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Diallel Analysis of Different Rice Genotypes under Water Deficiency Conditions and Assessing Genetic Diversity Using SSR Markers

Cross Mark

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ABSTRACT

A half diallel cross among seven diverse rice genotypes was carried out in 2019 growing season. Parents and their 21 F_1 crosses were evaluated under normal (continuous flooding) and water deficit (irrigation every 12 days) conditions during 2020 growing season, to estimate general (GCA) and specific (SCA) combining ability effects as well as identifying type of gene action controlling the inheritance of the studied traits.Both GCA and SCA mean squares were highly significant for all the studied traits under normal and stress conditions. The non-additive gene action played an important role in the inheritance of all the studied traits, except leaf rolling under stress treatment. The parents Sakha 107, NERICA 9 and N22 were the best general combiners for grain yield/plant. The crosses Sakha 107×Giza 177, Sakha 107×Fuknishiki, NERICA 9×Giza 177, NERICA 9×Akihikari, N22 ×IET1444, N22×Fuknishiki and IET1444 × Giza 177 were identified as promising specific combiners for improving grain yield/plant and one or more of its components under both conditions. The genetic diversity among the seven parental genotypes was assessed using ten Simple Sequence Repeats (SSR) markers. A total of 33 alleles were detected ranging from 2 to 5 with an average of 3.3 alleles per locus. The PIC values ranged from 0.32 to 0.69, with an average of 0.51.Genetic distance ranged from 0.24 to 0.92 with an average of 0.63. High genetic diversity was detected among the tested genotypes at the molecular level, hence these genotypes could be exploited to improve water deficit tolerance in rice breeding program.

Keywords: Rice, Water deficit, Diallel analysis, Molecular diversity, SSR markers.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the main cereal crops worldwide (Zewdu, 2020). Nearly, more than half of the world's population depends on rice as staple food, especially in developing countries (Saleh *et al.*, 2020). Hence, there is greater pressure on it for higher production. Water deficit stress is a major threat to rice production and negatively affects growth and yield (Kamarudin *et al.*, 2018). It reduced nutrients uptake, leaf water content, which led to stomatal closure, and consequently photosynthesis, total dry biomass accumulation and grain yield significantly decreased (Farooq *et al.*, 2009 and Wang *et al.*, 2019). Breeding for drought tolerance is crucial for maintaining stable yield (Oladosu *et al.*, 2018). In Egypt, rice occupies about 22% of the total cultivated area in the summer season (Elgamal *et al.*, 2018). It consumes more than 20% of the total irrigation water resources. Some rice growing areas, especially those placed at the end of the terminal canals, suffer from shortage of irrigation water during various growth stages (Abd Allah *et al.*, 2010). Increasing scarcity of the water resources in Egypt has posed a great challenge to rice breeders to develop new highly yielding cultivars with efficient water use to save more water without significant fall in rice grain yield.

Understanding the nature of gene action for different traits under water deficit will help to breed stress resilient genotypes (Verulkar *et al.*, 2010). The diallel cross analysis has been used to estimate general combining ability (GCA) and specific combining ability (SCA) of parents and crosses (Baker, 1978). The GCA and SCA provide a simple approach to predict additive and no-additive effects, respectively. Both additive and non-additive gene actions were reported to be important in the inheritance of rice grain yield under normal and water deficit conditions by El-Hity *et al.* (2016), Farid *et al.* (2016), El-Adl *et al.* (2019) and Abd El-Hadi *et al.* (2020). However, the grain yield and other assessed traits under water deficit condition were mostly controlled by non-additive gene action as reported by Hasan *et al.* (2015), Sathya and Jebaraj (2015), Malemba *et al.* (2017), Elgamal *et al.* (2018) and El-Sayed *et al.* (2018).

The success of rice breeding program is depending on the genetic variations within germplasm resources (Suvi *et al.*, 2020). Assessment of the genetic diversity among available genotypes is important in the hybrids development (Yan *et al.*, 2016). It facilitates the development of high yielding hybrids without making all possible hybrid combinations among all available parents (Mishra *et al.*, 2018). Utilization of more diverse parents is important to obtain maximum heterosis and the development of transgressive segregates (Verma *et al.*, 2019). The environmental influence on morphological and biochemical markers limits their utility of genetic diversity studies (Bhattarai and Subudhi, 2019). On the contrary, molecular markers are considered a powerful tool for estimation genetic diversity (Smith and Smith, 1992), as they are not influenced by environmental factors. Among molecular markers, simple sequence repeats (SSR) or microsatellites have advantages over other markers (Anandan *et al.*, 2016). The SSR markers are co-dominant, distributed well

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throughout the genome, multi-allelic, highly reproducible and highly informative, which make it ideal for genetic diversity studies in rice even with less number of markers (McCouch *et al.* 1997, Das *et al*. 2013, Babu *et al.* 2014 and Suvi *et al.* 2020).

The objectives of the present study were to: 1) evaluate the performance of seven rice genotypes and their 21 F_1 crosses under normal and water deficit conditions, 2) estimate combining ability, heterosis and type of gene action of the studied traits and 3) assess the genetic diversity among the seven parental rice genotypes using SSR markers.

MATERIALS AND METHODS

The present study was carried out at the Experimental Farm of Rice Research Department, Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt, during 2019 and 2020 growing seasons. Seven rice (*Oryza sativa* L.) genotypes which represented different degrees of drought tolerance were used as parents in this study (Table 1).

Table 1. Name, parentage, origin and drought tolerance of the seven rice genotypes used in the present study.

Name	Parentage	Origin	Drought tolerance reaction
Sakha 107	Giza 177 /BLI	Egypt	Tolerant
NERICA 9	WAB 56-104/ CG14//WAB56-104	Africa Rice	Tolerant
N22	Not available	India	Tolerant
IET1444	TN 1 / CO 29	India	Moderate
Giza 177	Giza171 / Yu mji No.1 // piNo.4	Egypt	Sensitive
Fuknishiki	KINKIUS45/KINKIUS11// ZENTH/3/KINKIUS45/ KINKIUS11/4HATSUNISHIKI	Japan	Sensitive
Akihikari	Toyonishiki / Reimei	Japan	Sensitive

Field experiments

In 2019 season, the seven genotypes were sown at three successive sowing dates with ten days intervals in order to overcome the differences in flowering time. After 30 days from sowing, each parent was individually transplanted in the permanent field. At flowering time, all possible cross combinations (excluding reciprocals) were made among the seven genotypes, to produce seeds of 21 F_1 crosses. The hybridization technique using the hot water method for emasculation was utilized according to Jodon (1938) and modified by Butany (1961). In 2020 season, the parents and their F_1 crosses were sown in the nursery on May 6th and the seedlings were transplanted individually after 30 days. The 28 entries (seven parents and 21 F_1\`s) were evaluated under two irrigation treatments in separated experiments. The first one was normally irrigated with continuous flooding (normal condition). The second was irrigated every 12 days without any standing water after irrigation (water deficit condition), that was applied after two weeks from transplanting till harvesting. Randomized complete block design (RCBD) with three replications was used for each experiment. Each genotype was planted in three rows per replicate. Each row was 5.0 m long with the spacing of 20 × 20 cm among rows and hills. All other recommended agricultural rice practices were applied at the proper time.

Data collection

Data were recorded on ten individual guarded plants for parents and F_1 crosses. The studied traits were; days to 50% heading (day), plant height (cm), leaf rolling score, leaf relative water content (%), No. of panicles/plant, panicle length (cm), sterility percentage (%) (percentage of unfilled grains over total number of grains/panicle), 1000-garin weight (g) and grain yield/plant (g). Leaf rolling score was recorded by visual determination based on method proposed by De Dattaet al., (1988). Leaf relative water content was recorded according to Barrs and Weatherly (1962) as follow:

$$\textbf{LRWC (\%)} = [(FW-DW) / (TW-DW)] \times 100$$

Where,

FW; is fresh weight, DW; is dry weight, TW; is turgid weight

Data Analysis

Analysis of variance for each experiment (normal and water deficit conditions) was estimated according to Steel and Torrie (1980). Combining ability analysis was performed accordinga to Griffing's (1956) method 2 model 1. Heterosis percentages relative to each of mid and better parents were calculated according Mather (1949) and Mather and Jinks (1971).

Molecular analysis

DNA isolation

Genomic DNA was extracted from the young leaves of the seven rice genotypes seedlings (25 days old) using Cetyl Trimethyl Ammonium Bromide (CTAB) method (Doyle and Doyle 1990). DNA quantity and quality was assessed using NanoDrop spectrophotometer (ND-1000, USA) at the Laboratory of Plant Cell Technology, Faculty of Applied Biological Sciences, Gifu University, Japan.

SSR primers and PCR amplification

Ten microsatellites (SSR markers) were used in this study. The sequence of the ten primer pairs were chosen from the Gramene database ((http://gramene.org/) as presented in Table 2.

Table 2. List of SSR primers and their sequences used in this study.

No.	Marker	Forward primer	Reverse primer
1	RM212	CCACTTTCAGCTACTACCAG	CACCCATTTGTCTCTCATTATG
2	RM11943	CTTGTTCGAGGACGAAGATAGGG	CCAGTTTACCAGGGTCGAAACC
3	RM279	GCGGGAGAGGGATCTCCT	GGCTAGGAGTTAACCTCGCG
4	RM55	CCGTCGCCGTAGTAGAGAAG	TCCCGGTTATTTTAAGGCG
5	RM234	ACAGTATCCAAGGCCCTGG	CACGTGAGACAAAGACGGAG
6	RM72	CCGGCGATAAAACAATGAG	GCATCGGTCCTAACTAAGGG
7	RM223	GAGTGAGCTTGGGCTGAAAC	GAAGGCAAGTCTTGGCACTG
8	RM219	CGTCGGATGATGTAAAGCCT	CATATCGGCATTCGCCTG
9	RM286	GGCTTCATCTTTGGCGAC	CCGGATTCACGAGATAAACTC
10	RM20A	ATCTTGTCCCTGCAGGTCAT	GAAACAGAGGCACATTTCATTG

Polymerase chain reaction (PCR) was performed using a volume of 10 µl reaction mixture containing 1 µL of 20 ng/µL genomic DNA template, 1 unit Taq DNA polymerase (Promega, USA), 2mM MgCl2, 0.2mM each dNTPs and 0·5 µM each of forward and reverse primer using TaKaRa PCR Thermal Cycler (Takara Bio, Otsu, Japan). The PCR reaction was initially started by denaturation at 94°C for 2 min, followed by 35 cycles consisting of denaturation at 94ºC for 30 sec, 30 sec of annealing at 55°C and 30 sec of extension at 72°C. The program ended with a final extension step at 72°C for 3 min. The amplified products were separated by electrophoresis in agarose gels (1.5%), stained with ethidium bromide and visualized under UV-Gel documentation system.

