strongly correlated with plant height, leaf (length and width), leaf area, panicle length, primary branches, panicle weight, spikelet per panicle and filled grains per panicle. The dendogram obtained from the cluster analysis divided the twenty rice genotypes into four clusters according to yield and its component traits. Hence it is suggested that, these characters could be used as a phenotypic marker for selecting the desirable genotype in the rice breeding programme.

Keywords: Rice, grain yield, heavy panicle, Genetic correlation, genetic parameters.

1. Introduction

Over 50% of the world's population primarily obtains their nourishment from rice, making it one of the most significant food crops globally. In Egypt, rice is considered the second-most important cereal crop after wheat also one of the main agricultural products for the farmers' income (Sedeek *et al.*, 2023). Strategies are needed to enhance grain yield in order to fulfill the food demand requirement of ever-increasing population. The only way to maximize returns on investment is to enhance crop harvest frequency and grain yield per unit area, as increasing rice planting area will not necessarily result in increased rice production (Ray and Foley, 2013; Peng, 2014). To satisfy this need, new, enhanced cultivars with higher yields will need to be developed faster (Seck *et al.*, 2012). However, most rice breeding programs in the world have not changed in several decades. A comprehensive approach to achieving food security must include the creation of new, higher-yielding rice varieties with improved resilience to biotic stressors, disease, and certain qualitative attributes (El-Namaky et al., 2023). Xing and Zhang (2010) reported that productivity of cereal crops is influenced by three major agronomic traits, grain weight, grains number per panicle, and effective tillers number per plant. The number of primary and secondary branches determines the

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number of grains per panicle, while the length, width, and thickness of the grains, as well as, the rate of filling them define the grain weight. Knowledge of interrelationship of the phenotypic traits among each other and their influence on yield is needed to facilitate the planning of a more efficient breeding program (Ashura 1998). Because phenotypic expression is influenced by environmental influences, selection based on phenotypic expression is attractive (Astarini *et al*., 2004). Agronomic traits like panicles number, spikelet's number per panicle, spikelet's filling percentage, and grain weight have also been shown in several studies to have a strong correlation with grain yield. For instance, Zhang et al. (2009) presented data relating high grain production of hybrid rice to the number of spikelets per panicle. According to Hau et al. (2020), plant height, the number of grains per panicle, the percentage of full grains, and the weight of the grains were all significantly and positively connected with grain yield. Principal components analysis (PCA) indicates that the number of grains and the number of full grains per panicle are important variables in predicting grain production. Overall, for inbred and hybrid rice cultivars produced in the agro-climatic conditions of southern China, the number of grains and the number of filled grains per panicle determine the grain yield. The objectives of the study are (i) to evaluate some of introduced rice genotypes for adaptation under Egyptian condition, (ii) to estimate the heritability and genetic parameters for agronomic and grain yield traits. (iii) estimate the correlation coefficient among agronomic and grain yield traits.

2. Materials and methods

2.1 Source of Materials

The experimental materials for the research work consist of some rice genotypes introduced from Africa Rice Center (ARC) and some other local varieties from Rice Research and Training Center (RRTC). Twenty genotypes of rice as a total were included in the study. Two check varieties were used in the evaluation process: Giza 178, a high-yielding Egyptian variety (Indica-japonica) and Giza 177 a desired Japonica check cultivar. These genotypes collected according to the collaborative research program between RRTC and ARC (Table 1).

Table 1. the pedigree and origin of the studied rice genotypes.

Entries	Parentage	Origin
Giza 177	Giza 171/YomjiNo.1//PiNo.4	Egypt
Giza 178	Giza 175/Milying 49	Egypt
GZ 10590-1-3-3-2	GZ8126-1-3-1-2/HR17570-21-5-2-5-2	Egypt
AFR-1	Introduction	Africa Rice Center
AFR-2	Introduction	Africa Rice Center
AFR-3	Introduction	Africa Rice Center
AFR-4	Introduction	Africa Rice Center
AFR-5	Introduction	Africa Rice Center
AFR-6	Introduction	Africa Rice Center
AFR-7	Introduction	Africa Rice Center
AFR-8	Introduction	Africa Rice Center
AFR-9	Introduction	Africa Rice Center
AFR-10	Introduction	Africa Rice Center
AFR-11	Introduction	Africa Rice Center
AFR-12	Introduction	Africa Rice Center
AFR-13	Introduction	Africa Rice Center
AFR-14	Introduction	Africa Rice Center
AFR-15	Introduction	Africa Rice Center
RM-1-2-3-3	Introduction	Africa Rice Center
RM-2-8-1-3-2	Introduction	Africa Rice Center

2.2 Experimental Site

The present investigation was carried out at the farm of Rice Research and Training Center (RRTC), Sakha, KafrEl-Sheikh, Egypt during two summer cropping seasons 2020 and 2021. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Genotypes were grown at may 1^{st} during two seasons, the seedling after thirty days were transplanting in the plot size five meter length with seven rows width with plant spacing of 20 cm x 20 cm row to row and plant to plant as individual plant per hill. Recommended fertilizer application and adequate crop care was maintained especially water supply, pesticide application, weed and rodent control and applied according to RRTC (2019).

2.3 Data Collection

Data collections were taken on the following studied traits i. e. days to heading (day), plant height (cm), leaf length (cm), leaf width (cm), leaf area (cm2), leaf angle(o), No. of panicles/plant, panicle length (cm), Primary branches/panicle, panicle weight (gm), spikelet's/panicle, number of filled grains/panicle, spikelet fertility (%), 1000-grain weight (gm), and grain yield (t/ha) as recommended according to standard evaluation system of rice (IRRI, 2016**).**

2.4 Statistical Analysis

The data were analysed during two growing seasons according to Zafar et al., (2015). Analysis of variance which helps to break down the total phenotypic variance into components that are due to genetic (hereditary) and non-genetic (environmental) factors was measured as well as estimating its size. Additionally, variance genotypic (Vg), variance phenotypic (*Vp*), and variance error (*Ve*) were calculated using the formula mentioned by Bernardo, (2020) and Prasad, (1981), as follows:

$$V_g = \frac{(MSG - MSE)}{r}$$

$$V_{ph} = \frac{(MSG)}{r}$$

$$V_e = \frac{(MSE)}{r}$$

MSG= Mean squares of genotypes; MSE = Mean squares of error; r = Number of replications. Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was estimated according to Burton, (1952) and Kumar et al., (1985) as follows:

$$\text{PCV} = \frac{\sqrt{Vp}}{X}\ x\ 100$$

$$\text{GCV} = \frac{\sqrt{Vg}}{X}\ x\ 100$$

Vp = Phenotypic variances; Vg = Genotypic variances; X = Grand mean per season, for the traits under consideration.

Broad sense heritability (h^2_b) was evaluated following the methods described by Acquaah (2017) as follows:

$$h^2_b = (\sigma^2_g / \sigma^2_p) \text{ x } 100$$

σ^2_g = Genotypic variance; σ^2_p = Phenotypic variance. Phenotypic correlation was estimated using the standard procedure suggested Kashiani and Saleh (2010). The pearson's correlation was calculated by corrplot package in R. The cluster analysis tree construction was expressed by using the Paleontological Statistics (PAST) software package using the mean performance of the studied genotypes (Hammer et al., 2001).

