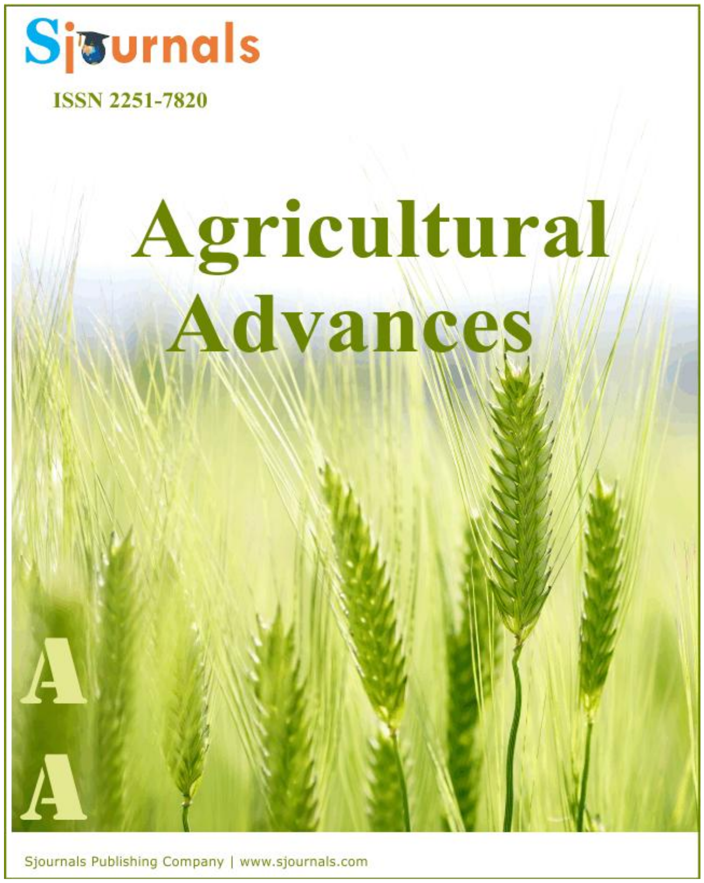
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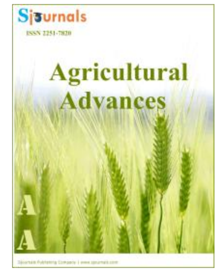

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Original article

Utilizing two line system in hybrid rice (*Oryza sativa* L.) and potential yield advantage under Egyptian conditions

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ABSTRACT

Photo-thermosensitive genic male sterile (PTGMS) lines of rice have tremendous potential in realizing further quantum yield and economical hybrid rice seed production cost. The study was conducted during two rice growing seasons of 2015 and 2016 at the Experimental Farm of the Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt. Ten hybrid rice combinations derived from hybridization of one elite and adapted Japonica PTGMS line (PTGMS-38) and ten Indica, Japonica and Indica Japonica genotypes along with two check (Giza 178 and Giza 179) were used to analyze the genetic parameters and standard heterosis for 10 traits. Highly significant positive standard heterosis over the best local check varieties Giza 178 and Giza 179 for grain yield/plant was observed in all hybrids. The hybrids, PTGMS-38 x Sakha 106 (H10), PTGMS-38 x GZ8479 (H9), PTGMS-38 x Chinese 2 (H8), PTGMS-38 x Giza 177 (H6) and PTGMS-38 x Sakha 101 (H7) with standard heterosis of 54.47, 54.03, 51.63, 50.98 and 49.24%, respectively over the best local check variety Giza 179 were considered as promising. Mean sum of squares due to genotypes showed significant differences for ten traits studied, indicating the presence of high genetic variability among the genotypes. The estimation of GCV was lower than the respective PCV, indicating the influence of environmental factor on the expression of the studied traits. Characters like, spikelet fertility percentage (99.12 and 47.21%), grain yield/plant (98.30 and 36.11%), plant height (99.20 and 35.28%), panicle weight (97.30 and 35.27%) and flag leaf area (89.32 and 31.97%) showed high heritability coupled with moderate genetic advance, suggesting that selection for the improvement of these characters may be rewarding and also greater role of non-additive gene action and suggesting heterosis breeding could be used to improve these characters. Based on ten studied characters, the genotypes were grouped into three clusters at 0.98% similarities coefficient.