SSR data analysis

The amplified bands were scored for each SSR marker based on the presence or absence of bands, generating a binary data matrix of (1) and (0) for each marker and analyzed using the computer software package, PowerMarker (Version 3.25) (Liu and Muse, 2005). The number of alleles per locus, major allele frequency, gene diversity and polymorphism information content (PIC) were calculated to assess allele diversity of each marker. The value of polymorphic information content (PIC) of each SSR marker was determined as described by Botstein *et al.* (1980) as follows:

$$1-\sum_{i=1}^{n}P_j^2-\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}2P_i^2P_j^2$$

Where

P_i and P_j are the frequencies of the i^{th} and j^{th} allele of a given marker, respectively.

Genetic dissimilarity coefficients between a pair of parental genotypes were calculated according to Nei and Li (1979). The dendrogram was generated with the unweighted pair group method using arithmetic averages (UPGMA) by the computational package MVSP version 3.1

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance for all the studied traits are presented in Table 3. The mean squares due to genotypes (G), parents (P) and crosses (C) were found to be highly significant for all the studied traits under both normal and water deficit conditions. This implied that there were sufficient amounts of genetic variability among the tested genotypes for each trait. Hence, selection is possible to identify the desirable genotypes under such conditions. These results are in agreement with those obtained by Malemba *et al.* (2017), Elgamal *et al.* (2018), El-Sayed *et al.* (2018) and Abd El-Hadi *et al.* (2020).

Table 3. Mean squares from ordinary and combining ability analysis for all the studied traits under normal and water deficit conditions.

SOV	df	Days to 50% heading		Plant height (cm)		leaf rolling	
		Normal	Stress	Normal	Stress	Normal	Stress
Replications	2	5.08	2.20	6.33*	8.18	0.13	0.11
Genotypes (G)	27	62.76**	65.53**	112.18**	173.93**	0.42**	7.50**
Parents (P)	6	91.15**	115.67**	154.98**	218.78**	0.64**	12.28**
F_1 Crosses (C)	20	54.34**	46.89**	99.97**	158.01**	0.37**	6.45**
P *vs.* C	1	60.82**	137.29**	99.70**	223.12**	0.09	0.00
Error	54	1.68	1.33	1.84	3.07	0.05	0.08
GCA	6	49.61**	48.23**	109.53**	173.51**	0.25**	9.15**
SCA	21	12.72**	14.30**	16.78**	24.97**	0.11**	0.60**
Error term	54	0.56	0.44	0.61	1.02	0.02	0.03
K^2GCA/K^2SCA		0.45	0.38	0.75	0.80	0.28	1.77
SOV	df	Relative water content (%)		No. of panicles/plant		Panicle length (cm)	
		Normal	Stress	Normal	Stress	Normal	Stress
Replications	2	1.84	2.71	2.27	2.49*	1.25	2.17
Genotypes (G)	27	43.65**	151.07**	16.74**	13.13**	13.10**	6.94**
Parents (P)	6	39.91**	172.46**	15.19**	8.17**	5.85**	5.23**
F_1 Crosses (C)	20	45.48**	151.21**	15.64**	12.04**	13.44**	6.86**
P *vs.* C	1	29.35**	19.77**	48.13**	64.69**	49.85**	18.86**
Error	54	0.96	1.15	0.89	0.57	0.57	0.89
GCA	6	36.33**	134.29**	10.49**	8.76**	8.22**	5.80**
SCA	21	8.32**	26.37**	4.18**	3.13**	3.27**	1.32**
Error term	54	0.32	0.38	0.30	0.19	0.19	0.30
K^2GCA/K^2SCA		0.50	0.57	0.29	0.32	0.29	0.60
SOV	df	Sterility (%)		1000-grain Weight (g)		Grain yield/plant (g)	
		Normal	Stress	Normal	Stress	Normal	Stress
Replications	2	0.69	0.73	0.46	0.18	2.99*	3.16*
Genotypes (G)	27	6.99**	62.57**	8.01**	10.71**	36.13**	49.24**
Parents (P)	6	4.47**	55.24**	7.08**	11.53**	21.04**	50.34**
F_1 Crosses (C)	20	7.16**	67.38**	7.81**	9.13**	37.49**	40.71**
P *vs.* C	1	18.50**	10.39**	17.52**	37.42**	99.50**	213.18**
Error	54	0.32	0.41	0.17	0.13	0.74	0.92
GCA	6	4.13**	51.55**	21.50**	28.28**	21.66**	35.05**
SCA	21	1.81**	12.09**	4.15**	5.69**	9.30**	11.09**
Error term	54	0.11	0.14	0.06	0.04	0.25	0.31
K^2GCA/K^2SCA		0.26	0.48	0.59	0.56	0.26	0.36

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

Mean squares due to parents *vs.* crosses were highly significant for all the studied traits, except leaf rolling trait under stress conditions, suggesting the presence of significant heterosis for these traits under both environments. Similar results have been reported by Omar *et al.* (2017), Kumar *et al.* (2018) and Shukla *et al.* (2020).

The mean squares associated with general (GCA) and specific (SCA) combining ability were highly significant for all the studied traits under both conditions (Table 3). These results would indicate the importance of both additive and non-additive gene effects in the inheritance of these traits. The ratio of GCA/SCA was less than unity for all the studied traits, except leaf rolling trait under water deficit treatment, indicating that these traits were mainly controlled by the non-additive type of gene action. Therefore, breeding methods based on hybridization could be effective for the improvement of these traits. These results are in general agreement with those obtained by Sedeek *et al* (2012), Sathya and Jebaraj (2015), Abo-Youssef *et al.* (2017), Malemba *et al.* (2017), Elgamal *et al.* (2018), El-Sayed *et al.* (2018) and Bano and Singh (2019).

Mean performance of parents and F_1 crosses

Mean performance of the seven parents and their respective 21 F_1 hybrids under normal and water deficit conditions for all the studied traits are shown in Table 4. Generally, water deficit dramatically decreased the mean values of all the evaluated traits compared with normal irrigation, except leaf rolling and sterility percentage which significantly increased. These results are in good agreement with those reported by Abd Allah *et al*. (2010), Sedeek *et al.* (2012), Abd EL-Aty *et al.* (2017) and Elgamal *et al.* (2018).

The data in Table 4 indicated that the tested genotypes showed early heading under water deficit compared with well-irrigated conditions. Thus, earliness could be considered as an escape strategy and resilient adaptation under drought stress (Abd Allah *et al*., 2010).

The parents Giza 177, Sakha107 and NERICA 9 as well as the cross combinations Giza 177 × Akihikari, N22 × Giza 177 and Sakha 107 × NERICA 9 exhibited the earliest heading under stressed and non-stressed environments.

Plant height was significantly depressed in all tested genotypes due to decreasing of the applied amount of irrigation water. The reduction of plant height in response to water deficit agree with previous results of El-Hity *et al.* (2016), Kamarudin *et al.* (2018) and Yang *et al.* (2019). The two parents Fuknishik and Giza 177 and the two hybrids Giza 177 × Fuknishiki and Giza 177 × Akihikari had the shortest plant height under both conditions. Meanwhile, the tallest plants were observed by the parent NERICA 9 and the hybrids NERICA 9 × Giza 177 and NERICA 9 × N22 across the two environments. Short stature plants are suitable for mechanical harvesting and lodging resistance.

The parental genotypes N22 and Fuknishiki and the crosses NERICA 9 × Akihikari, N22 × Fuknishiki and N22 × Akihikari had the lowest mean values of leaf rolling under normal condition. Meanwhile, the parental genotypes NERICA 9, N22 and IET1444 as well as the crosses N22 × IET1444, NERICA 9 × N22 and IET1444 × Fuknishiki gave the lowest mean values under stress condition. This result suggests that these genotypes could be considered as a good candidate for drought tolerance (Abd Allah *et al.* 2010 and Elgamal 2018). Leaf rolling is one of the drought avoidance mechanisms to minimum water losses during drought stress (O'Toole and Change 1978). With respect to relative water content, the parents IET1444, Sakha 107 and N22 as well as the crosses Sakha 107× IET1444, NERICA 9 × Akihikari and Sakha 107 × NERICA 9 gave the highest mean values under both normal and stress conditions. The results in Table 4 showed that relative water content in the leaves of all the tested genotypes significantly decreased under water deficit conditions. These results are consistent with those reported by Abd Allah (2009) and Dien *et al.* (2019). This trait is widely used as an indicator for defining the sensitivity of rice plants to tissue and cell dehydration (Dien *et al.*, 2019). In this regard, Khan *et al.* (2017) showed that rice genotypes that can maintain high level of water in its leaf tissues under water deficit could be considered more tolerant than other genotypes.