3. Results and discussion

3.1. Analysis of variance:

Data in Table 2 displays the analysis of variance for fifteen traits that were evaluated during two-years period involving 20 genotypes. The findings showed that, there was a substantial degree of genetic variability among the rice genotypes, as seen by the presence of highly significant variances among genotypes for all variables examined. This would be proved to beneficial for improvement the rice crop production. These results were similar to obtained by Singh et al. (2005). The significant differences among the rice genotypes studied suggest that, this variability could be further utilized as new genetic resources in rice breeding program. The combined analysis exhibited non-significant interaction between the genotypes and years (G x Y) for all studied characters except number of days to heading, Leaf area (cm^2) and spikelet fertility (%), were recorded highly significant difference, indicated to the three traits may be affected with environmental conditions. Numerous authors have previously documented significant variance in rice genotypes for various parameters (Agbo and Obi, 2005 and Ukaoma *et al*., 2013).

3.2. Mean performance:

Performance for number of days to heading and leaf characteristic of twenty rice genotypes during two seasons (2020 and 2021) were shown in Table 3. Results revealed that, a significant difference for days to heading among the rice genotypes which ranged from 88.67 to 106.67 days and from 89.33 to 104 days during 2020 and 2021, respectively. The rice genotype AFR278-17 was the earliest heading (88.67 and 89.67 day) compared with the Egyptian rice cultivars Giza178 (99.3 and 100.7 day) and Giza177 (90.0 and 91.3 day) for both seasons (2020 and 2021), respectively. Early heading date rice varieties play an important role for water saving in irrigation ecology and allow growing more crops per year.

Regarding to the Flag leaf length, highly significant differences were observed among the tested rice genotypes due to its genetic background. AFR0280-2 was recorded as the longest flag leaf in both seasons followed by AFR0280 and AFR278-8 (Table 3). While, Giza177 recorded the shortest flag leaf length (28.07 and 29.40 cm) followed by AFR278-2 (34.2 and 35.87 cm) during both growing seasons, respectively. The results indicated that, the interaction between the two seasons under this study had no significant effect on flag leaf length of rice genotypes. In terms of flag leaf width trait, AFR278-33 recorded the maximum values (2.95 cm) followed by AFR051 (2.797 cm) and AFR021-B (2.633 cm) with similar flag leaf widths under both seasons. While, Giza177 recorded the narrowest flag leaf width (1.30 and 1.33 cm) during 2020 and 2021 seasons, respectively. Leaf area (cm^2) expressed as from leaf length and width, the rice genotype AFR0280-2 recorded the maximum flag leaf area (111.21 and 112.06 cm^2) during 2020 and 2021 seasons, respectively. While, the minimum values were found of Giza 177 (27.39 cm^2) and (29.42 cm^2) during the first and second seasons, respectively. These results are agreement with Taha et al., (2023). Highest flag leaf area will increase the photosynthetic rate then yield production. These results were confirmed by Osekita et al, (2015) and Wei et al, (2020). Regarding leaf angle (^{o}), the results showed that, highly significant among studied rice genotypes.

Table 2. Mean squares for fifteen characters studied of twenty new exotic rice genotypes during the two years of (2020 and 2021).

Characters:	Mean sum of squares				
	Year (d.f.= 1)	Reps/ Year (d.f.=4)	Genotypes(G) (d.f.= 19)	G x Y (d.f.=19)	Bold error (d.f.= 76)
Days to heading	0.0333	0.7271	156.16**	2.1912**	0.6306
Plant height (cm)	10.800	8.9037	1033.1**	7.7474	13.134
Leaf Length (cm)	2.8213	8.2162	205.56**	4.4003	3.9007
Leaf width (cm)	0.0056	0.0362**	1.0621**	0.0088	0.0079
Leaf area (cm^2)	20.746**	4.3165	2099.3**	25.603**	2.2347
Leaf angle(^{o})	31.930**	0.3601	37.323**	7.9862	0.8851
No. of panicles/plant	10.920**	1.3393	120.31**	1.8298	3.1028
Panicle Length (cm)	67.500**	3.6500	1113.0**	1.1896	46.267
Primary branches/ panicle	20.008**	1.5083	252.18**	0.1136	2.5259
Panicle weight (g)	24.526**	0.6230	77.467**	0.1406	0.7207
Spikelets/ Panicl	25375**	685.88	107566**	282.95	1936.5
No. of filled grains/panicle	12834**	1656.0	86787**	99.903	1481.1
Spikelet fertility (%)	93.414**	0.9475	47.110**	27.590**	0.9544
1000 grain weight(gm)	29.018**	1.7346*	50.058**	0.1008	0.4895
Grain yield (t/ha)	4.2639**	0.0567	13.101**	0.3643	0.0475

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

The lowest flag leaf angle (^{o}) was recorded for rice genotypes AFR021-B (13.67^o), while, AFR278-36, AFR278-2-2 and GZ10590 were recorded the highest angle for flag leaf (14.67^o) in the averaged across two years. The longer and erect flag leaf it is the important morphological trait to increase photosynthesis and filled grains. These findings support the findings of Meng et al., (2016), who hypothesized that the key plant morphological characteristics of the high-filled grains % were the longer, thicker and more erect upper three leaves. According to Zhang et al. (2009), an upright flag leaf may facilitate greater light penetration into the plant canopy. This in turn, may increase irradiance penetration to the lower leaves, which may improve photosynthesis and ultimately increase root (2004) and Jiang et al. (2014). activity. Data of panicle characters (panicle length (cm), panicle weight (g), primary branches/panicle, spikelet's/panicle and number of filled grains/panicle) are presented in Table 4 and Figures 1, 2 and 3.

Panicle length (cm) recorded highly significant between rice genotypes according to its genetic differences; whereas AFR051 was recorded the longest panicle (31.25 cm) during both seasons followed by AFR278-36 (30.92 cm) and AFR0280 (30.75 cm) (Table 4). While, the shortest one Giza 177 (19 and 20.5 cm) followed by Giza 178 (21.17 and 22.67 cm) during both growing seasons, respectively (Figure 1). The results indicated that the interaction between the two seasons under this study had no significant effect on panicle length for rice genotypes. These results were the same with Laza et al.

Table 3. Mean performances number of days to heading and flag leaf characteristics for twenty genotypes in both seasons (2020and 2021) and their combined.