1. Introduction

Rice crop plays a significant role in sustaining the food self-sufficiency and for increasing the export in Egypt. Furthermore, it provides 20 % of the world's dietary energy (FAO, 2004). The production of rice should increase by about 60% by the year 2025 to feed the additional rice consumers (Duwayri et al., 1999). Therefore, Hybrid rice technology is one such innovative breakthrough that can further increase rice production, leading to food security and reduction of poverty in Egypt. This technology can be used to break the current yield plateau in rice, where yield levels of the conventional cultivars have stabilized (El-Mowafi et al., 2005). Hybrid rice had a yield advantage of 20% over semi-dwarf varieties. Further, the high productivity of hybrid rice enabled China to increase its rice production from 129 to 200 million tonnes (Chandirakala et al., 2009).

Commercial hybrids typically yield 15-20% more than the best inbred varieties grown under similar conditions believed to be the result of "hybrid vigor" or "heterosis" from genetic combination of two parents (Yuan et al., 1989). The heterosis advantage of hybrids may be expressed by superiority over inbred varieties in grain yield, vigor, panicle size, number of spikelets per panicle, and number of productive tillers. Hybrid varieties are generally developed by the "three-line" or the "two-line" breeding method. The cytoplasmic genetic male sterility system is a three-line system involving a CMS source, a maintainer and a suitable restorer is extensively being used in rice hybrids production (Virmani et al., 1997; Krishnalatha and Sharma, 2012). In the two-line system, certain lines, referred to as S lines, can be either male sterile (functionally female) or male (produces viable pollen) depending upon temperature and day length. Under one set of temperature/ day length combination, the S lines are crossed as females to fertile inbred lines to produce hybrid seed, while under separate temperature/day length combination, the same lines are allowed to self-pollinate and produce viable seeds to maintain a source of the line.

In spite of challenges faced in the technology of hybrid rice, various countries have begun their own hybrid rice research and improvement programs (Virmani et al., 1997). So, for filling up the gap between the production and demand, increasing the production is the key option left since the other alternatives like expanding cultivable land and water are unavailable and resources either stagnant or declining (Viraktamath, 2010). Fortunately, rice breeders have overcome these hurdles by developing a usable system of cytoplasmic-genetic male sterility and packages for efficient and economic seed production. The success of hybrid rice technology primarily depends on genetic purity, timely availability and the affordability of hybrid seed costs to the farmers (Singh and Sunder, 2012). So, The Improvement of hybrid rice technology will further reduce the cost of seed. It is one of the strongest tools to break the yield barriers in rice. Therefore, In this study, deliberate effort was made to evaluate ten promising hybrid combinations derived from two-line system for some agronomic and yield and its related traits which can be used for commercial exploitation of two line hybrid rice breeding.

2. Materials and methods

The research was conducted at the research area of Rice research and training center, Sakha, Kafr El-Sheikh, Egypt during the two successive rice seasons 2015 and 2016. The experimental materials used for the study consisted of one newly developed and well adapted photo-thermo sensitive genic male sterile line (PTGMS-38) as female while 10 testers; Giza 178, GZ6296, PR 78, Giza 179, Large stigma, Giza 177, Sakha 101, Chinese 2, GZ8479 and Sakha 106 were used as male parents to get 10 F_1 hybrids in line x tester combinations (Table 1).

Table 1
Photo-thermosensitive genic male sterility lines (PTGMS) and tester lines/varieties used for the experiment.

Photo-thermosensitive genic male sterile lines		
Line	**Source**	**Origin**
PTGMS -38	Cross breeding Nongken 58s/Sakha101 then acquired by another culture	Egypt
Tester lines		
Testers	**Parentage**	**Origin**
Giza 178	Giza175/Milyang 49	Egypt
GZ6296	AC1225/Hualien Yu 202	Egypt
PR 78	IR58025A/Pusa basmati-1	China
Giza 179	GZ1368-5-S-5/GZ6296-12-1-2-1-1	Egypt
Large stigma	Unknown	China
Giza 177	Giza 171/Yomjo No. 1//PiNo.4	Egypt
Sakha 101	Giza 176/Milyang 79	Egypt
Chinese 2	Unknown	China
GZ8479	Gz6214/EMPSSK 104	Egypt
Sakha 106	Giza 177/Hexi 30	Egypt

Hybrids were evaluated along with parents and two commercial rice varieties as check (Giza 178 and Giza 179) in a Randomized Complete Block Design with three replications. When 30-day old seedlings were transplanted (20 cm x 20 cm) spacing and one seedling/hill. Each test genotypes consisted of three rows of 5m length. The observations were recorded on five plants at random from each replication for growth and yield and its components.