For number of panicles/plant, the parent Akihikari and the cross Sakha 107 × Akihikari under normal irrigation and the parent N22 and the cross Sakha 107 × IET144 under stress condition produced the highest number of panicles/plant. Moreover, the parents Sakha 107 and IET 1444 as well as the cross combinations Sakha 107 × N22, NERICA 9 × Akihikari and Sakha 107 × NERICA 9 gave the highest mean values of this trait under both conditions. Regarding panicle length, the parents NERICA 9, N22 and IET 1444 under both conditions as well as the cross combinations NERICA 9 × Fuknishiki under normal condition, NERICA 9 × Akihikari under stress condition and NERICA 9 × N22 and Sakha 107 × NERICA 9 under both conditions exhibited the longest panicles. Hereby, these genotypes could be considered promising in rice breeding programs aiming to improve panicle length.

As shown in Table 4, the parents Akihikari, Sakha 107 and IET 1444 and the crosses NERICA 9 × Akihikari, Sakha 107 × IET1444 and NERICA 9 × IET1444 gave the lowest mean values of sterility percentage under normal environment. Meanwhile, the parents IET 1444, Sakha 107 and N22 and the crosses N22 × IET144, Sakha 107 × IET144 and Sakha 107 × N22 had the lowest percentage of sterility under stress treatment. Concerning 1000-grain weight, results showed that the parent Akihikari under normal, N22 under stress and Sakha 107 under both conditions showed the highest mean values this trait. Among the F_1 hybrids, it is apparent that the crosses NERICA 9 × Akihikari, Sakha 107 × NERICA 9 and NERICA 9 × N22 gave the heaviest grains under both conditions. As illustrated in Table 4, grain yield per plant significantly decreased under water deficiency, and the genotypes exhibited different performances. These findings are consistent with Kamarudin *et al.* (2018) and Yang *et al.* (2019) who reported that water deficit through rice growth stages leads to poor dry matter assimilation and high losses in grain yield. Among the parents, Akihikari under normal condition, NERICA 9 under stress condition and N22 and Sakha 107 under both conditions exhibited the highest mean values for this trait. Moreover, the crosses N22 × Fuknishiki and Sakha 107 × Akihikari under normal condition, Sakha 107 × N22 and N22 × IET144 under stress condition and NERICA 9 × Akihikari under both conditions had the highest grain yield/plant. These genotypes could be used in future rice breeding programs to improve grain yield under normal and stress conditions. These results are in harmony with those reported by El-Hity *et al.* (2016), El-Sayed *et al.* (2018) and Abd El-Hadi *et al.* (2020).

Table 4. Mean performance of the seven parental rice genotypes and their 21 F_1 for all studied traits under normal and stress conditions.

Genotypes	Days to 50% heading		Plant height(cm)		Leaf rolling		Relative water content (%)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Sakha 107	94.50	91.33	102.50	91.50	2.32	3.52	91.95	84.78
NERICA 9	99.67	96.50	118.65	108.60	1.33	2.33	87.50	78.36
N22	108.60	106.44	105.76	96.60	1.00	2.59	90.50	83.40
IET1444	107.50	104.80	108.87	94.50	1.40	3.00	92.00	86.84
Giza 177	95.33	89.83	99.56	85.70	1.82	6.78	89.50	67.50
Fuknishiki	103.50	98.67	96.50	83.88	1.30	5.90	81.50	70.50
Akihikari	102.83	97.90	104.50	86.50	1.98	6.92	87.59	72.96
Sakha 107 × NERICA 9	97.80	95.67	115.58	104.68	1.42	3.50	92.56	87.56
Sakha 107 × N22	106.67	102.50	100.43	96.50	1.33	2.82	89.50	85.75
Sakha 107 × IET1444	102.70	99.33	107.75	96.50	1.70	3.30	94.63	87.00
Sakha 107 × Giza 177	99.50	98.00	105.85	91.80	1.53	4.95	88.60	76.54
Sakha 107 × Fuknishiki	104.67	102.83	105.62	92.50	2.00	5.60	85.72	77.90
Sakha 107 × Akihikari	103.92	98.90	108.23	93.60	1.67	6.20	89.50	81.56
NERICA 9 × N22	104.60	103.33	118.21	109.56	1.33	2.43	88.50	75.60
NERICA 9 × IET1444	108.80	105.33	106.52	91.63	1.45	3.70	91.33	86.50
NERICA 9 × Giza 177	97.83	96.67	117.50	108.50	2.30	4.00	88.50	68.50
NERICA 9 × Fuknishiki	108.93	107.33	106.89	97.60	1.89	5.00	82.50	70.78
NERICA 9 × Akihikari	102.87	99.50	116.50	107.50	1.00	2.90	92.69	87.33
N22 × IET1444	105.17	102.67	104.73	97.58	1.33	2.10	86.50	80.90
N22 × Giza 177	96.33	95.00	103.80	94.50	1.60	4.30	82.63	79.50
N22 × Fuknishiki	108.33	105.33	110.58	103.87	1.02	3.90	89.50	86.90
N22 × Akihikari	106.67	104.20	112.56	96.80	1.06	5.60	87.80	86.50
IET1444 × Giza 177	104.60	100.33	105.93	93.50	1.13	5.50	87.79	82.63
IET1444 × Fuknishiki	101.17	96.67	104.25	88.90	1.56	2.52	82.50	76.50
IET1444 × Akihikari	107.33	102.50	110.67	92.65	1.88	5.50	85.60	69.50
Giza 177 × Fuknishiki	108.50	106.50	98.50	80.87	1.56	6.00	83.60	68.50
Giza 177 × Akihikari	95.00	93.50	100.78	86.84	1.92	6.76	80.50	69.10
Fuknishiki × Akihikari	105.67	102.33	100.98	95.00	1.17	6.70	82.50	71.50
LSD 0.05	2.12	1.89	2.22	2.87	0.35	0.46	1.61	1.76
LSD 0.01	2.82	2.52	2.96	3.82	0.47	0.61	2.14	2.34

Table 4. Cont.

Genotypes	No. of panicles/plant		Panicle length (cm)		Sterility (%)		1000–grain weight (g)		Grain yield/plant (g)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Sakha 107	20.88	13.98	20.33	19.20	5.51	15.02	29.40	26.85	41.29	31.36
NERICA 9	15.33	13.50	22.90	20.80	7.30	16.93	31.82	28.45	39.78	32.26
N22	17.52	14.35	22.80	20.70	8.15	15.22	29.23	26.90	41.60	29.56
IET1444	20.36	15.70	22.54	19.70	5.77	12.60	28.36	25.33	34.53	26.50
Giza 177	19.20	11.65	20.42	17.88	8.32	23.53	28.32	24.86	38.56	21.78
Fuknishiki	18.00	10.80	19.66	17.70	6.92	19.62	26.82	22.53	36.58	22.65
Akihikari	21.88	13.26	20.33	18.00	5.45	23.51	29.65	24.32	40.85	28.79
Sakha 107 × NERICA 9	22.96	16.98	25.60	22.50	6.06	14.83	31.90	29.92	42.60	34.86
Sakha 107 × N22	23.80	18.82	24.54	20.69	4.56	13.41	30.65	28.45	43.56	36.22
Sakha 107 × IET1444	22.36	17.80	20.50	18.42	3.98	12.88	29.56	25.56	38.34	30.50
Sakha 107 × Giza 177	21.56	16.20	23.38	20.53	4.38	16.90	29.90	26.76	46.21	32.92
Sakha 107 × Fuknishiki	22.86	15.60	24.72	19.95	5.32	20.20	30.56	25.33	42.36	32.64
Sakha 107 × Akihikari	23.95	16.75	22.58	18.53	4.37	16.39	31.25	28.36	46.30	30.53
NERICA 9 × N22	18.92	12.80	25.60	21.80	4.83	24.10	31.52	28.92	40.80	31.29
NERICA 9 × IET1444	19.50	16.80	24.46	21.76	4.03	13.50	30.68	27.69	38.65	31.50
NERICA 9 × Giza 177	15.63	12.88	22.20	20.66	6.82	19.10	31.76	27.60	42.32	30.81
NERICA 9 × Fuknishiki	22.42	14.28	26.72	20.68	5.64	17.56	29.96	26.52	38.60	27.50
NERICA 9 × Akihikari	23.69	18.70	25.40	22.62	3.97	13.50	32.56	29.96	48.82	37.96
N22 × IET1444	21.62	16.95	23.45	21.52	4.77	12.73	30.56	28.21	40.92	35.42
N22 × Giza 177	20.11	14.30	22.62	19.63	6.32	16.58	29.96	25.69	41.80	28.95
N22 × Fuknishiki	21.96	16.36	21.84	20.67	4.56	13.63	30.78	28.93	46.50	33.60
N22 × Akihikari	21.42	15.33	24.57	20.75	5.42	15.60	30.80	27.60	44.12	33.27
IET1444 × Giza 177	19.24	14.80	22.50	21.45	6.03	13.56	30.36	27.54	41.89	33.52
IET1444 × Fuknishiki	18.15	15.20	23.68	20.32	6.18	15.62	27.62	25.88	38.92	27.69
IET1444 × Akihikari	19.93	13.85	19.36	17.54	6.82	15.23	30.23	27.69	38.50	28.53
Giza 177 × Fuknishiki	17.32	12.76	20.34	18.61	8.87	30.87	25.95	23.62	34.60	24.03
Giza 177 × Akihikari	20.26	12.22	19.88	18.69	9.75	25.50	26.85	24.20	37.65	23.60
Fuknishiki × Akihikari	18.56	12.90	20.36	17.60	6.82	20.53	29.54	25.65	38.90	30.62
LSD 0.05	1.55	1.24	1.24	1.55	0.93	1.05	0.67	0.60	1.40	1.57
LSD 0.01	2.06	1.65	1.65	2.06	1.24	1.40	0.89	0.80	1.87	2.10

General combining ability (GCA) effects

Estimates of general combining ability ($\hat{g}_i$) effects of the seven parents under normal and water deficit conditions are presented in Table 5. High positive values of ($\hat{g}_i$) effects would be of interest for all studied traits in question, except days to 50% heading, plant height, leaf rolling and sterility percentage, where high negative values would be useful from the breeder point of view. The parental genotype Sakha 107 showed highly significant and negative ($\hat{g}_i$) effects for days to 50% heading and sterility percentage under both conditions, plant height under normal condition and leaf rolling under stress condition. Moreover, it showed significant positive ($\hat{g}_i$) effects for relative water content, number of panicles/plant, 1000-grain weight and grain yield/plant under both normal and stress conditions. This indicates that this parent could be considered as a good general combiner for earliness, yield attributes and high grain yield. The parental genotype NERICA 9 gave significant and negative ($\hat{g}_i$) effects for days to 50% heading under normal irrigation as well as leaf rolling and sterility percentage under water deficit conditions. Also, it gave highly significant and positive ($\hat{g}_i$) effects for relative water content, panicle length, 1000-grain weight and grain yield/plant under both normal and stress conditions. This implied that this parent could be considered as a good combiner for the aforementioned traits. The parental genotype N22 displayed highly significant and negative ($\hat{g}_i$) effects for leaf rolling under both conditions and sterility percentage under stress condition.