Genotypes	Days to heading			Leaf Length (cm)			Leaf width (cm)			Leaf area (cm^2)			Leaf angle(^{o})		
	2020	2021	Comb.	2020	2021	Comb.	2020	2021	Comb.	2020	2021	Comb.	2020	2021	Comb.
Giza177	90.00	91.33	90.67	28.07	29.40	28.73	1.30	1.33	1.32	27.39	29.42	28.40	19.53	20.87	20.20
Giza178	99.33	100. 7	100.0	39.20	40.33	39.77	1.38	1.35	1.36	40.58	40.74	40.66	16.00	18.00	17.00
GZ10590	91.33	89.33	90.33	36.20	37.20	36.70	1.73	1.70	1.72	47.06	47.44	47.25	14.00	15.33	14.67
AFR061	90.33	91.17	90.75	45.13	44.47	44.80	2.55	2.48	2.51	86.14	82.73	84.43	17.67	18.67	18.17
AFR278-17	88.67	89.67	89.17	42.80	42.80	42.80	2.39	2.36	2.38	76.83	75.77	76.30	15.00	16.67	15.83
AFR278-22	95.33	96.00	95.67	41.13	42.47	41.80	2.46	2.43	2.44	75.82	77.26	76.54	18.33	20.00	19.17
AFR0280	94.67	96.33	95.50	49.60	51.27	50.43	2.60	2.53	2.57	96.72	97.44	97.08	14.67	16.33	15.50
AFR0280-2	100.0	102.0	101.0	56.27	58.27	57.27	2.63	2.57	2.60	111.20	112.10	111.60	14.33	16.00	15.17
AFR079	101.0	102.0	102.0	40.93	42.27	41.60	2.19	2.26	2.23	67.32	71.63	69.48	20.33	21.67	21.00
AFR051	106.7	106.0	106.3	40.07	41.73	40.90	2.85	2.75	2.80	85.57	86.05	85.81	14.67	16.67	15.67
AFR021-B	104.7	105.0	104.7	41.53	42.20	41.87	2.60	2.67	2.63	81.01	84.39	82.70	13.00	14.33	13.67
AFR278-36	98.67	99.33	99.00	41.53	43.20	42.37	2.49	2.55	2.52	77.46	82.86	80.16	13.67	15.67	14.67
AFR278-41	97.00	95.33	96.17	38.13	39.47	38.80	2.44	2.54	2.49	69.81	75.11	72.46	24.00	22.33	23.17
AFR278-8	97.67	95.50	96.58	46.40	45.07	45.73	2.25	2.31	2.28	78.21	78.19	78.20	16.67	18.00	17.33
AFR278-33	105.3	104.2	105.1	40.90	39.90	40.40	2.92	2.99	2.95	89.72	89.54	89.63	15.33	17.00	16.17
AFR278-2	95.67	96.33	96.00	34.20	35.87	35.03	2.09	2.16	2.13	53.74	58.10	55.92	14.00	16.67	15.33
AFR278-8-8	95.33	96.67	96.00	47.53	43.87	45.70	2.12	2.22	2.17	75.69	72.92	74.30	15.33	16.67	16.00
AFR278-2-2	96.00	94.67	95.33	46.20	43.53	44.87	2.32	2.42	2.37	80.35	78.99	79.67	13.67	15.67	14.67
RM-1-2	94.00	95.67	94.83	43.00	40.33	41.67	2.37	2.48	2.42	76.28	74.95	75.61	17.67	16.00	16.83
RM-2-8	94.67	95.33	95.00	35.80	37.13	36.47	2.45	2.32	2.39	66.08	64.70	65.39	22.67	21.00	21.83
L.S.D 0.05	1.407	1.638	1.511	3.41	3.11	3.23	0.16	0.13	0.15	2.834	2.035	2.44	1.49	1.62	1.54
L.S.D 0.01	1.883	2.191	2.010	4.56	4.16	4.29	0.22	0.17	0.19	3.791	2.723	3.25	1.99	2.16	2.04

Fig. 1. Panicle size of some introduced genotypes from Africa Rice with local Egyptian variety Giza 177 and Giza 178.

Fig. 2. A) Panicle weight of Giza 178. B) Heavy panicle weight and big number of spikelet's of AFR0280-1 line. C) Panicle weight of Giza 177.

Fig. 3. Number of primary branches panicle^{-1} for one of the exotic rice genotypes.

Primary branches/panicle of studied rice genotypes during two seasons is presented in Table 4 and Figure 3. The rice panicle is a complicated branching structure made up of a primary branch (rachis) carrying secondary branches that are carried by lateral branches that are dubbed primary branches. Primary branches/panicle of the tested genotypes which ranged from 9.5 to 27.17 as compared to the check variety Giza177 and Giza178 (7.5 and 9.8). According to Yang et al. (2002), choosing the right parent lines can lead to the development of large-panicle indica/japonica hybrids. The branching complexity (number and order of branches) is strongly correlated with the number of spikelets and number of grains per panicle. Genetic constitution has an impact on the extremely complex process of panicle branching, according to El-Tahan (2022b).

Regarding number of spikelet's per panicle, in this study most of tested rice genotypes recorded highest spikelet's per panicle where exceeded 350 over the two years up to 686 spikelet's in the first year and 720 spikelet's during the second year. This number was recorded of the rice genotype AFR0280, with spikelet fertility percentage more than 90% for all genotypes except GZ10590 and RM-2-8 which recorded values less than 300, 218.5 and 248.7spikelet's per panicle, respectively. Significant variations were seen across genotypes in all of the measurements. However variance resulting from the year and variety interaction was not statistically significant. These results are consistent with those of Meng et al. (2016), who conducted an experiment over the course of two continuous cropping seasons. They found that Yongyou 4540 and Yongyou 1540 each had roughly 350 spikelets per panicle and a filled grain percentage of almost 90%, indicating that they are large-panicle varieties with the highest percentage of filled grains.

Table 4. Mean performance of panicle characteristics for twenty genotypes in both seasons (2020 and 2021).

Genotypes	Panicle Length (cm)			Panicle weight (g)			Primary branches/ panicle			Spikelets/ Panicle			No. of filled grains/panicle		
	2020	2021	Comb.	2020	2021	Comb.	2020	2021	Comb.	2020	2021	Comb.	2020	2021	Comb.
Giza177	19.00	20.50	19.75	3.4	3.4	3.38	7.0	8.0	7.50	145.7	145.3	145.5	145.3	141.3	143.3
Giza178	21.17	22.67	21.92	4.5	4.5	4.50	9.7	10.0	9.83	212.0	203.7	207.8	200.7	198.3	199.5
GZ10590	24.67	26.17	25.42	5.0	6.0	5.53	10.0	11.0	10.50	218.0	219.0	218.5	190.7	214.0	202.3
AFR061	25.00	26.50	25.75	11.2	12.3	11.75	19.3	20.3	19.83	430.3	465.0	447.7	400.0	423.3	411.7
AFR278-17	24.33	25.83	25.08	10.3	11.3	10.79	16.3	17.0	16.67	427.0	461.7	444.3	390.0	413.3	401.7
AFR278-22	29.50	30.17	29.83	13.1	14.1	13.55	21.3	22.3	21.83	490.3	525.0	507.7	468.3	491.7	480.0
AFR0280	30.00	31.50	30.75	17.6	18.6	18.09	26.7	27.7	27.17	686.0	720.7	703.3	628.0	651.3	639.7
AFR0280-2	26.33	28.17	27.25	11.5	12.5	12.02	21.0	21.7	21.33	500.3	535.0	517.7	432.3	455.7	444.0
AFR079	27.33	28.83	28.08	7.8	8.8	8.26	11.7	12.0	11.83	354.0	388.7	371.3	326.7	350.0	338.3
AFR051	30.50	32.00	31.25	13.3	14.3	13.79	22.3	23.3	22.83	438.7	473.3	456.0	402.3	425.7	414.0
AFR021-B	27.33	28.83	28.08	10.0	11.0	10.50	13.0	14.0	13.50	428.7	463.3	446.0	393.3	416.7	405.0
AFR278-36	30.17	31.67	30.92	8.9	9.9	9.39	22.3	23.3	22.83	440.0	474.7	457.3	405.7	429.0	417.3
AFR278-41	25.67	27.17	26.42	10.3	11.3	10.76	11.7	12.0	11.83	352.0	386.7	369.3	331.7	355.0	343.3
AFR278-8	25.83	27.33	26.58	10.6	11.6	11.12	24.3	25.3	24.83	514.7	549.3	532.0	471.0	494.3	482.7
AFR278-33	27.67	29.17	28.42	12.2	13.2	12.72	23.3	24.3	23.83	424.7	459.3	442.0	377.3	400.7	389.0
AFR278-2	23.17	24.67	23.92	5.7	6.7	6.25	10.7	11.0	10.83	310.7	345.3	328.0	285.0	308.3	296.7
AFR278-8-8	24.17	25.67	24.92	9.4	10.4	9.95	24.0	25.0	24.50	461.0	495.7	478.3	421.7	445.0	433.3
AFR278-2-2	25.50	27.00	26.25	10.8	11.8	11.29	24.0	25.0	24.50	523.3	558.0	540.7	482.7	506.0	494.3
RM-1-2	28.17	29.67	28.92	10.6	11.6	11.11	22.0	22.7	22.33	464.7	499.3	482.0	451.3	474.7	463.0
RM-2-8	21.67	23.17	22.42	4.9	5.9	5.38	9.0	10.0	9.50	231.3	266.0	248.7	210.0	233.3	221.7
L.S.D 0.05	**1.28**	**1.29**	**1.27**	**1.40**	**1.40**	**1.39**	**2.54**	**2.70**	**2.60**	**72.70**	**72.53**	**71.86**	**63.37**	**63.64**	**62.85**
L.S.D 0.01	**1.72**	**1.73**	**1.70**	**1.88**	**1.87**	**1.84**	**3.40**	**3.62**	**3.45**	**97.26**	**97.05**	**95.57**	**84.79**	**85.15**	**83.59**