Days to heading (day): It was measured as number of days from sowing to the time when more than 50% of panicles emerged.
Plant height (cm): Measured on the main clum from ground level to the tip of the panicle in centimeter (cm).
Number of tillers/plant: Total numbers of tillers were counted on each plant at the time of maturity.
Number of panicles/plant: Counted as number of panicles bearing tillers / plant at the maturity stage.
Flag leaf area (cm^2): Estimated at the pre-flowering stage following the formula reported by Yoshida et al. (1976) as follows:

$$\text{Flag leaf area } (cm^2) = K \times \text{length (cm)} \times \text{width (cm)}$$

Where: K (0.75) is a correction factor.
Panicle length (cm): The main panicle was measured from panicle base up to apiculus of the upper most spikelet of the panicle.
Panicle weight (g): Defined as weight of the main panicle for each plant.
Grain weight (g): It was measured as weight of 1000 random filled grains / plant.
Fertility of spikelet%: Spikelet fertility % can be expressed as the following:

$$\text{Spikelet fertility \%} = \frac{\text{No. of fertile spikelets/ panicle}}{\text{Total No. of spikelets / panicle}} \times 100$$

Grain yield/plant (g): It was measured as individual plant, (moister was 14%).
Statistical analysis: Analysis of variance was computed by IRRISTAT program. The correlation coefficients (r) among all parameters were computed by SPSS. The calculation of (σ^2 g), (σ^2 e), genotypic x environmental variance

(σ^2gy), (σ^2ph), (GCV), (PCV) coefficient of variation components and the expected genetic advance from selection (Δg %) was described according to Burton, (1952) as follows:

$$\text{Genotypic variance } (\sigma^2 g) = M_1\text{-}M_2/ry$$
$$\text{Environmental variance } (\sigma^2 e) = M_3$$
$$\text{Phenotypic variance } (\sigma^2 ph) = \sigma^2 g + \sigma^2 gy + \sigma^2 e$$

Where: M_1= Mean square due to varieties within treatment, M_2 = Mean square due to varieties x year interaction, M_3 = Mean squares due to error, and r = replications number.

$$\text{Phenotypic coefficient of variability (P.C.V.)} = \frac{\sqrt{Ph}}{X} \times 100$$

$$\text{Genotypic coefficient of variability (G.C.V.)} = \frac{\sqrt{g}}{X} \times 100$$

The genetic parameters i.e., heritability (H^2) and genetic advance upon selection (ΔG) were measured as follows:

Heritability (H^2): was measured according to Hansen et al. (1956).

$$H_{2b}\ \% = \frac{\sigma^2 g}{\sigma^2 Ph} \times 100$$

Genetic advance upon selection (ΔGs) as percent of the mean (ΔG %) were computed as follows:

$$\Delta Gs = K * H_{2b} * \sigma_{Ph}$$

$$\Delta G\% = \frac{\Delta G}{X} \times 100$$

Where K is the selection differential and equals 2.06 at selection intensity of 5%.

3. Results and discussion

3.1. Mean performance

The data relating to the measurement of mean performance of F_1 rice hybrids for different quantitative traits are produced in (Table 2). The early maturity hybrids are desirable as they produce more yield/day and fit well in multiple cropping systems (Neelam et al., 2009). Four days to heading, the screened lines ranged from 93.0 days to 127.0 days with the mean of 112.2 days. The check variety Giza 179 (93.0 days) and hybrid PTGMS-38/Sakha 106 (101.0 days) were identified to be early maturing varieties, while PTGMS-38/PR78 (127.0 days) was a late maturing hybrid. Selection of rice genotypes with appropriate plant height and non-lodging characteristic is important for high yielding potential of hybrids (Ikehashi et al., 1994) have suggested use of dominant. Highest plant height was observed in hybrids PTGMS-38/PR78 (157.3 cm) and PTGMS-38/Giza 179 (139.3 cm) and the lowest value observed for hybrid PTGMS-38/GZ8479 (94.3 cm). For number of tillers/plant mean performance ranged from 19.3 to 28.0 tillers with the mean of 22.5 tillers. The hybrid combination PTGMS-38/PR78 recorded the highest mean value (28.0 tillers). Among hybrids under studied, the number of panicles/plant was (18.7 to 26.7). The hybrid PTGMS-38/PR78 was exhibited highest panicles/plant and least was observed in PTGMS-38/Gz6296, while Giza 178 and Giza 179 (check) exhibited 22.8 and 23.4 panicles, respectively. Concerning flag leaf area trait, the hybrid combinations PTGMS-38/Giza 179 and PTGMS-38/PR78 gave the highest mean values for this trait with 49.0 and 48.8 cm^2, respectively.