Table 5. General combining ability ($\hat{g}_i$) effects of the seven parents for all the studied traits under normal and stress conditions.

Parent	Days to 50%heading		Plant height(cm)		Leaf rolling	
	Normal	Stress	Normal	Stress	Normal	Stress
Sakha 107	-2.35**	-2.36**	-0.91**	-0.42	0.22**	-0.23**
NERICA 9	-0.58*	-0.03	6.87**	8.26**	-0.03	-1.04**
N22	2.17**	2.76**	0.58*	3.30**	-0.29**	-1.02**
IET1444	2.15**	1.70**	0.11	-1.40**	-0.05	-0.77**
Giza 177	-3.67**	-3.49**	-2.79**	-3.88**	0.15**	1.06**
Fuknishiki	2.09**	1.91**	-4.09**	-3.98**	-0.05	0.67**
Akihikari	0.19	-0.49*	0.23	-1.88**	0.04	1.33**
LSD 0.05 (gi)	0.46	0.41	0.48	0.63	0.08	0.10
LSD 0.01 (gi)	0.62	0.55	0.65	0.83	0.10	0.13
LSD 0.05 (gi-gj)	0.71	0.63	0.74	0.96	0.12	0.15
LSD 0.01 (gi-gj)	0.93	0.84	0.97	1.27	0.15	0.20
Parent	Relative water content (%)		No. of panicles/plant		Panicle length(cm)	
	Normal	Stress	Normal	Stress	Normal	Stress
Sakha 107	2.60**	4.12**	1.84**	1.27**	0.12	-0.07
NERICA 9	1.12**	0.46*	-0.99**	0.08	1.65**	1.33**
N22	0.49**	3.68**	0.02	0.50**	0.81**	0.75**
IET1444	1.26**	3.10**	-0.13	0.90**	-0.21	0.08
Giza 177	-1.15**	-5.45**	-1.13**	-1.36**	-1.02**	-0.48**
Fuknishiki	-3.52**	-3.97**	-0.60**	-1.11**	-0.44**	-0.72**
Akihikari	-0.80**	-1.94**	0.99**	-0.27*	-0.90**	-0.88**
LSD 0.05 (gi)	0.35	0.38	0.34	0.27	0.27	0.34
LSD 0.01 (gi)	0.47	0.51	0.45	0.36	0.36	0.45
LSD 0.05 (gi-gj)	0.54	0.59	0.52	0.41	0.41	0.52
LSD 0.01 (gi-gj)	0.70	0.78	0.68	0.55	0.54	0.69
Parent	Sterility (%)		1000–grain weight(g)		Grain yield/plant(g)	
	Normal	Stress	Normal	Stress	Normal	Stress
Sakha 107	-0.89**	-1.66**	0.40**	0.44**	1.63**	1.98**
NERICA 9	-0.19	-0.35**	1.45**	1.49**	0.45**	1.77**
N22	-0.10	-1.46**	0.41**	0.83**	1.51**	1.70**
IET1444	-0.48**	-3.43**	-0.36**	-0.10	-2.34**	-0.26
Giza 177	1.24**	3.33**	-0.84**	-1.00**	-0.63**	-2.79**
Fuknishiki	0.39**	2.00**	-1.22**	-1.46**	-1.58**	-2.35**
Akihikari	0.04	1.57**	0.17*	-0.22**	0.97**	-0.05
LSD 0.05 (gi)	0.20	0.23	0.15	0.13	0.31	0.34
LSD 0.01 (gi)	0.27	0.31	0.19	0.17	0.41	0.46
LSD 0.05 (gi-gj)	0.31	0.35	0.22	0.20	0.47	0.52
LSD 0.01 (gi-gj)	0.41	0.47	0.29	0.27	0.62	0.70

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

Moreover, it gave highly significant and positive effects for number of panicles/plant under stress condition and relative water content, panicle length, 100-grain weight and grain yield/plant under both normal and stress conditions. The parental genotype IET 1444 had highly significant and negative ($\hat{g}_i$) effects for plant height and leaf rolling under stress treatment and sterility percentage under both normal and stress treatments. Further, it gave highly significant and positive ($\hat{g}_i$) effects for relative water content under both conditions and number of panicles/plant under stress environment. The parental genotype Giza 177 seemed to be excellent combiner for developing early and short stature genotypes under normal and stress conditions, since it had negative and significant ($\hat{g}_i$) effects for days to 50% heading and plant height. The parental genotype Fuknishiki exhibited highly significant and negative ($\hat{g}_i$) effects for plant height under both conditions. However, it gave significant undesirable or insignificant ($\hat{g}_i$) effects for other traits. The parental genotype Akihikari exhibited highly significant and negative ($\hat{g}_i$) effects for days to heading and plant height under stress condition and showed positive and significant ($\hat{g}_i$) effects for number of panicles/plant, 1000-grain weight and grain yield/plant under normal condition. These results suggest that these parents have favorable genes and that improvement in respective traits can be achieved if they are included in the rice hybridization program. It is worth noting that the parents which had high ($\hat{g}_i$) effects for grain yield, also exhibited desirable ($\hat{g}_i$) effects for one or more of the traits contributing to grain yield. Moreover, none of the parents exhibited significant GCA effects for all the measured traits under both conditions. These results are in agreement with those reported by Sedeek *et al*. (2012), Malemba *et al.* (2017) and Abd El-Hadi *et al.* (2020).

Specific combining ability (SCA) effects

Data in Table 6 revealed that, five hybrid combinations Sakha 107 × NERICA 9, N22 × IET1444, N22 × Giza 177, IET1444 × Fuknishiki and Giza 177 × Akihikari had highly significant negative ($\hat{S}_{ij}$) effects for days to 50% heading under both conditions. These crosses could be utilized in rice breeding program for improving earliness. For plant height, the five crosses Sakha 107 × N22, NERICA 9 × IET1444, NERICA 9 × Fuknishiki, Giza 177 × Fuknishiki and Giza 177 × Akihikari under both normal and stress conditions exhibited highly significant and negative ($\hat{S}_{ij}$) effects towards shortness. Four crosses Sakha 107 × NERICA 9, N22 × Akihikari, IET1444 × Giza 177 and Fuknishiki × Akihikari under normal condition and other four crosses Sakha 107 × N22, NERICA 9 × Giza 177, N22 × IET1444 and IET1444 × Fuknishiki under stress condition as well as two cross Sakha 107 × Giza 177 and NERICA 9 × Akihikari under both conditions exhibited desirable significant and negative SCA effects for leaf rolling. The highest desirable positive and significant ($\hat{S}_{ij}$) effects for relative water content were assigned for the hybrids Sakha 107 × NERICA 9, Sakha 107 × IET1444, NERICA 9 × IET1444, NERICA 9 × Akihikari and N22 × Fuknishiki under both conditions.

Regarding number of panicles/plant, three crosses Sakha 107 × Fuknishiki, NERICA 9 × Fuknishiki and N22 × Giza 177 under normal condition, four crosses Sakha 107 × IET1444, Sakha 107 × Giza 177, Sakha 107 × Akihikari and NERICA 9 × IET1444 under stress condition and five crosses Sakha 107 × NERICA 9, Sakha 107 × N22, NERICA 9 × Akihikari, N22 × IET1444 and N22 × Fuknishiki under both conditions exhibited significant and positive ($\hat{S}_{ij}$) effects. Therefore, these crosses could be used in breeding program to improve number of panicles/plant under such conditions. The cross combinations Sakha 107 × NERICA 9, Sakha 107 × Giza 177, NERICA 9 × Akihikari, N22 × Akihikari, IET1444 × Giza 177 and IET1444 × Fuknishiki were the best specific combiners for improving panicle length under both conditions.

Regarding sterility percentage, the data showed that the three crosses Sakha 107 × IET1444, NERICA 9 × IET1444 and NERICA 9 × N22 under normal condition, the four crosses Sakha 107 × NERICA 9, Sakha 107 × N22, NERICA 9 × Giza 177 and N22 × Akihikari under stress condition and the seven crosses Sakha 107 × Giza 177, Sakha 107 × Akihikari, NERICA 9 × Fuknishiki, NERICA 9 × Akihikari, N22 × Giza 177, N22 × Fuknishiki and IET1444 × Giza 177 under both normal and stress conditions exhibited highly significant and negative ($\hat{S}_{ij}$) effects for this trait. Concerning 1000-grain weight, eight crosses Sakha 107 × Giza 177, Sakha 107 × Akihikari, NERICA 9 × Giza 177, NERICA 9 × Akihikari, N22 × IET1444, N22 × Fuknishiki, IET1444× Giza 177 and T1444 × Akihikari displayed the highest positive and significant ($\hat{S}_{ij}$) effects under both conditions. These crosses could be used in rice breeding program for improving this trait. Similar results were reported by El-Refaey *et al.* (2009) and Abd El-Hadi *et al.* (2020).