As one of the elements of grain yield in cereal crops, the number of filled grains per panicle is a significant determinant. Among of 20 genotypes tested in this study, 12 rice genotypes recorded more than 400 filled grains/panicle during both of two years (2020 – 2021), this lead to heavy panicle type which used as physical marker selection in the rice breeding program to develop high yielding potential. The rice genotypes AFR278-2-2 and AFR0280 recorded the good values (494.3 and 639.7 grains), so, could be used as a donor to produce new rice varieties with high number of filled grains/panicle through other study. These findings suggest that, it is feasible to create large-panicle cultivars with high percentages of filled grains. According to Tsuneo Kato (2010), such genetic variety in the extra-heavy panicle type's grain filling should be a vital genetic resource for enhancing the character of the grain filling. This result is in agreement with the result of Sarkar et al. (2016) who observed that yield was affected by number of filled grains/panicle. Most of the introduced genotypes performed better than the local check varieties.

Results of plant height, number of panicles/plant, spikelet fertility (%), 1000-grain weight (g) and grain yield (t/ha) are presented in Table 5. Regarding plant height trait, wide range of variations was observed among tested rice genotypes. Giza178 was the shortest stature (93.2 and 94.87 cm), while, AFR 287-33 recorded the longest plant height (148.7 and 145.3 cm) during both seasons 2020 and 2021, respectively. These results are agreed with (Hassan et al., 2017). Several authors reported that transplantation time, water and soil condition, planting and sowing method affect plant height in rice (Shrestha et al., 2021 and Ibrahim et al., 2024).

Concerning number of panicles per plant, the rice genotype AFR278-17 recorded the lowest panicles/plant, while, the highest number (29.77 panicles) was produced by Egyptian cultivar Giza178 during both seasons. All introduced rice genotypes were recorded lowest number of panicles per plant and heavy panicles compared to Egyptian cultivars Giza178 and Giza177 that considered as a modern plant type. Crowell et al, (2016) suggested that, optimizing rice panicle size and structure represents a challenge for breeders attempting to improve yield potential. Spikelet fertility percentage ranged from 86.38% to 96.66%. The two checks rice varieties Giza177 and Giza178 gave the maximum mean values of spikelet fertility 96.66% and 96.05% respectively. Conversely, the exotic rice genotypes recorded average spikelet fertility percentage ranged from 86.38 to 93.9%, less than the Egyptian check variety, that referred to number of spikelet's/panicle to studied rice genotypes.

Regarding to 1000-grain weight, the rice genotypes AFR278-36, AFR278-33 and AFR051 recorded as the highest mean values for 1000-grain weight with values of 29.79, 31.81 and 32.02 gm, respectively, under the two years 2020 and 2021 that could be used as a donor to improve the grain weight in Egyptian rice breeding program. While, Giza 178 and AFR278-8-8 recorded the lowest mean values (21.71 and 22.58 g) for 1000-grain weight during both seasons. Hassan et al., (2017) studied different modern cultivars of rice and reported that, 1000-grain weight for exotic rice genotypes was higher than the two Egyptian cultivars (Giza 179 and Egyptian Yasmin). For Grain yield (t/ha), most of tested rice genotypes were higher than Egyptian rice cultivars under both seasons. The highest genotypes for grain yield were AFR0280, AFR278-2-2 and AFR278-8 which had an average yield 14.26, 14.03 and 14.00 (t/ha), respectively. This rice genotypes were recorded the desirable panicle characters (panicle length, panicle weight, primary branches and number of spikelet's per panicle) which lead to recorded the highest grain yield. This result is in harmony with the results obtained by Eng et al., (2016), who found that high value of filled grain percentage give high grain yield (12.9 t/ha^{-1}) while low filled-grain percentage yielded (11.0 t/ha^{-1}).

Table 5. Mean performances for grain yield and some yield components traits for 20 genotypes in both seasons (2020and 2021).

Genotypes	Plant height (cm)			No. of panicles/plant			Spikelet fertility (%)			1000 grain weight(gm)			Grain yield (t/ha)		
	2020	2021	Comb.	2020	2021	Comb.	2020	2021	Comb.	2020	2021	Comb.	2020	2021	Comb.
Giza177	101.0	99.0	100.0	26.7	28.3	27.50	96.1	97.2	96.66	26.1	27.1	26.58	9.70	9.37	9.533
Giza178	93.2	94.9	94.0	29.5	30.1	29.77	96.5	97.7	97.06	21.4	22.1	21.71	10.57	10.44	10.50
GZ10590	100.0	96.3	98.2	30.0	28.3	29.17	94.1	98.0	96.06	24.8	26.1	25.43	10.38	10.20	10.29
AFR061	124.3	122.3	123.3	18.9	20.0	19.43	91.1	91.0	91.01	26.9	28.0	27.45	13.16	12.15	12.65
AFR278-17	114.7	116.7	115.7	14.6	15.4	15.00	97.6	87.9	92.74	26.6	27.7	27.15	13.55	13.51	13.53
AFR278-22	115.9	113.9	114.9	15.9	14.6	15.23	97.2	94.6	95.91	28.1	29.2	28.64	13.98	13.97	13.98
AFR0280	120.7	118.0	119.3	16.2	16.9	16.53	92.9	90.6	91.78	27.2	28.2	27.68	14.32	14.20	14.26
AFR0280-2	127.2	125.5	126.4	16.0	14.2	15.10	82.5	90.3	86.38	25.8	26.7	26.21	14.02	13.56	13.79
AFR079	130.0	128.0	129.0	19.9	18.3	19.07	95.5	97.3	96.40	28.0	28.8	28.41	14.01	13.94	13.98
AFR051	148.7	144.7	146.7	17.3	17.8	17.52	95.3	90.6	92.94	31.5	32.5	32.02	13.65	12.38	13.01
AFR021-B	124.7	127.3	126.0	17.7	17.4	17.52	89.2	94.5	91.81	23.7	24.7	24.18	13.45	13.38	13.41
AFR278-36	125.0	126.0	125.5	18.7	16.9	17.83	92.5	88.8	90.67	29.1	30.5	29.78	14.57	13.95	13.76
AFR278-41	125.0	124.7	124.8	18.6	17.3	17.93	96.7	93.2	94.99	27.2	27.6	27.41	13.84	13.86	13.85
AFR278-8	121.7	120.0	120.8	17.1	17.1	17.07	97.3	93.0	95.14	24.2	25.2	24.71	14.05	13.950	14.00
AFR278-33	148.7	145.3	147.0	16.2	15.2	15.70	93.3	89.5	91.39	31.3	32.3	31.81	14.31	13.53	13.92
AFR278-2	118.7	118.7	118.7	18.9	17.5	18.20	94.2	90.6	92.38	23.1	23.5	23.28	12.54	13.21	12.87
AFR278-8-8	122.3	124.0	123.2	16.3	16.3	16.27	96.3	89.6	92.94	22.1	23.1	22.58	14.01	13.89	13.95
AFR278-2-2	122.1	124.5	123.3	19.3	17.7	18.50	96.2	91.5	93.85	22.8	24.2	23.51	14.00	14.06	14.03
RM-1-2	123.3	122.0	122.7	19.5	18.1	18.80	99.0	96.1	97.59	23.5	24.5	23.98	11.66	11.66	11.66
RM-2-8	118.0	121.3	119.7	22.3	20.9	21.60	93.3	86.4	89.83	24.0	25.0	24.51	11.31	10.44	10.88
L.S.D 0.05	**6.99**	**4.76**	**5.92**	**3.22**	**2.58**	**2.89**	**1.61**	**1.69**	**1.63**	**1.07**	**1.23**	**1.14**	**0.415**	**0.294**	**0.356**
L.S.D 0.01	**9.35**	**6.37**	**7.87**	**4.31**	**3.45**	**3.84**	**2.15**	**2.26**	**2.17**	**1.43**	**1.65**	**1.52**	**0.555**	**0.394**	**0.473**