Panicle length was exhibited highest in PTGMS-38/Large Stigma (24.9 cm) and lowest in PTGMS-38/GZ8479 (18.6 cm). The trait panicle weight was varied from 4.3 g (in Giza178) to 7.4 g (in PTGMS-38/Sakha 106). Hybrid PTGMS-38/Large Stigma was exhibited highest 1000-grain weight (35.2 g), while Giza 178 and Giza 179 both were exhibited lowest (21.5 g and 27.5 g), respectively. All rice hybrids showed yield advantages over the high yielding checks i.e. Giza 178 and Giza 179. Achieved maximum production of hybrids resulted from the increase spikelet fertility %, which enhance the sink capacity. (Peng et al., 2003) found that the yield for F1 hybrid rice was 17% higher than that of indicainbreds. Yield/plant was observed highest in PTGMS-38/Sakha 106 (70.9 g) and lowest in check Giza 178 (44.5 g).

Standard heterosis (Yield advantage over checks %): Promising hybrids should manifest high heterosis for commercial exploitation (Malini et al., 2006). Standard heterosis of ten hybrid combinations for grain yield studied trait on the basis of the check varieties (Giza 178 and Giza 179) is presented in (Table 2). The average of observed heterosis of each hybrid for this trait was compared with the standard varieties. Highly significant positive heterosis was observed in all hybrids for this trait. The highest values of heterosis were recorded for hybrid combinations PTGMS-38/GZ8479 and PTGMS-38/Sakha 106 over the check varieties Giza 178 and Giza 179. Hence, these hybrids may be used for commercial exploitation of two line hybrid rice breeding.

3.2. Analysis of variance

Analysis of variance of morphological and yield traits are presented in (Table 3). The measured values for genotypes with respect to ten traits were significant. The data indicated that varietal differences were significant and a wide variability was observed among the genotypes. From these results it was also noticed, that the least significant difference revealed highly diversified genotypes for their performance and selection can be performed for different traits and this high rate of variation strongly increases the efficiency of selection in the program of breeding. These results correspond with some previous research (Rasheed et al., 2002; Binodh et al., 2007).

3.3. Estimates of genetic variability

Variance components: The results in (Table 4) indicated that the phenotypic variance was achieved higher value more than the genotypic variances in respect to parameters which could be due to the impact of environmental condition on these traits (Devi et al., 2006; Prajapati et al., 2011; EL-Badri et al., 2016; Anis et al., 2016a).

Coefficient of variability: The genotypic coefficient of variability and phenotypic coefficient of variability achieved high value for spikelets fertility % (Table 4). PCV and GCV was achieved moderate values for grain yield/plant, panicle weight, plant height and flag leaf area, while rest of the characters recorded low PCV and GCV. The measure of PCV was achieved higher value than GCV for all the characters. The variation between GCV and PCV for all character sunder investigation, which indicated less effect of environment over expression of the characters (Manikya and Reddy, 2011).

Heritability and genetic advance: The results revealed that high heritability rates were achieved for all traits (Table 4). The expected genetic advance values for characters of the genotypes measured are presented in (Table 4). High heritability coupled with high genetic advance was observed for spikelets fertility % (99.12% and 47.21%), grain yield/plant (98.30% and 36.11%), plant height (99.20% and 35.28%) and panicle weight (97.30% and 35.27%). Thus, it can be understood that the characters *viz.,* spikelets fertility %, grain yield/plant, plant height and panicle weight were controlled by additive gene action, which could be improved through simple selection methods. The characters showing high heritability with low genetic advance indicated the presence of non-additive gene action (Singh et al., 2011).