Table 6. Estimates of specific combining ability ($\hat{S}_{ij}$) effects of the 21 F_1 crosses for all the studied traits under normal and stress conditions.

Cross	Days to 50% heading		Plant height(cm)		Leaf rolling		Relative water content(%)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Sakha 107 × NERICA 9	-2.44**	-2.08**	2.53**	1.55	-0.31**	0.33**	1.21**	4.38**
Sakha 107 × N22	3.67**	1.96**	-6.32**	-1.67*	-0.14	-0.36**	-1.22**	-0.65
Sakha 107 × IET1444	-0.28	-0.15	1.47*	3.02**	-0.01	-0.14	3.15**	1.18*
Sakha 107 × Giza 177	2.34**	3.71**	2.47**	0.81	-0.38**	-0.32*	-0.47	-0.73
Sakha 107 × Fuknishiki	1.75**	3.14**	3.54**	1.61*	0.30**	0.73**	-0.99*	-0.85
Sakha 107 × Akihikari	2.91**	1.61**	1.82**	0.61	-0.13	0.66**	0.08	0.78
NERICA 9 × N22	-0.17	0.47	3.68**	2.71**	0.11	0.05	-0.74	-7.15**
NERICA 9 × IET1444	4.06**	3.52**	-7.54**	-10.52**	-0.01	1.06**	1.32**	4.34**
NERICA 9 × Giza 177	-1.10	0.06	6.34**	8.83**	0.63**	-0.46**	0.91*	-5.12**
NERICA 9 × Fuknishiki	4.24**	5.31**	-2.97**	-1.97*	0.43**	0.93**	-2.73**	-4.31**
NERICA 9 × Akihikari	0.09	-0.12	2.31**	5.83**	-0.55**	-1.83**	4.75**	10.20**
N22 × IET1444	-2.33**	-1.93**	-3.03**	0.39	0.13	-0.55**	-2.88**	-4.48**
N22 × Giza 177	-5.35**	-4.40**	-1.06	-0.21	0.20*	-0.18	-4.33**	2.67**
N22 × Fuknishiki	0.89	0.52	7.01**	9.26**	-0.17	-0.19	4.90**	8.59**
N22 × Akihikari	1.13	1.79**	4.67**	0.09	-0.23*	0.85**	0.49	6.15**
IET1444 × Giza 177	2.94**	1.98**	1.54*	3.49**	-0.51**	0.77**	0.06	6.38**
IET1444 × Fuknishiki	-6.25**	-7.08**	1.15	-1.01	0.13	-1.82**	-2.87**	-1.23*
IET1444 × Akihikari	1.81**	1.15*	3.25**	0.64	0.35**	0.50**	-2.48**	-10.27**
Giza 177 × Fuknishiki	6.90**	7.94**	-1.69**	-6.56**	-0.08	-0.17	0.65	-0.68
Giza 177 × Akihikari	-4.70**	-2.66**	-3.74**	-2.69**	0.19	-0.07	-5.17**	-2.12**
Fuknishiki × Akihikari	0.21	0.76	-2.24**	5.57**	-0.35**	0.26*	-0.80	-1.20*
LSD 5% (s_{ij})	1.14	1.02	1.20	1.55	0.19	0.25	0.87	0.95
LSD 1% (s_{ij})	1.52	1.36	1.60	2.06	0.25	0.33	1.15	1.26
LSD 5% (s_{ij}-s_{ik})	2.00	1.78	2.09	2.70	0.33	0.43	1.51	1.65
LSD 1% (s_{ij}-s_{ik})	2.66	2.37	2.79	3.60	0.44	0.57	2.02	2.20
LSD 5% (s_{ij}-s_{kl})	1.87	1.67	1.96	2.53	0.31	0.40	1.42	1.55
LSD 1% (s_{ij}-s_{kl})	2.49	2.22	2.61	3.37	0.41	0.54	1.89	2.06

Table 6. Cont.

Cross	No. of panicles/plant		Panicle length (cm)		Sterility (%)		1000–grain weight(g)		Grain yield/plant (g)	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Sakha 107 × NERICA 9	1.77**	0.79*	1.22**	1.29**	1.18**	-0.61*	0.18	1.23**	-0.39	0.79
Sakha 107 × N22	1.60**	2.21**	1.00**	0.05	-0.41	-0.92**	-0.04	0.41*	-0.49	2.22**
Sakha 107 × IET1444	0.31	0.80*	-2.02**	-1.55**	-0.61*	0.52	-0.35	-1.55**	-1.87**	-1.54**
Sakha 107 × Giza 177	0.51	1.46**	1.67**	1.13**	-1.93**	-2.22**	0.47*	0.55**	4.30**	3.41**
Sakha 107 × Fuknishiki	1.29**	0.61	2.43**	0.78	-0.15	2.41**	1.50**	-0.42*	1.41**	2.69**
Sakha 107 × Akihikari	0.79	0.92**	0.75*	-0.47	-0.74**	-0.97**	0.80**	1.38**	2.79**	-1.72**
NERICA 9 × N22	-0.45	-2.62**	0.52	-0.24	-0.83**	8.46**	-0.21	-0.17	-2.07**	-2.50**
NERICA 9 × IET1444	0.28	0.98**	0.41	0.39	-1.26**	-0.17	-0.28	-0.47**	-0.38	-0.32
NERICA 9 × Giza 177	-2.59**	-0.68*	-1.05**	-0.14	-0.18	-1.33**	1.28**	0.34*	1.59**	1.52**
NERICA 9 × Fuknishiki	3.68**	0.47	2.89**	0.11	-0.52*	-1.54**	-0.14	-0.28	-1.18**	-2.23**
NERICA 9 × Akihikari	3.36**	4.05**	2.04**	2.22**	-1.84**	-5.17**	1.07**	1.93**	6.49**	5.92**
N22 × IET1444	1.39**	0.71*	0.24	0.73	-0.61*	0.17	0.64**	0.71**	0.83*	3.66**
N22 × Giza 177	0.88*	0.32	0.21	-0.60	-0.77**	-2.74**	0.51**	-0.91**	0.01	-0.28
N22 × Fuknishiki	2.21**	2.13**	-1.15**	0.67	-1.69**	-4.37**	1.71**	2.79**	5.66**	3.93**
N22 × Akihikari	0.08	0.26	2.05**	0.92*	-0.48	-1.97**	0.34	0.23	0.73	1.30**
IET1444 × Giza 177	0.16	0.42	1.11**	1.89**	-0.68**	-3.79**	1.69**	1.87**	3.95**	6.26**
IET1444 × Fuknishiki	-1.45**	0.58	1.71**	1.00*	0.31	-0.40	-0.67**	0.67**	1.93**	-0.01
IET1444 × Akihikari	-1.26**	-1.62**	-2.14**	-1.62**	1.30**	-0.36	0.55**	1.25**	-1.04**	-1.47**
Giza 177 × Fuknishiki	-1.28**	0.40	-0.82*	-0.15	1.28**	8.09**	-1.86**	-0.69**	-4.09**	-1.14**
Giza 177 × Akihikari	0.07	-0.99**	-0.81*	0.10	2.51**	3.15**	-2.35**	-1.34**	-3.59**	-3.87**
Fuknishiki × Akihikari	-2.16**	-0.55	-0.91**	-0.76	0.43	-0.50	0.71**	0.57**	-1.39**	2.70**
LSD 5% (s_{ij})	0.84	0.67	0.67	0.84	0.50	0.57	0.36	0.32	0.76	0.85
LSD 1% (s_{ij})	1.11	0.89	0.89	1.11	0.67	0.76	0.48	0.43	1.01	1.13
LSD 5% (s_{ij}-s_{ik})	1.46	1.17	1.17	1.46	0.88	0.99	0.63	0.57	1.32	1.48
LSD 1% (s_{ij}-s_{ik})	1.94	1.55	1.55	1.94	1.17	1.32	0.84	0.75	1.76	1.98
LSD 5% (s_{ij}-s_{kl})	1.36	1.09	1.09	1.36	0.82	0.93	0.59	0.53	1.24	1.39
LSD 1% (s_{ij}-s_{kl})	1.82	1.45	1.45	1.82	1.09	1.24	0.78	0.70	1.65	1.85

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

Regarding grain yield/plant, the data showed that the two crosses Sakha 107 × Akihikari and IET1444 × Fuknishiki under normal condition, the three crosses Sakha 107 × N22, N22 × Akihikari and Fuknishiki × Akihikari under stress condition and the seven crosses Sakha 107 × Giza 177, Sakha 107 × Fuknishiki, NERICA 9 × Giza 177, NERICA 9 × Akihikari, N22 × IET1444, N22 × Fuknishiki and IET1444 × Giza 177 under both conditions exhibited significant and positive ($\hat{S}_{ij}$) effects. It is notable that the crosses that showed high ($\hat{S}_{ij}$) effects for grain yield/plant also showed high SCA effects for one or more traits of yield components.