3.3. Estimates of genetic parameters

The estimates of genetic parameters including coefficient of variation and heritability deserve attention in deciding selection criteria for improvement in the concerned characters. Estimates of genotypic variance (σ^2g), phenotypic variance (σ^2p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and broad sense heritability (H_2) are shown in Table 6 and Figure 4. Environmental and genotype variations made up the two categories of phenotypic variation. Genotypic variance outweighed environmental variance for every trait under study, While, the phenotypic coefficient of variation (PCV) was close to the genotypic coefficient of variation (GCV). These results indicating the influence of genetic factors on the expression of the studied characters agree with the findings of Paikhomba, et al, (2014), Tuhina-Khatun et al., (2015) and Negm et al., (2019), who reported that genetic variance (σ^2g) was higher than the environmental variance (σ^2e). The phenotypic variance in a population is estimated using heritability analysis, which also quantify the relative contributions of genetic and non-genetic component differences. All of the examined attributes had broad-sense heritability estimates that were comparatively high, suggesting a major genetic advancement related to breeding for grain yield and agronomic qualities. High broad-sense heritability was also observed for most of studied traits, indicating that these traits were simply inherited, requiring only a few major genes to controlling the expression for most studied characters. Additionally, the results supported earlier study by indicating a considerable level of genetic variability among the genotypes studied as well as selecting superior genotypes based on phenotypic performance could be very successful (Singh et al., (1996) and El-Namaky, 2018). While, low heritability estimates were showed a non-additive kind of gene action and a strong genotype × environment interaction affecting the expression of traits, high heritability estimates should allow for genotype selection (Hossain et al., 2016). This result indicates that these characters could be easily improved by selection. Also, these characters were under genetic control and the environmental effect was insignificant (Chaurasia et al., 2012 and Kumar et al., 2012).

Table 6. Estimates of genetic parameters for 15 characters in 20 rice genotypes over two years.

Characters	Variance			GCV	PCV	h^2(b.s.) (%)
	σ^2g	σ^2p	σ^2e			
Days to heading	25.921	26.552	0.6306	4.985	5.046	97.625
Plant height (cm)	169.987	183.121	13.134	10. 240	10.629	92.828
Leaf Length (cm)	33.611	37.512	3.9007	13.149	13.891	89.601
Leaf width (cm)	0.176	0.184	0.0079	17.212	17.597	95.673
Leaf area (cm2)	343.49	350.89	7.398	24.204	24.464	97.892
Leaf angle(o)	6.073	6.958	0.885	13.771	14.74	87.280
No. of panicles/plant	19.534	22.637	3.1028	21.912	23.589	86.293
Panicle Length (cm)	9.498	10.107	46.267	11.009	11.356	93.977
Primary branches/ panicle	41.609	44.135	2.5259	34.250	35.275	94.277
Panicle weight (g)	12.791	13.512	0.7207	33.959	34.902	94.666
Spikelets/ Panicle	17604.97	19541.44	1936.5	30.213	31.831	90.090
No. of filled grains/panicle	14217.69	15698.83	1481.1	29.728	31.238	90.565
Spikelet fertility (%)	7.693	8.647	0.9544	2.822	2.992	88.962
1000 grain weight(gm)	8.261	8.751	0.4895	10.362	10.665	94.406
Grain yield (t/ha)	2.176	2.223	0.0475	10.869	10.987	97.864

* σ^2g = Genotypic variance; GCV = Genotypic coefficient of variation;
σ^2p = Phenotypic variance; PCV = Phenotypic coefficient of variation;σ^2e = Environmental variance; h^2 (b.s.) = Heritability broad sense.

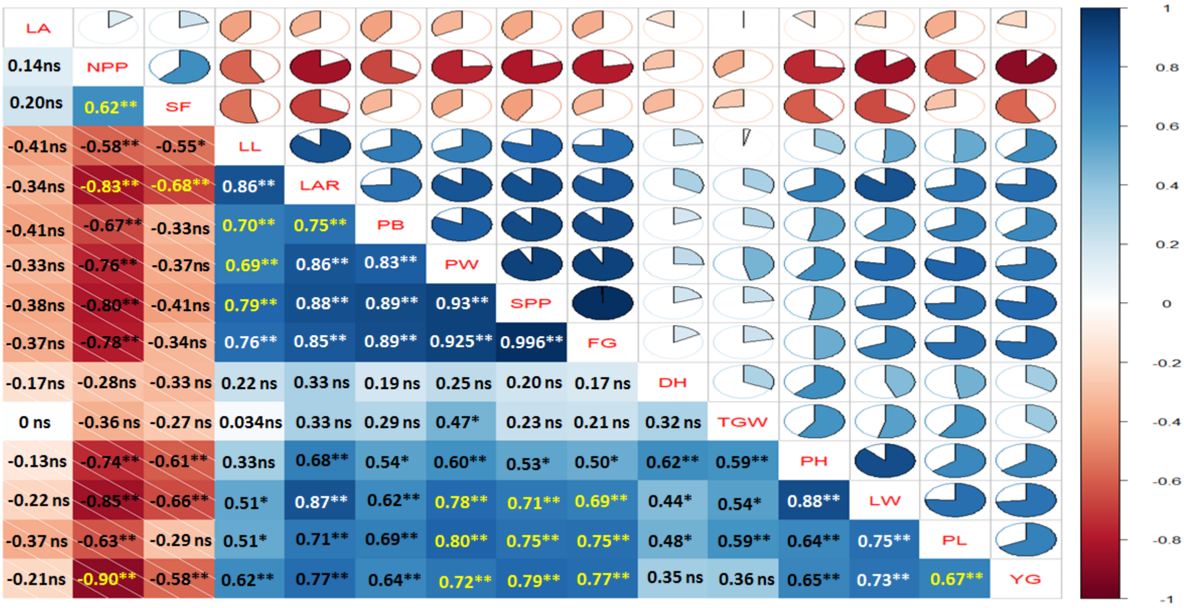
3.4. Phenotypic Correlation Coefficients:

The relative performance of rice genotypes under the two years 2020 and 2021 was shown by the heat map of phenotypic correlation-coefficients. The blue square colour scale represents the positive values, while the brown square colour represents the negative values according to the colour scale (Fig. 4). Similarly, with lower colour intensity, the genotypes perform moderately in both positive and negative ranges. The results indicated that, the phenotypic correlation coefficients among agronomic and yield components are displayed in Figure 4. Grain yield over the two years was positively correlated with panicle characters (number of branches, panicle weight, spikelets per panicle and filled grains per panicle) as well as flag leaf characteristics (leaf length, width and area). Moreover, there was a favourable correlation between plant height and grain yield. This was due to the fact that most of new test genotypes showed high stature and high grain yield. Selection that was based on both correlated and non-correlated responses proved to be effective, moving rice breeding forward. In almost crops, grain yield is referred to as an important trait, that results from the multiplicative interactions of yield components. Thus, identifying the important yield components and their relationships with grain yield it's useful for selecting the promising genotypes for develop high yielding varieties. In this regard, the correlation coefficient, which provides a symmetrical measurement for the degree of association between two variables or characters, which lead to comprehending the nature and magnitude of association among yield and yield components (Al-Daej, 2022). These results were match the findings of Al-Salim et al., (2016) who reported that, number of grains per plant, 1000-grains weight, number of productive tillers per plant and number of tillers per plant was positively correlated with grain yield, although not significantly. At the same time, the number of panicles per plant was highly positive correlation with spikelet fertility %. These results were disagreement with Konate et al., (2016) who reported that plant height and number of panicles/plant showed significant negative correlation with number of fertile spikelet's. Positive and significant correlations were shown for panicle weight with plant height, flag leaf length, width, area, panicle length and primary branches, indicating the improvement for these agronomic traits will be increasing the weight of panicle. Similar findings were documented by Abd elaty et al., (2022); under both normal and water-deficit situations, grain yield/plant had a highly significant positive correlation with panicle length, number of panicles/plant, panicle weight, and 1000-grain weight. Furthermore, since these characteristics accounted for the majority of grain yield, selecting for them could increase grain yield. Also, Parte et al., (2022) had the same trend of results, and concluded their results to features like as the number of filled spikelet's in each panicle and the weight of the panicles per plant have a strong direct impact and association with grain yield.

3.5. Cluster analysis

Cluster analysis of 20 rice genotypes using 15 traits in four clusters exhibited significant differences among the rice genotypes (Fig. 5). The dendogram obtained from the cluster analysis grouped the 20 rice genotypes into main four clusters. Cluster I was the largest cluster which consisted of 12 genotypes (60%) followed by cluster IV which comprised of 4 genotypes (33.33%), and cluster II had 3 genotypes (16.67%), while cluster III had the lowest number of genotypes that comprises only one genotypes (5%). Dendogram showed that, maximum genetic distance was found between clusters I and cluster IV, indicated that, they had diverse genetic material, although they belong to the same types, the parents involved in genetic background were different and may have different origin. The three Egyptian genotypes were in cluster IV with RM-2-8-1-3-2. Within cluster I, AR061-15-3-4-1-1-1-1 and RM-1-2-3-3 had most diversity which was probably due to the involvement of different parents in their pedigree. Although the two rice genotypes AR0280-14-1-1-2-1-2 (cluster I) and AR0280-14 -1-1-2-2 (cluster III) are sister lines had the same parent, but significant differences showed and located in different group this may be due their adaptability to environmental condition . Cluster analysis provided a complete view of the variation in the adaptability among the 20 rice genotypes, and it might be used for the plant breeders for the genetic improvement of rice.

Variations in the number of distinct clusters in which rice genotypes are classified have been reported by various investigators. Baloch et al., (2016) demonstrated significant genetic variation among the genotypes they examined when they categorized 20 irrigated lowland rice genotypes with 11 morphological characteristics into four clusters. Worede et al., (2014) divided 24 upland rice varieties into two groups based on 17 morpho-agronomic parameters. According to Bekis et al., (2021), understanding genetic divergence and cluster distance across rice genotypes is necessary for genetic improvement, which is crucial for increasing crop productivity and production.



LA= Leaf angle, **NPP**= Number of panicle per plant, **SF**= Spikelet fertility, **LL**= Leaf length, **LAR**= Leaf area (cm^2), **PB**= Primary branches, **PW**= Panicle weight, **SPP**= Spikelets per panicle, **FG**= Filled grains, **DH**= Days to heading, **TGW**= 1000 grain weight, **PH**= plant height, **LW**= Leaf width, **PL**= panicle length and **YG**= Yield (t/ha).

Fig. 4. Heat map phenotypic correlation coefficient of 15 agronomic, yield and its components characters of 20 exotic rice genotypes under Egyptian conditions over two years 2020 and 2021.