3.4. Correlation coefficient

Out of 15 significant measures among 45 correlations obtained between various character pairs, 8 correlation coefficients were positive in nature while only 7 measures were negative (Table 5). The measure of degree of symmetrical association between two variables or traits indicated that grain yield/plant had highly significant and positive correlation with panicle weight besides having significant and positive association with spikelets fertility %. Therefore, these traits emerged as most important associates of grain yield. The spikelet fertility % exhibited strong negative association with days to heading, plant height, flag leaf area and panicle length. The flag leaf area had a strong positive association with panicle length, which augurs well for providing correlated response during selection for improving these characters. The above observations of strong positive associations between yield and yield components are in agreement with the earlier reports in rice (Zahid et al., 2006; Yadav et al., 2011; Hefena et al., 2016; Hassan et al., 2016; Abdel-Moneam et al., 2016; Anis et al., 2016b).

Table 2
Mean values of hybrid combinations for agro-botanical characters and standard heterosis over two commercial rice varieties.

		Measured traits										Grain yield heterosis over standard checks (%)	
No.	Hybrid combination	Days to heading (day)	Plant height (cm)	Number of tillers/ plant	Number of panicles/ plant	Flag leaf area (cm^2)	Panicle length (cm)	Panicle weight (g)	1000-grain weight (g)	Spikelets fertility %	Grain yield/ plant (g)	Giza178	Giza179
1	PTGMS-38/Giza 178 (H1)	122.3	129.7	23.0	21.7	44.1	21.4	6.1	28.4	65.6	54.6	22.70**	18.95**
2	PTGMS-38/Gz6296 (H2)	111.0	135.0	19.3	18.7	48.4	23.3	6.0	29.6	73.4	62.4	40.22**	35.95**
3	PTGMS-38/PR78 (H3)	127.0	157.3	28.0	26.7	48.8	21.9	5.5	29.4	68.8	55.5	24.72**	20.92**
4	PTGMS-38/Giza 179 (H4)	113.0	139.3	21.3	20.0	49.0	22.0	4.6	29.5	45.6	48.7	9.44**	6.10**
5	PTGMS-38/Large Stigma (H5)	125.3	138.7	20.0	19.0	47.2	24.9	5.5	35.2	47.2	49.5	11.24**	7.84**
6	PTGMS-38/Giza 177 (H6)	105.7	105.0	22.2	21.0	29.3	20.0	5.6	29.3	96.4	69.3	55.73**	50.98**
7	PTGMS-38/Sakha 101 (H7)	120.0	105.0	25.0	23.3	39.5	20.4	6.3	29.6	82.4	68.5	53.93**	49.24**
8	PTGMS-38/Chinese 2 (H8)	112.7	114.0	20.0	19.3	36.2	19.1	7.3	27.8	88.3	69.6	56.40**	51.63**
9	PTGMS-38/GZ8479 (H9)	109.0	94.3	20.8	19.3	35.3	18.6	6.4	27.6	94.5	70.7	58.88**	54.03**
10	PTGMS-38/Sakha 106 (H10)	101.0	102.0	22.1	20.5	36.3	19.7	7.4	28.8	94.5	70.9	59.33**	54.47**
11	Giza 178 (Check)	106.0	105.0	23.9	22.8	38.1	22.3	4.3	21.5	89.5	44.5	--	--
12	Giza 179 (Check)	93.0	98.0	24.8	23.4	33.5	21.7	4.6	27.5	90.8	45.9	--	--
L.S.D.	0.05 %	1.29	2.58	2.21	2.03	3.22	0.74	0.24	0.36	2.37	1.93	--	--
	0.01 %	1.88	3.77	3.23	2.97	4.71	1.09	0.34	0.52	3.46	2.82		

Table 3
Mean squares of twelve rice genotypes for agro-morphological and yield traits.