It could be conclude that the previous crosses might be of interest in rice breeding programs as most of them involved at least one good combiner for the traits in view. Also, these crosses might be of interest to develop new cultivars or produce pure lines under water deficit stress conditions. These results are in agreement with those reported by El-Hity *et al*. (2015), Elgamal *et al*. (2018), El-Adl *et al.* (2019) and Abd El-Hadi *et al.* (2020)

Heterosis relative to Mid (MP) and Better (BP) Parents

Heterosis percentages relative to mid parents (MP) and better parent (BP) are presented in Table 7. A high magnitude of heterosis was occurred in many crosses for all the studied characters in positive or negative directions. Favorable MP and BP heterosis in the studied F_1 crosses was considered negative for days to 50% heading, plant height, leaf rolling and sterility percentage and positive for the rest of studied traits under both environments. For days to 50% heading, the cross Giza 177 × Akihikari under normal condition and N22 × Giza 177 under both conditions expressed significant and negative heterotic effects relative to MP. Moreover, the two crosses N22 × IET1444 and IET1444 × Fuknishiki recorded significant and negative heterotic effects over both MP and BP under both conditions. Similar results were obtained by Elgamal *et al.* (2018) and El-Adl *et al.* (2019), they found negative and significant heterotic effects for days to heading in some rice crosses under water normal and water deficit conditions. Regarding plant height, the crosses Sakha 107 × N22 and N22 × IET1444 under normal condition and the cross Giza 177 × Fuknishiki under stress condition showed negative and significant heterosis over the MP. While, the highest estimated values for the BP were observed in the cross Giza 177 × Fuknishiki under stress condition. Moreover, the cross NERICA 9 × IET1444 showed negative and significant heterosis values relative to MP and BP under both conditions. Therefore, these hybrids could be of practical interest in rice breeding programs for the short stature plant. Significant and negative heterotic effects over MP for leaf rolling trait were obtained in the crosses Sakha 107 × NERICA 9, Sakha 107 × N22, Sakha 107 × Giza 177, Sakha 107 × Akihikari, N22 × Akihikari, IET1444 × Giza 177 and Fuknishiki × Akihikari under normal condition and NERICA 9 × Akihikari under both conditions.

Meanwhile, the two hybrids N22 × IET1444 and IET1444 × Fuknishiki had significant and negative heterosis over MP and BP under stress condition for leaf rolling trait. For relative water content, the desirable significant and positive MP and BP heterotic effects were recorded by the three crosses Sakha 107 × NERICA 9, NERICA 9 × Akihikari and N22 × Fuknishiki under both irrigation treatments, except heterotic effects relative to BP were not significant for the last two crosses under normal condition. However, positive heterotic effects relative to MP were obtained in the crosses Sakha 107 × IET1444 under normal condition and Sakha 107 × N22, Sakha 107 × Akihikari, N22 × Giza 177, N22 × Akihikari and IET1444 × Giza 177 under stress condition. For number of panicles/plant, 13 and 6 hybrids displayed significant and positive heterosis relative to MP and BP under both conditions, respectively. Moreover, the hybrids Sakha 107 × NERICA 9, Sakha 107 × N22, Sakha 107 × Fuknishiki, Sakha 107 × Akihikari, and

NERICA 9 × Akihikari exhibited significantly positive heterotic effects over both mid and better parents under both conditions.

Regarding panicle length, the data presented in Table (7) showed that the seven crosses Sakha 107 × NERICA 9, Sakha 107 × Giza 177, Sakha 107 × Fuknishiki, NERICA 9 × Fuknishiki, NERICA 9 × Akihikari, N22 × Akihikari and IET1444 × Fuknishiki under the two irrigation treatments as well as the crosses Sakha 107 × N22, Sakha 107 × Akihikari and NERICA 9 × N22 under well watered treatment and N22 × Fuknishiki and IET1444 × Giza 177 under stress treatment exhibited positive and significant mid-parents heterotic effects. Moreover, the two crosses Sakha 107 × NERICA 9 and NERICA 9 × Akihikari under both conditions as well as the crosses Sakha 107 × N22, Sakha 107 × Giza 177, Sakha 107 × Fuknishiki, Sakha 107 × Fuknishiki Sakha 107 × Akihikari, NERICA 9 × N22, NERICA 9 × Fuknishiki ans N22 × Akihikari under normal treatment and the cross IET1444 × Giza 177 under stress treatment exhibited positive and significant better-parent heterosis values for this trait. Concerning sterility percentage, 13 hybrid combinations had desirable significant and negative heterotic effects as deviation from the MP under both conditions. The cross combinations Sakha 107 × IET1444, Sakha 107 × Giza 177, Sakha 107 × Akihikari, NERICA 9 × IET1444, NERICA 9 × Akihikari and N22 × Fuknishiki gave the highest significant and negative values. On the other hand, the three crosses Sakha 107 × N22, NERICA 9 × Akihikari and N22 × Fuknishiki under both conditions as well as eight crosses under normal condition exhibited desirable significant and negative BP heterosis for this trait.

Table 7. Heterosis percentages relative to mid parents (MP) and better parent (BP) for all the studied traits under normal and water deficit conditions.

Cross	Days to 50%heading				Plant height(cm)				Leaf rolling			
	M.P		B.P		M.P		B.P		M.P		B.P	
	N	S	N	S	N	S	N	S	N	S	N	S
Sakha 107 × NERICA 9	0.74	1.87*	3.49**	4.75**	4.53**	4.63**	12.76**	14.40**	-22.26**	19.66**	6.50	50.21**
Sakha 107 × N22	5.04**	3.65**	12.88**	12.23**	-3.55**	2.60	-2.02	5.46**	-19.88*	-7.69	33.00	8.88
Sakha 107 × IET1444	1.68	1.29	8.68**	8.76**	1.95*	3.76**	5.12**	5.46**	-8.60	1.23	21.43	10.00
Sakha 107 × Giza 177	4.83**	8.19**	5.29**	9.09**	4.77**	3.61*	6.32**	7.12**	-26.09**	-3.88	-15.93	40.63**
Sakha 107 × Fuknishiki	5.73**	8.24**	10.76**	12.59**	6.15**	5.49**	9.45**	10.28**	10.50	18.90**	53.85**	59.09**
Sakha 107 × Akihikari	5.33**	4.53**	9.97**	8.28**	4.57**	5.17**	5.59**	8.21**	-22.33**	18.77**	-15.66	76.14**
NERICA 9 × N22	0.45	1.83*	4.95**	7.08**	5.35**	6.78**	11.77**	13.42**	14.00	-1.22	33.00	4.29
NERICA 9 × IET1444	5.03**	4.65**	9.16**	9.15**	-6.36**	-9.77**	-2.16*	-3.04*	6.10	38.84**	8.75	58.80**
NERICA 9 × Giza 177	0.34	3.76**	2.62*	7.61**	7.69**	11.68**	18.02**	26.60**	45.88**	-12.18**	72.50**	71.67**
NERICA 9 × Fuknishiki	7.23**	9.99**	9.29**	11.22**	-0.64	1.41	10.77**	16.36**	43.54**	21.51**	45.38**	114.59**
NERICA 9 × Akihikari	1.60	2.37**	3.21**	3.11**	4.41**	10.20**	11.48**	24.28**	-39.64**	-37.30**	-25.00	24.46*
N22 × IET1444	-2.67**	-2.79**	-2.17*	-2.03*	-2.41**	2.12	-0.97	3.26*	10.83	-24.87**	33.00	-18.92*
N22 × Giza 177	-5.53**	-3.19**	1.05	5.76**	1.11	3.68**	4.26**	10.27**	13.48	-8.22	60.00**	66.02**
N22 × Fuknishiki	2.15*	2.71**	4.67**	6.75**	9.34**	15.10**	14.59**	23.83**	-11.30	-8.13	2.00	50.58**
N22 × Akihikari	0.90	1.99*	3.73**	6.44**	7.07**	5.73**	7.71**	11.91**	-28.86**	17.77**	6.00	116.22**
IET1444 × Giza 177	3.14**	3.10**	9.72**	11.69**	1.65	3.77**	6.40**	9.10**	-29.81**	12.47**	-19.29	83.33**
IET1444 × Fuknishiki	-4.10**	-4.98**	-2.25*	-2.03*	1.52	-0.33	8.03**	5.98**	15.56	-43.37**	20.00	-16.00*
IET1444 × Akihikari	2.06*	1.13	4.38**	4.70**	3.74**	2.38	5.90**	7.11**	11.24	10.89**	34.29**	83.33**
Giza 177 × Fuknishiki	9.14**	13.00**	13.82**	18.56**	0.48	-4.62**	2.07	-3.59*	0.00	-5.36	20.00	1.69
Giza 177 × Akihikari	-4.12**	-0.39	-0.35	4.09**	-1.23	0.86	1.23	1.33	1.05	-1.31	5.49	-0.29
Fuknishiki × Akihikari	2.43**	4.12**	2.76**	4.53**	0.48	11.52**	4.64**	13.26**	-28.66**	4.52	-10.00	13.56**

Table 7. Cont.