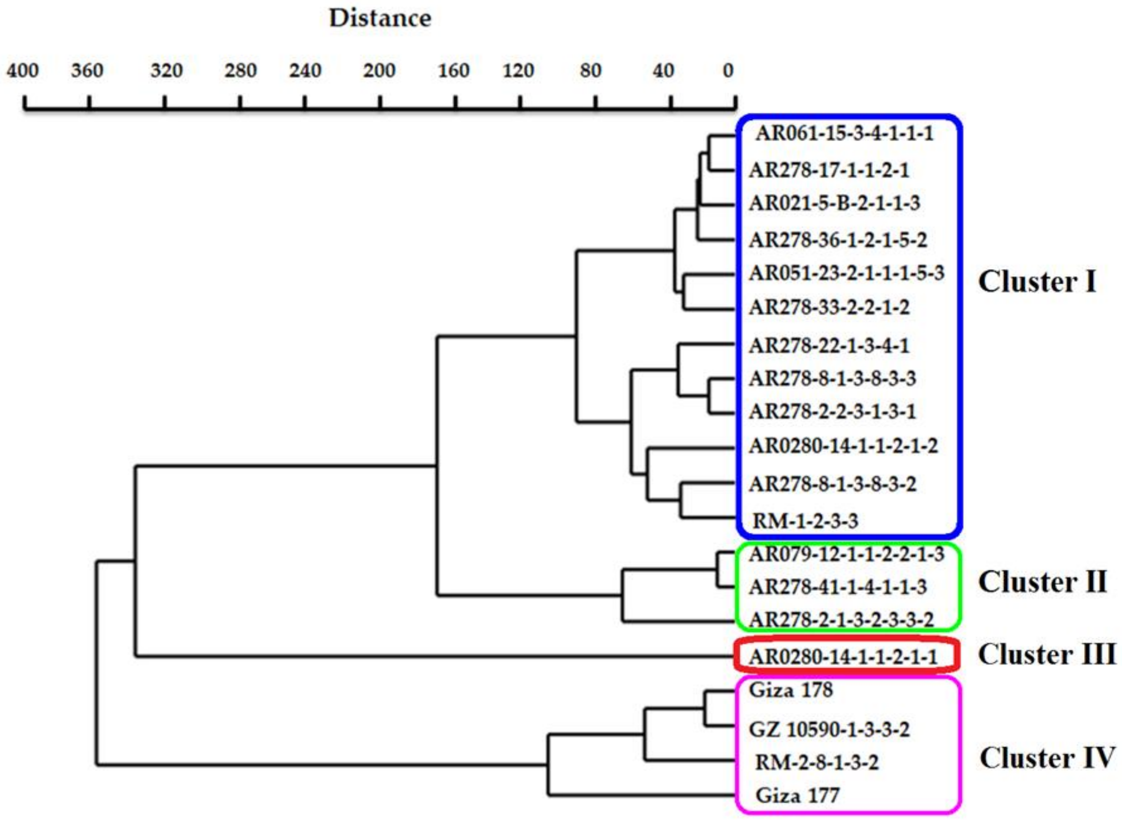


Fig. 5. Cluster analysis method for 20 rice genotypes for 15 characters evaluated in 2020 and 2021 seasons.

4. Conclusion

The result indicated significant superiority for the yield of 11 exotic rice genotypes over the two local varieties Giza 177 and Giza 178, under Egyptian conditions which yielded more than 13.5 t/ha. AFR0280, AFR278-2 and AFR278-8 exhibited highly adaptability and recorded the desirable agronomic traits, further more grain yield. On the other side, plant height, flag leaf (length and width), flag leaf area, panicle length, primary branches, panicle weight, spikelet per panicle and filled grains per panicle were positively and strongly correlated with grain yield. Selection of superior genotypes with heavy-panicle and yield characters can be considered as a new trend in rice breeding program in Egypt.

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References

Abd El-Aty, M. S., A. B. El-Abd, M. H. Ibrahim, A. Youssif, Maria Batool, Rokayya Sami, Amal A. Ashour, A. Shafie, and H. M. Hassan (2022a). Identification of drought tolerant rice genotypes based on morpho-physiological and yield traits under normal and drought stress conditions. Journal of Biobased Materials and Bioenergy 2022, 16 (3): 390–401.

Abd El-Aty, M. S., M. I. Abo-Youssef, A. A. Galal, Ayaa M. Salama, A. A. Salama, A. M. El-Shehawi, Mona M. Elseehy, M.T. El-Saadony and Amira M. El-Tahan (2022b). Genetic behavior of earliness and yield traits of some rice (*Oryza sativa* L.) genotypes. Saudi Journal of Biological Sciences 29: 2691–2697.

Al-Daej, M.I (2022). Estimation of heterosis, heritability and genetic parameters for some agronomic traits of rice using the linextester method. Journal of King Saud University, (34): 1-6.

Al-Salim, S.H.F., Al-Edelbi, R., Aljbory, F. and Saleh M.M. (2016). Evaluation of the performance of some rice (*Oryza sativa* L.) varieties in two different environments. Open Access Library Journal, 3: 1 – 7.

Acquaah, G., 2017. Principles of plant breeding. Encyclopedia of Applied Plant Sciences, 2 : pp.236–242.

Astarini, I. A., J. A. Plummer, R. A. Lancaster and G. Yan,. (2004). Fingerprinting of cauliflower cultivars using RAPD markers. Australian Journal of Agricultural Research, 55(2): 117-124.

Agbo, C. U. and I. U. Obi (2005). Agronomic evaluation of some rice genotypes in Nsukka. Journal of Agriculture, Food, Environment and Extension, 4(2): 23-27.

Baloch, A. W., M. Baloch, R. Baloch, M. N. Kandhro, I. A. Odhano, H. R. Bughio. and A. S. Rajput (2016). Evaluation of genetic diversity in rice (*Oryza Sativa* L.) genotypes. Sindh University Research. Journal-SURJ (Science Series). 48(1).

Bekis, D., H. Mohammed and B. Belay (2021). Genetic Divergence and Cluster Analysis for Yield and Yield Contributing Traits in Lowland Rice (*Oryza sativa* L.) Genotypes at Fogera, Northwestern Ethiopia. International Journal of Advanced Research in Biological Sciences, 8(5): 1-11.

Bernardo, R. 2020. Reinventing quantitative genetics for plant breeding: Something old, something new, something borrowed, something BLUE. Heredity, 125(6): pp.375–385.

Burton, G.W. 1952. Quantitative inheritance in grasses. Proceedings of 6th International Grassland Congress, 1: pp.277–283.

Chaurasia, A. K., P.K. Rai and A. Kumar (2012). Estimation of genetic variability,heritability and genetic advance in aromatic fine grain rice. Romanian Journal of Biology-Plant Biology (Bucharest) 57: 71-76.

Crowell, S., P. Korniliev, A. Falcao, A. Ismail, G. Gregorio, J. Mezeyand S. McCouch (2016). Genome-wide association and high-resolution phenotyping link *Oryza sativa* panicle traits to numerous trait-specific QTL clusters. Nature communications, 7(1): 10527.

El-Namaky, R.A., S.E. Seedek, O.A. Elbadawy, E.A. belih, S.A. Sultan, M. Awadallah, A. Tahon and A. Taha (2023). Shorting Rice Breeding Cycle and Developing New Promising Lines. Iinternational conference of Field Crops Research Institute (FCRI), 13-16 March, Cairo, Egypt. J. Agric. Res., 101, (2): 685-699.

Hammer, O., D.A.T. Harper and P.D. Ryan (2001). PAST: Paleontological statistics software package for education and data analysis. Paleontol. Electron., 4: 1-9.

Hassan, H. M.; G. B. Anis and I. H. Abou El-Darag (2017). Utilization of wide adaptability of some imported rice (*Oryza sativa* L.) genotypesfor weed suppression and fertility restoration ability. Egypt. J. Plant Breed. 21 (5): 181 – 201.

Hossain, M.A., M. A. K. Mian, M. G. Rasul, M. J. Hasan, M. U. Kulsum and M. A. Karim (2016). Genetic variability in floral Traits of CMS lines and their relationship with outcrossing in rice. Tropical Agriculture and Development, 60(4): 236-241.

Ibrahim A., S. Stuerz, B. Manneh, M. C. Rebellodo and K. Saito (2024). Consistent yield performance of rice genotypes grown under irrigated conditions in wet and dry seasons in West Africa. Field Crops Research, 306, 109231.

IRRI, (2016). "Standard Evaluation System for Rice". International Rice Research Institute (IRRI), P.O. Box 933, 1099 Manila, Philippines.

Jiang Y, H. Zhang, K. Zhao, J. Xu, H. Wei, H. Long, W. Wang, Q. Dai , Z. Huo, K. Xu, H. Wei, B. Guo (2014). Difference in yield and its components characteristics of different type rice cultivars in the lower reaches of the Yangtze River. Chinese Journal of Rice Science, 28(6): 621-631.

Kashiani P. and G. Saleh (2010). Estimation of genetic correlations on sweet corn inbred lines using SAS mixed model. American Journal of Agricultural and Biological Sciences, 5(3): 309-314.

Konate A. K., A. Zongo, H. Kam, A. Sanni and A. Audebert (2016). Genetic variability and correlation analysis of rice (*Oryza sativa* L.) inbred lines based on agromorphological traits. African Journal of Agricultural Research 11(35): 3340-3346.