		Sum of mean square									
S.O.V.	d.f.	Days to heading (day)	Plant height (cm)	Number of tillers/plant	Number of panicles/ plant	Flag leaf area (cm^2)	Panicle length (cm)	Panicle weight (g)	1000-grain weight (g)	Spikelets fertility percentage	Grain yield/plant (g)
Replications	2	0.08	1.44	1.03	4.26	0.68	0.29	0.07	0.05	0.18	0.11
Genotypes	11	311.67**	1251.57**	19.41**	16.97**	137.87**	9.94**	3.07**	27.46**	972.37**	330.22**
Error	22	0.84	3.38	2.48	2.10	5.29	0.28	0.03	0.07	2.86	1.89

*significant at 5% probability level, **significant at 1% probability level.

Table 4
Grand mean, range, variance components, estimates of phenotypic (PCV) and genotypic (GCV) coefficient of variation, heritability (h_{2b}%) and genetic advance for 10 characters in rice.

Studied traits	Grand mean	Range	Variance components $\sigma^2 g$	$\sigma^2 p$	$\sigma^2 e$	Coefficient of variation GCV	PCV	Heritability (h_{2b}%)	Genetic advance G.S.	G.S.(%)
Days to heading (day)	112.2	93.0-127.0	103.61	104.45	0.84	9.07	9.11	99.19	20.88	18.61
Plant height (cm)	118.6	94.3-157.3	416.06	419.44	3.38	17.20	17.27	99.20	41.84	35.28
N. of tillers/plant	22.5	19.3-28.0	5.64	8.13	2.48	10.54	12.65	69.46	4.07	18.09
N. of panicles/ plant	21.3	18.7-26.7	4.95	7.06	2.10	10.44	12.47	70.19	3.84	18.02
Flag leaf area (cm^2)	40.5	29.3-49.0	44.19	49.48	5.29	16.43	17.38	89.32	12.94	31.97
Panicle length (cm)	21.3	18.6-24.9	3.22	3.50	0.28	8.44	8.80	91.98	3.54	16.67
Panicle weight (g)	5.8	4.30-7.40	1.01	1.04	0.03	17.36	17.60	97.30	2.04	35.27
1000-grain weight (g)	28.7	21.5-35.2	9.13	9.20	0.07	10.54	10.58	99.29	6.20	21.63
Spikelets fertility percentage	78.1	45.6-96.4	323.17	326.03	2.86	23.02	23.12	99.12	36.86	47.21
Grain yield/plant (g)	59.5	44.5-70.9	109.44	111.34	1.89	17.68	17.83	98.30	21.36	36.11

Table 5
Estimates of simple correlation coefficients among pairs of the studied characters.

	Days to heading (day)	Plant height (cm)	Number of tillers/ plant	Number of panicles/ plant	Flag leaf area (cm^2)	Panicle length (cm)	Panicle weight (g)	1000-grain weight (g)	Spikelets fertility percentage	Grain yield/ plant (g)
Days to heading (day)	1									
Plant height (cm)	0.729**	1								
Number of tillers/plant	0.118	0.094	1							
Number of panicles/plant	0.143	0.153	0.993**	1						
Flag leaf area (cm^2)	0.684**	0.892**	-0.011	0.026	1					
Panicle length (cm)	0.335	0.624*	-0.033	0.018	0.677**	1				
Panicle weight (g)	0.106	-0.191	-0.319	-0.343	-0.196	-0.570*	1			
1000-grain weight (g)	0.486	0.466	-0.272	-0.283	0.396	0.358	0.232	1		
Spikelets fertility percentage	-0.654**	-0.818**	0.127	0.107	-0.868**	-0.708**	0.324	-0.570*	1	
Grain yield/plant (g)	-0.042	-0.367	-0.263	-0.297	-0.414	-0.730**	0.851**	0.13	0.526*	1

3.5. Cluster analysis

Cluster analysis was applied in the distance criteria of 0.98 grouped genotypes into three clusters (Fig. 1). Cluster I comprised of five hybrid combinations *viz.,* H6, H7, H8, H9 and H10. These hybrids were similar in most of traits and high in grain yield/plant. Cluster II is the least cluster comprising two check varieties (Giza 178 and Giza 179) were placed in it. While there are the rest five hybrid combinations H1, H2, H3, H4 and H5 in cluster III. There are several studies on rice diversity and clustering using agronomic traits (Saravanan and Sabesan, 2010).