Cross	Relative water content(%)				No. of panicles/plant				Panicle length (cm)			
	M.P		B.P		M.P		B.P		M.P		B.P	
	N	S	N	S	N	S	N	S	N	S	N	S
Sakha 107 × NERICA 9	3.16**	7.34**	0.66	3.28**	26.82**	23.58**	9.96**	21.46**	18.44**	12.50**	11.79**	8.17*
Sakha 107 × N22	-1.89*	1.97*	-2.66**	1.14	23.96**	32.86**	13.98**	31.15**	13.80**	3.71	7.63**	-0.05
Sakha 107 × IET1444	2.89**	1.39	2.86**	0.18	8.44*	19.95**	7.09	13.38**	-4.36	-5.30	-9.05**	-6.50
Sakha 107 × Giza 177	-2.34**	0.53	-3.64**	-9.72**	7.58*	26.41**	3.26	15.88**	14.75**	10.73**	14.50**	6.93
Sakha 107 × Fuknishiki	-1.16	0.33	-6.78**	-8.12**	17.59**	25.91**	9.48*	11.59*	23.63**	8.13*	21.59**	3.91
Sakha 107 × Akihikari	-0.30	3.41**	-2.66**	-3.80**	12.02**	22.98**	9.46**	19.81**	11.07**	-0.38	11.07**	-3.49
NERICA 9 × N22	-0.56	-6.53**	-2.21*	-9.35**	15.19**	-8.08*	7.99	-10.80*	12.04**	5.06	11.79**	4.81
NERICA 9 × IET1444	1.76*	4.72**	-0.73	-0.39	9.27*	15.07**	-4.22	7.01	7.66**	7.46*	6.81*	4.62
NERICA 9 × Giza 177	0.00	-6.07**	-1.12	-12.58**	-9.47*	2.43	-18.59**	-4.59	2.49	6.83	-3.06	-0.67
NERICA 9 × Fuknishiki	-2.37**	-4.90**	-5.71**	-9.67**	34.53**	17.53**	24.56**	5.78	25.56**	7.43*	16.68**	-0.58
NERICA 9 × Akihikari	5.88**	15.42**	5.82**	11.45**	27.33**	39.76**	8.27*	38.52**	17.51**	16.60**	10.92**	8.75*
N22 × IET1444	-5.21**	-4.96**	-5.98**	-6.84**	14.15**	12.81**	6.19	7.96*	3.44	6.53	2.85	3.96
N22 × Giza 177	-8.19**	5.37**	-8.70**	-4.68**	9.53*	10.00*	4.74	-0.35	4.67	1.76	-0.79	-5.17
N22 × Fuknishiki	4.07**	12.93**	-1.10	4.20**	23.65**	30.10**	22.00**	14.01**	2.87	7.66*	-4.21	-0.14
N22 × Akihikari	-1.40	10.64**	-2.98**	3.72**	8.73*	11.05**	-2.10	6.83	13.93**	7.24*	7.76**	0.24
IET1444 × Giza 177	-3.26**	7.08**	-4.58**	-4.85**	-2.73	8.23*	-5.50	-5.73	4.75	14.16**	-0.18	8.88*
IET1444 × Fuknishiki	-4.90**	-2.76**	-10.33**	-11.91**	-5.37	14.72**	-10.85**	-3.18	12.23**	8.66*	5.06	3.15
IET1444 × Akihikari	-4.67**	-13.02**	-6.96**	-19.97**	-5.63	-4.35	-8.91*	-11.78**	-9.68**	-6.95	-14.11**	-10.96**
Giza 177 × Fuknishiki	-2.22**	-0.72	-6.59**	-2.84*	-6.88	13.67**	-9.79*	9.53	1.50	4.61	-0.39	4.08
Giza 177 × Akihikari	-9.09**	-1.61	-10.06**	-5.29**	-1.36	-1.89	-7.40*	-7.84	-2.43	4.18	-2.64	3.83
Fuknishiki × Akihikari	-2.42**	-0.32	-5.81**	-2.00	-6.92*	7.23	-15.17**	-2.71	1.83	-1.40	0.15	-2.22

Table 7. Cont.

Cross	Sterility(%)				1000–grain weight (g)				Grain yield/plant (g)			
	M.P		B.P		M.P		B.P		M.P		B.P	
	N	S	N	S	N	S	N	S	N	S	N	S
Sakha 107 × NERICA 9	-5.39	-7.16*	9.98	-1.24	4.21**	8.22**	0.25	5.17**	5.09**	9.59**	3.16	8.06**
Sakha 107 × N22	-33.24**	-11.30**	-17.24*	-10.70**	4.55**	5.87**	4.25**	5.76**	5.10**	18.91**	4.71**	15.50**
Sakha 107 × IET1444	-29.43**	-6.72*	-27.77**	2.22	2.35*	-2.02*	0.54	-4.79**	1.13	5.43*	-7.15**	-2.74
Sakha 107 × Giza 177	-36.66**	-12.31**	-20.51*	12.54**	3.60**	3.51**	1.70	-0.32	15.74**	23.90**	11.91**	4.97
Sakha 107 × Fuknishiki	-14.40*	16.64**	-3.45	34.52**	8.72**	2.60*	3.95**	-5.65**	8.80**	20.87**	2.59	4.08
Sakha 107 × Akihikari	-20.26**	-14.92**	-19.82*	9.15*	5.84**	10.85**	5.40**	5.64**	12.73**	1.51	12.12**	-2.65
NERICA 9 × N22	-37.48**	49.92**	-33.84**	58.34**	3.26**	4.50**	-0.94	1.65	0.27	1.23	-1.92	-3.01
NERICA 9 × IET1444	-38.33**	-8.57**	-30.16**	7.14	1.96*	2.97**	-3.58**	-2.67*	4.02*	7.22**	-2.84	-2.36
NERICA 9 × Giza 177	-12.68*	-5.59*	-6.58	12.82**	5.62**	3.54**	-0.19	-2.99**	8.04**	14.03**	6.39**	-4.49
NERICA 9 × Fuknishiki	-20.68**	-3.91	-18.50**	3.72	2.18*	4.04**	-5.85**	-6.78**	1.10	0.16	-2.97	-14.76**
NERICA 9 × Akihikari	-37.73**	-33.23**	-27.16**	-20.26**	5.94**	13.55**	2.33*	5.31**	21.10**	24.36**	19.51**	17.67**
N22 × IET1444	-31.47**	-8.48*	-17.33*	1.03	6.13**	8.02**	4.55**	4.87**	7.50**	26.36**	-1.63	19.82**
N22 × Giza 177	-23.25**	-14.43**	-22.45**	8.94*	4.12**	-0.73	2.50*	-4.50**	4.29**	12.78**	0.48	-2.06
N22 × Fuknishiki	-39.48**	-21.76**	-34.10**	-10.45**	9.83**	17.05**	5.30**	7.55**	18.96**	28.71**	11.78**	13.67**
N22 × Akihikari	-20.29**	-19.44**	-0.55	2.50	4.62**	7.77**	3.88**	2.60*	7.02**	14.04**	6.06**	12.55**
IET1444 × Giza 177	-14.41*	-24.94**	4.51	7.62	7.13**	9.74**	7.05**	8.72**	14.63**	38.86**	8.64**	26.49**
IET1444 × Fuknishiki	-2.60	-3.04	7.11	23.97**	0.11	8.15**	-2.61*	2.17	9.46**	12.68**	6.40**	4.49
IET1444 × Akihikari	21.57**	-15.65**	25.14**	20.87**	4.22**	11.54**	1.96	9.32**	2.15	3.20	-5.75**	-0.90
Giza 177 × Fuknishiki	16.40**	43.08**	28.18**	57.34**	-5.88**	-0.32	-8.37**	-4.99**	-7.91**	8.17*	-10.27**	6.09
Giza 177 × Akihikari	41.61**	8.42**	78.90**	8.46**	-7.37**	-1.59	-9.44**	-2.65*	-5.18**	-6.66*	-7.83**	-18.03**
Fuknishiki × Akihikari	10.27	-4.80*	25.14**	4.64	4.62**	9.50**	-0.37	5.47**	0.48	19.05**	-4.77**	6.36*

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

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For 1000-grain weight, 14 and 7 hybrids showed significant and positive heterosis relative to MP and BP under both conditions, respectively. The seven hybrids Sakha 107 × N22, Sakha 107 × Akihikari, NERICA 9 × Akihikari, N22 × IET1444, N22 × Fuknishiki, N22 × Akihikari and IET1444 × Giza 177 manifested higher mid and better parents heterosis under both environments.

With respect to grain yield per plant, the five crosses Sakha 107 × N22, NERICA 9 × Akihikari, N22 × Fuknishiki, N22 × Akihikari, IET1444 × Giza 177 and IET1444 × Fuknishiki had significant positive heterotic effects relative to mid and better parents under the two irrigation treatments. Also significant positive heterotic effects relative to MP were recorded for this trait by the crosses Sakha 107 × NERICA 9, Sakha 107 × Giza 177, Sakha 107 × Fuknishiki, NERICA 9 × IET1444, NERICA 9 × Giza 177, N22 × IET1444, N22 × Giza 177 and IET1444 × Fuknishiki under both treatments. Meanwhile, the crosses Sakha 107 × Giza 177, Sakha 107 × Akihikari, NERICA 9 × Giza 177 and IET1444 × Fuknishiki under normal condition and the cross Sakha 107 × NERICA 9 under stress condition exhibited significant and positive better parent heterotic effects. Consequently, one or more of these crosses could be used in rice breeding programs for producing hybrid rice under normal and stress conditions. Positive and significant heterosis for grain and some of its components in rice under normal and water deficit conditions have been reported by Sultan *et al.* (2014), Ushakumari *et al.* (2014), El-Sayed *et al.* (2018) and Abd El-Hadi *et al.* (2020).

SSR polymorphism

Ten SSR markers related to drought tolerance were used in this study to evaluate allelic diversity, gene diversity, polymorphism information content (PIC), and genetic relationships among the studied seven parental genotypes. All the markers used in this study were polymorphic and generated a total of 33 reproducible DNA bands/alleles. The number of alleles per locus ranged from 2 (RM212 and RM11943) to 5 (RM72), with an average number of 3.3 alleles/locus (Table 8 and Fig. 1). Furthermore, the effective number of alleles ranged from 1.70 to 3.77 with an average of 2.56 allele/ locus. The mean number of alleles per locus detected in this study was higher than those reported by Joshi *et al.* (2010), Upadhyay *et al*. (2011), Abdel-Rahman *et al.* (2013), Ming *et al.* (2015), Farid *et al.* (2016), Mishra *et al*. (2018) and Embate *et al.* (2020)

Table 8. Data generated by ten SSR markers among the seven studied rice genotypes.