Kumar, A., Misra, S.C., Singh, V.P. and Chaahan, B.P.S., 1985. Variability and correlation studies in triticale. Journal of the Maharashira Agricultural University, 10: pp.273–275.

Kumar A, A. K. Chaurasia, N. Paikhomba, P.K. Rai (2012). Evaluation of quantitative and qualitative analysis of aromatic fine grain rice (*Oryza sativa* L.) genotypes. Progressive Research: 133-136.

Laza M. R. C., S. Peng, S. Akita and H. Saka (2004). Effect of panicle size on grain yield of IRRI-released indica rice cultivars in the wet season. Plant Production Science, 7(3): 271-276.

Luzikihupi, A. (1998). Inter-relationship between yield and some selected agronomic characters in rice. Africa crop science Journal, 6(3): 323-328.

Meng T. Y., H. H. Wei, C. Li, Q. G. Dai, K. Xu, Z. Y. Huo, H. Y. Wei, B. W. Guo, H. C. Zhnag (2016). Morphological and physiological traits of large-panicle rice varieties with high filled-grain percentage. Journal of Integrative Agriculture, 15(8): 1751–1762.

Negm M. E., W.H. El-Kallawy and A. G. Hefeina (2019). Comparative Study on Rice Germination and Seedling Growth under Salinity and Drought Stresses. Env. Biodiv. Soil Security Vol. 3: pp. 109 – 117.

Osekita O. S., B. O. Akinyele and A. C. Odiyi (2015). Evaluation of exotic rice varieties for genetic parameters in a Nigerian Agro-Ecology. Int. J. of Plant & Soil Science, 5(6): 350-358.

Paikhomba N, Kumar A, Chaurasia AK, Rai PK (2014). Assessmentof genetic parameters for yield and yield components in hybrid rice and parents. J Rice Res 2: 117.

Prasad, S.R., Prakash, R., Sharma, C.M. and Itaque, M.F., 1981. Genotypic and phenotypic variability in quantitative characters in oats. Indian Journal of Agricultural Science, 51(7): pp.480–482.

Parte D., Konreddy S., Parmeshwar S., Deepak S., Kuber B., B. K. Dasand Rajeev S. (2022). Correlation and path analysis studies for yield and quality traits of rice landraces and mutants of Chhattisgarh, India. Int. J. Environ. Clim. Change, 12, (12): pp. 1771-1779.

Peng S.B. (2014). Reflection on China's rice production strategies during the transition period. Scientia Sinica Vitae. 44: 845-850.

Raafat El-Namaky (2018). The Genetic Variability of Floral and Agronomic Characteristics of Newly-Bred Cytoplasmic Male Sterile Rice. Agriculture, 8(5): 68.

Ray D.K., and Foley J.A. (2013). Increasing global crop harvest frequency: recent trends and future directions. Environmental Research Letter 8: 44041-44050.

Reddy JN and De RN (1996). Study of genetic variability, heritability and genetic advance for panicle characters in rice. Oryza 35: 19-21.

RRTC, (2019). Proceeding of the National program Rice Research and Development Program Workshop. RRTC, ARC, Egypt, 50 pp.

Sarkar S. C., M. Akter, M. R. Islam and Md. M. Haque (2016). Performance of five selected hybrid rice varieties in aman season. Journal of Plant Sciences, 4(4): 72-79.

Seck P. A., Diagne A., Mohanty S. & Wopereis M. C. (2012). Crops that feed the world 7: Rice. Food security, 4: 7-24.

Sedeek S.E., M.I. Aboyousef, I.S. EL-Rafaee, A.A. Abdallah, S.A. Hammoud, M.M. El-Malky, R.A. EL-Namaky, et al., (2023). Giza 183 Egyptian rice variety: a step to confront climate change challenges. International Conference of Field Crops Research Institute Egypt. J. Agric. Res., 101 (2): 519-537.

Shrestha, J., S. Subedi, U.K.S. Kushwaha, and B. Maharjan (2021). Evaluation of rice genotypes for growth, yield and yield components. Journal of Agriculture and Natural Resources, 4(2): 339-346.

Singh, R.K. and B. D. Chowdhury(1996). Variability, heritability, and genetic advance in cultivars of rice (Oryza sativa L.). Crop Res. Hisar, 12: 165–167.

Singh S.P., Singharia G.S., Parry G.A. and Bhat G.N. (2005). Genetic variability and heritability in rice (Oryza sativa L.). Env Ecology 3: 549-551.

Taha A. S., W. T. Abd El-Rahem, O.A. Elbadawy and E. A. Khattab (2023). Effect of Potassium Fertilization Levels on Rice Yield, Yield Attributes and Rice Stemborer infestation of Giza 178 Rice Cultivar Grown under Nitrogen Fertilizer Levels. Env. Biodiv. Soil Security, Vol. 7, pp: 231 – 242.

Tsuneo Kato (2010). Variation and association of the traits related to grain filling in several extra-heavy panicle type rice under different environments. Plant Production Science, 13(2): 185-192.

Tuhina-Khatun, M. , M. M. Hanafi, M. Rafii Yusop, M. Y. Wong, F. M. Salleh and J. Ferdous (2015). Genetic variation, heritability, and diversity analysis of upland rice (*Oryza sativa* L.) genotypes based on quantitative traits. BioMed Research International. 7 pages.

Ukaoma, A. A., P. I. Okocha and R. I. Okechukwu (2013). Heritability and character correlation among some rice genotypes for yield and yield components. J. Plant Breed. Genet., 01(02): 73-84.

Wei H., Y. Yang, X. Shao., T. Shi, T. Meng, Y. Lu, Y. Tao, X. Li, E. Ding , Y. Chen and Q. Dai (2020). Higher leaf area through leaf width and lower leaf angle were the primary morphological traitsfor yield advantage of japonica/indica hybrids. Jouranal of integrative Agriculture 19(2): 483-494.

Worede Fisiha., Sreewongchai T., Phumichai C. and Sripichitt P. (2014). Multivariate analysis of genetic diversity among some rice genotypes using morpho-agronomic traits. Journal of Plant Sciences.9:14-24.

Xing Q. Y. and Zhang (2010): Genetic and molecular bases of rice yield. Ann Rev Plant Biol, 61:421–442.

Yang J. C., Peng S. B., Zhang Z. J., Wang Z. Q., Visperas R. M., Zhu Q. S. (2002). Grain and dry matter yields and partitioning of assimilates in japonica/indica hybrid rice. Crop Science , 42: 766–772.

Zafar, F., Mumtaz, A., Saif-ul-Malook, and Aleem, M.U., 2015. Areview on statistical tools for genetic diversity of crop improvement. Nature and Science, 13(2): pp.83–87.

Zhang H, Xue Y, Wang Z, Yang J, Zhang J. (2009). Morphological and physiological traits of roots and their relationships with shoot growth in "super" rice. Field Crops Research, 113: 31–40.

Zhang Y., Tang Q., Zou Y., Li D., Qin J., Yang SH., Chen L., Xia B., Peng, SH. (2009). Yield potential and radiation use efficiency of "super" hybrid rice grown under subtropical conditions. Field Crops Research 114: 91-98.

Zhao, H., Mo, Z., Lin, Q., Pan, S., Duan, M., Tian, H., and Tang, X. (2020). Relationships between grain yield and agronomic traits of rice in southern China. Chilean journal of agricultural research, 80(1): 72-79.