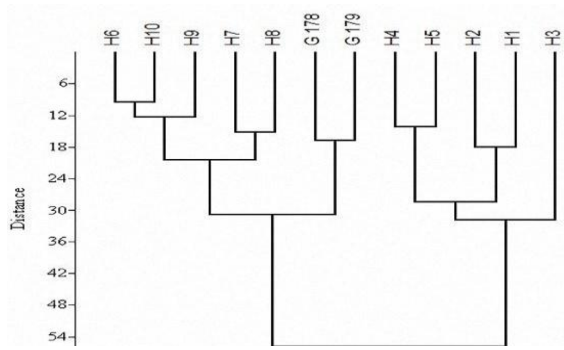

Fig. 1. Dendogram of ten hybrid combinations and two commercial rice varieties based on ten quantitative traits.

4. Conclusion

The presence of substantial heterosis and economic hybrid seed production are two most desirable traits for success of any commercial hybrid rice breeding programme. Photo-thermo-sensitive genic male sterile (PTGMS) lines of rice in this regard have tremendous potential in realizing further quantum yield and economical hybrid rice seed production cost. Therefore, it can be concluded that the hybrids, PTGMS-38 x Sakha 106, PTGMS-38 x GZ8479, PTGMS-38 x Chinese 2, PTGMS-38 x Giza 177 and PTGMS-38 x Sakha 101 with high standard heterosis over the best local check variety Giza 179 were considered as promising. Hence, these hybrid rice combinations could be used for commercial exploitation of two lines hybrid rice breeding.

References

Abdel-Moneam, M.A., Sultan, M.S., Hammoud, S.A., Hefena, A.G., Barutçular, C., EL Sabagh, A., 2016. Studies on heterosis for qualitative and quantitative traits in rice. J. Anim. Plant. Sci., 30(2), 4736-4747.

Anis, G., EL Sabagh, A., Ghareb, A., EL-Rewainy, I., 2016a. Evaluation of promising lines in rice (*Oryza sativa* L.) to agronomic and genetic performance under Egyptian conditions. Int. J. Agron. Agr. Res., 8(3), 52-57.

Anis, G., El-Sabagh, A., El-Badry, A., Barutçular, C., 2016b. Improving grain yield in rice (*Oryza sativa* L.) by estimation of heterosis, genetic components and correlation coefficient. Int. J. Curr. Res., 8(01), 25080-25085.

Binodh, A., Kalaiyarasi, K.R., Thiyagarajan, K., 2007. Genetic parameter studies on quality traits in rice. Centre of Plant Breeding and Genetics, Tamil Nadu Agricultural Univ.; Coimbatore-641 003. Madras Agr. J., 94(1-6), 109-113.

Chandirakala, R., Kandasamy, G., Thiyagarajan, K., 2009. *Heterotic expression of two line hybrids in rice (Oryza sativa* L.). Curr. Biot., 3(3), 353-365.

Devi, S.L., Raina, F.A., Pandey, M.K., Cole, C.R., 2006. Genetic parameters of variation for grain yield and its components in rice. Crop. Res., 32(1), 69-71.

Duwayri, M., Tran, D.V., Nguyen, V.N., 1999. Reflection on yield gaps in rice production. Intr. Rice Commission Newsletter. FAO, Rome. (48), 13-25.

EL-Badri, A., Anis, G., Hefeina, A., Barutçular, C., EL Sabagh, A., 2016. Genetic variability in F2 generation for some physio-morphological characteristics in rice. J. Agr. Biotechnol., 1(2), 68-75.

El-Mowafi, H.F., Bastawisi, A.O., Abou Youssef, M.I., Zaman, F.U., 2005. Exploitation of rice heterosis under Egyptian conditions. Egypt. J. Agr. Res., 389(5A), 143-166.

FAO, 2004. The state of food and agriculture 2003-2004. Agricultural Biotechnology: Meeting the Needs of the Poor? (1 June 2005).

Gomez, K.A., Gomez, A.A., 1984. Statistical procedures for agricultural research. 2nd ed. Jhon Willy Sons, New York, U.S.A., 680.

Hansen, G.H., Robinson, H.F., Comstock, R.E., 1956. Bio-metrical studies of yield in segregating population of Korean bespedese. Agron. J., 48, 267-282.

Hassan, H.M., Arafat, E.F.A., EL Sabagh, A., 2016. Genetic studies on agro-morphological traits in rice (*Oryza sativa* L.) under water stress conditions. J. Agr. Biotechnol., 01(02), 76- 84.