Marker	Ch.	Size Range (bp)	Number of Alleles	Effective number of alleles	Major Allele Frequency	Gene Diversity	PIC
RM212	1	120-140	2	1.70	0.71	0.41	0.32
RM11943	1	85-93	2	1.80	0.64	0.46	0.35
RM279	2	150-200	4	3.08	0.46	0.68	0.62
RM55	3	200-240	3	1.81	0.71	0.45	0.41
RM234	7	120-150	4	2.80	0.50	0.64	0.58
RM72	8	150-200	5	3.63	0.43	0.72	0.69
RM223	8	150-170	3	2.58	0.43	0.61	0.53
RM219	9	200-240	4	3.77	0.29	0.73	0.68
RM286	11	110-150	3	1.81	0.71	0.45	0.41
RM20A	12	200-230	3	2.58	0.43	0.61	0.53
	Mean		3.30	2.56	0.53	0.58	0.51

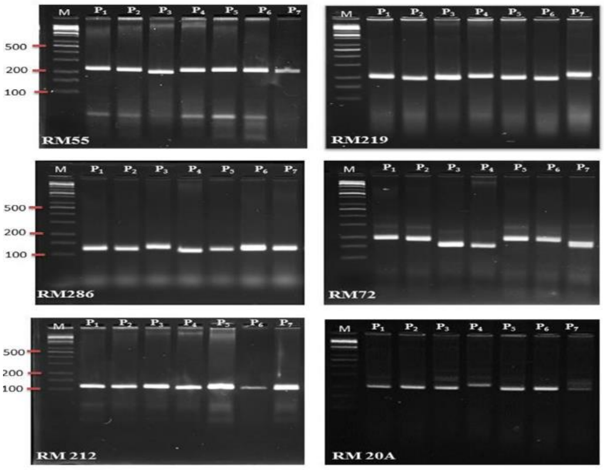

Fig. 1. DNA banding pattern of the SSR markers (RM55,RM219, RM286, RM72, RM212 and RM20A) with the seven rice genotypes (P_1-P_7), P_1; Sakha 107, P_2; NERICA 9, P_3; N22, P_4; ET1444, P_5; Giza 177, P_6; Fuknishiki and P_7; Akihikari . M refer to 100bp DNA ladder

However, it was lower than the 4.91alleles/locus found by Das *et al.* (2013) and 6.21 alleles/locus reported by Tabkhkar *et al.* (2018) in rice genotypes using SSR markers. The discrepancy among various studies in the mean of alleles might be due to the differences in germplasm type, repeat length and number of the SSR markers used (Davierwala *et al.* 2000 and Verma *et al.* 2019). The major allele frequency had an average of 0.53 with a range extended from 0.29 (RM219) to 0.88 (RM212, RM55 and RM286). This indicates that 53.0% of the tested genotypes shared a common major allele at any of the tested loci. This result is in close agreement with the findings reported by Kaushik *et al.* (2011), Abdel-Rahman *et al.* (2013) and Ramadan *et al.* (2015). As shown in Table (8), the gene diversity ranged from 0.41 to 0.73 with an average of 0.58. Similar results were obtained by Aljumaili *et al.* (2018) and Donde *et al.* (2019). The markers RM 219 (0.73), RM72 (0.72) and RM 320 (0.68) showed the highest estimated values. Gene diversity is defined as the probability that two alleles randomly chosen from the tested samples are different (Liu, 1998). The level of polymorphism was assessed by calculating polymorphism information content (PIC). It indicates the power of a marker locus to discriminate among the tested genotypes (Donde *et al.* 2019). The PIC values ranged from 0.32 to 0.69, with an average of 0.51 (Table 8). The mean PIC value observed in this study was close to those reported by Zhang *et al.* (2011), Abdel-Rahman *et al.* (2013) and Verma *et al.* (2019) who detected an averages of 0.54, 0.53 and 0.51, respectively. The PIC values of SSR markers higher than 0.50 are considered highly informative as reported by Botstein *et al.* (1980). Accordingly, six SSR markers RM72, RM219, RM279, RM234, RM20A and RM223 showed higher discriminatory power to distinguish the tested genotypes and considered highly informative due to its high PIC value which ranged from 0.53 to 0.69. These markers are important for exploring the genetic diversity of rice genotypes for drought tolerance (Mishra *et al.*, 2018).

Genetic distance and cluster analysis

Genetic distance is a measure of the genetic divergence between pairs of genotypes (Suvi *et al.* 2020). Genetic distance in the present study ranged from 0.24 to 0.92 with an average of 0.63 (Table 9), indicating a wide range of genetic variation present among the seven studied genotypes using these set of SSR markers. This result is consistent with the findings of Abdel-Rahman *et al.* (2013), Farid *et al.* (2016) and Mishra *et al.* (2018).

The lowest genetic distance (0.24) was obtained between Giza 177 and Fuknishiki (Table 9). These two varieties are japonica type. Moreover, the obtained results confirmed the sensitivity of those varieties to drought stress. On the other hand, the highest genetic distance (0.92) was observed between N22 and Akihikari rice genotypes (Table 9). It is evident that these two genotypes have different origin and different degree of drought tolerance, N22 is indica type and drought tolerant while, Akihikari is japonica type and drought sensitive. Similar results were reported by Chakravarthi and Naravaneni (2006) and Ramadan *et al.* (2015) who found high genetic distance between japonica and indica types in their respective studied using SSR markers. Kanawapee *et al.* (2011) found high level of similarity between closely related genotypes. The dendrogram constructed using the UPGMA clustering grouped the seven rice genotypes into two main clusters almost agree with their drought tolerance level and their types (Fig. 2). The first main cluster contained the three drought sensitive and japonica rice genotypes; Akihikari, Fuknishiki and Giza 177, indicating high similarity among them. This cluster separated into two sub-clusters; the first one grouped the two genotypes Fuknishiki and Giza 177, whereas the second sub-cluster included Akihikari only. The second main cluster included four rice genotypes; IET1444, N22, NERICA 9 and Sakha 107 and this cluster separated into two sub-clusters; the first sub-cluster consists of the drought tolerant and japonica variety Sakha 107. While, the second sub-cluster divided into two sub-sub clusters; one contained the indicia and the moderately drought tolerant genotype IET1444, and the second included the drought tolerant rice genotypes N22 and NERICA9. These findings are agreed with Farid *et al.* (2016) and Aboulila *et al.* (2019) who reported the ability of SSR makers to divide the genotypes into distinct clusters according to their drought tolerance response and their types. These results could be useful for choosing appropriate parental genotypes with desirable genetic divergence values for developing superior rice genotypes with improved grain yield under normal and water deficit conditions.

Table 9. Genetic distance (GD) matrix among the tested genotypes based on SSR analysis.

Parent	Sakha 107	NERICA 9	N22	IET1444	Giza 177	Fuknishiki	Akihikari
Sakha 107	-						
NERICA 9	0.57	-					
N22	0.64	0.44	-				
IET1444	0.73	0.52	0.50	-			
Giza 177	0.70	0.57	0.82	0.91	-		
Fuknishiki	0.71	0.50	0.91	0.74	0.24	-	
Akihikari	0.73	0.68	0.92	0.83	0.27	0.39	-

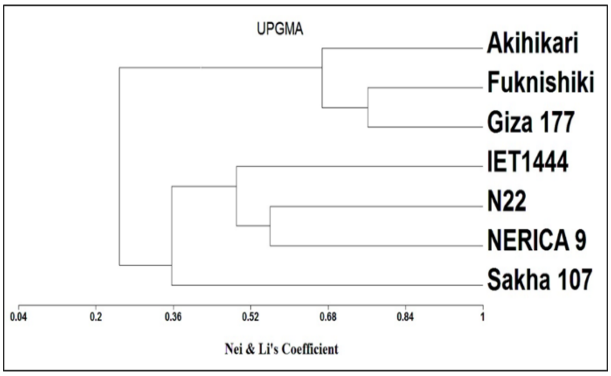

Fig. 2. Dendrogram of the seven rice genotypes constructed from SSR data using (UPGMA) method according to Nei and Li coefficients.

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تحليل الهجن الدائريه لتراكيب وراثيه مختلفه من الأرز تحت ظروف نقص المياة وتقدير التباعد الوراثى بإستخدام الدلائل الجزيئية SSR

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مركز البحوث والتدريب فى الارز- معهد بحوث المحاصيل الحقلية - مركز البحوث الزراعية

تم إجرء التهجين النصف دائرى بين سبعة تراكيب وراثية مختلفه من الأرز فى موسم 2019. تم تقيم الأباء وال21 هجين الناتجه منها تحت كل من الرى العادى (الرى بالغمر) ونقص المياة (الرى كل 12 يوم) خلال موسم 2020. بغرض تقدير القدرة العامة والخاصة على التآلف وتحديد الفعل الجينى المتحكم فى وراثة جميع الصفات المدروسه تحت كلا من المعاملتين. أشارت النتائج إلي أن التباين الراجع للقدرة العامة والخاصة على التآلف كان عالى المعنوية لجميع الصفات المدروسة تحت ظروف الري العادي ونقص المياة. كان الفعل الجينى غير المضيف هو الاكثر اهمية فى وراثة معظم الصفات تحت الدراسة ما عدا صفه إلتفاف الأوراق تحت ظروف نقص المياه. أظهرت الأباء , Sakha 107 NERICA 9و N22 قدرة عامة جيدة على التآلف لصفة محصول الحبوب ومعظم مكوناتة. أظهرت الهجن ,Sakha 107 × Fuknishiki, Sakha 107, × Giza 177 NERICA 9 × Giza 177, NERICA 9 × Akihikari, N22 × IET1444, N22 × Fuknishiki and IET1444 × Giza 177 أفضل القيم لتأثيرات القدرة الخاصة على التآلف لصفة محصول الحبوب وبعض مكوناتة. تم تقدير التباعد الوراثى بين السبعه تراكيب وراثيه بإستخدام عشرة دلائل جزيئة (SSR) وتم الحصول على 33 اليل كناتج لإستخدام هذة المعلمات ترواح عدد الأليلات بين 2 الى 5 بمتوسط 3.3 اليل لكل موقع ورثى. بدراسة محتوى المعلومات الخاصة بتعدد الشكل المظهرى (PIC) تبين انة يترواح من 0.32 الى 0.69 بمتوسط بلغ نحو0.51 تراوحت قيم التباعد الوراثى بين 0.24 الى 0.92 بمتوسط 0.63أظهرت نتائج هذة الدراسه وجود قدر كبير من الاختلافات الوراثيه بين التراكيب الوراثيه المستخدمه فى هذة الدراسه على المستوى الجزيئيى وبالتالى يمكن الاستفادة منها فى برامج التربية لتحمل نقص المياه فى الأرز.