Hefena, A.G., Sultan, M.S., Abdel-Moneam, M.A., Hammoud, S.A., Barutçular, C., EL-Sabagh, A., 2016. Genetic variability, heritability and genetic advance for yield and associated traits in F2 rice population. J. Agr. Biotechnol., 1(2), 49-58.

Ikehashi, H., Zau, J.S., Moon, H.P., Maru Yama, 1994. Wide compatibility gene(s) and indica-japonica heterosis in rice for temperate countries. In: Virmani, S.S. (Ed.). Hybrid rice technology: New development and future prospects, IRRI, Manila, Philippines. 21-31.

Johanson, H.W., Robinson, H.F., Cosnstock, 1955. Estimation of genetic and environmental variation in soybeans. Agron. J., 47, 314-318.

Krishnalatha, S., Sharma, D., 2012. Identification of maintainers and restorers for WA and Kalinga sources of CMS lines in rice (*Oryza sativa* L.). Elec. J. Plant. Breed., 3(4), 949-951.

Malini, N., Sundaram, T., Hari Ramakrishnan, S., Saravanan, S., 2006. Prediction of hybrid vigour for yield attributes among synthesized hybrids in rice (*Oryza sativa* L.). Res. J. Agr. Biol. Sci., 2(4), 166-170.

Manikya, C.M., Reddy, T.D., 2011. Studies on genetic divergence in medium duration elite rice genotypes (*Oryza sativa* L.). J. Res. ANGRAU, 39(4), 122.

Neelam, S., Ramesha, M.S., Reddy, T.D., Sankar, A.S., 2009. Study of heterosis by utilizing male sterility-restoration system in rice (*Oryza sativa* L.). J. Rice. Res., 2(2), 93-98.

Peng, S., Yang, J., Laza, R.C., Sanico, A.L., Visperas, R.M., Song, T.T., 2003. Physiological bases of heterosis and crop management strategies for hybrid rice in the tropics. In: Virmani, S.S., Mao, C.X., Dardy, B., (eds.). Hybrid rice for food security, poverty alleviation, and environment protection. Proc. 4th Intl. Symp. Hybrid Rice, 14-17 May 2002, Intl. Rice Res. Inst., Los Baños Philippines. 153-170.

Prajapati, M., Singh, C.M., Suresh, B.G., Lavanya, G.R., Jadhav, P., 2011. Genetic parameters for grain yield and its component characters in rice. Elec. J. Pl. Breed., 2(2), 235-238.

Rasheed, M.S., Sadaqat, H.A., Babar, M., 2002. Correlation and path co-efficient analysis for yield and its components in rice (*Oryza sativa* L.). Asian J. Plant. Sci., 1(3), 241-244.

Saravanan, K., Sabesan, T., 2010. Genetic divergence analysis of rice (*Oryza sativa* L.) grown in coastal saline low land of Tamilnadu, India. Plant. Arch., 10, 685-688.

Singh, R., Sunder, S., 2012. Foot rot and bakanae of rice: An overview. Rev. Plant. Pathol., 5, 565-604.

Singh, S.K., Singh, C.M., Lal, G.M., 2011. Assessment of genetic variability for yield and its component characters in rice (*Oryza sativa* L.). Res. Plant. Biol., 1(4), 73-76.

Viraktamath, B.C., 2010. Hybrid rice in India. Bulletin No. 47.

Virmani, S.S., Viraktamath, B.C., Casal, C.L., Toledo, R.S., Lopez, M.T., Manalo, J.O., 1997. Hybrid rice breeding manual, International Rice Resaerch Institute, Philipines.

Yadav, S.K., Pandey, P., Kumar, B., Suresh, B.G., 2011. Genetic architecture, interrelationship and selection criteria for yield improvement in rice (*Oryza sativa* L.). Pak. J. Biol. Sci., 14, 540-545.

Yuan, L.P., Virmani, S.S., Mao, C.X., 1989. Hybrid rice - achievements and future outlook. In: Progress in irrigated rice research. IRRI, Manila, Philippines. 219-235.

Zahid, M.A., Akhter, M., Sabar, M., Zaheen, M., Awan, T., 2006. Correlation and path analysis studies of yield and economic traits in Basmati rice (*Oryza sativa* L.). Asian J. Plant. Sci., 5(4), 643-645.

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