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Combining ability and heterosis for yield and grain quality in two line rice (*Oryza sativa* L.) hybrids

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Abstract

Thirty two rice (*Oryza sativa* L.) hybrids involving four TGMS (Thermo Sensitive Gene Male Sterile) lines and eight testers were evaluated for combining ability and heterosis. Among the parents, the TGMS lines *viz.*, GD 98049 and GD 98014, and the testers CB 97033 and IR 72 were the best based on the mean and *gca* effects. Considering the mean performance, *sca* effects and standard heterosis, six hybrids *viz.*, GD 98013/CB 97033, GD 98013/CO 47, GD 98014/ADT 45, GD 98014/PMK 2, GD 98049/ADT 39 and GD 98049/CB 97033 were superior for grain yield and kernel quality traits and recommended for further evaluation.

Key words: Rice, gene action, combining ability, heterosis, TGMS

Introduction

Rice (*Oryza sativa* L.) is the most important food crop of India, occupying 44.9 mha with a total production of 89.4 mt and the average productivity of 1.9 t ha^{-1}. The average productivity of rice in India is low in contrast to nearly 6.0 t ha^{-1} in China [1]. All the commercial rice hybrids currently being are based on Cytoplasmic Gene Male Sterility (CGMS) system. Eventhough this system is most stable system, excessive dependence on a single source of cytoplasm and cumbersome process of hybrid seed production and parental line development warrants the development of alternate approaches to exploit hybrid vigour. Two line breeding is one such possibility. Hence the present study was conducted with four thermo sensitive gene male sterile lines to identify superior two line hybrids.

Materials and methods

Thermo sensitive gene male sterility is a type of gene male sterility expression regulated by certain temperature conditions. The TGMS lines have complete pollen sterility at 30-32°C/22-23°C and partial to normal pollen fertility at 24-27°C/18-19°C [2, 3]. Under tropical conditions, where day length differences are marginal, the TGMS system is considered to be more useful than PGMS system [4]. Two line hybrid employing thermo sensitive gene male sterility (TGMS) system has distinct advantages over the standard cytoplasmic male sterility system with regard to larger choice of male parents, simplified and economic seed production and being devoid of any negative effect associated with male sterile cytoplasm [5]. In China, several rice hybrids in two line combinations with 5-10 % higher yield than the three line combinations have been developed and are being commercialized [6].

Thus the present investigation was carried out with four TGMS lines (GD 98013, GD 98014, GD 98029 and GD 98049) and eight testers (ASD 16, ADT 39, ADT 45, PMK 2, TRY 2, IR 72, CO 47 and CB 97033), crossed in Line × Tester fashion to get 32 hybrids. These hybrids along with parents were evaluated during *kharif* 2003 season in a Randomized Block Design (RBD) with three replications. The row length was 15 meter and each treatment accommodated in two rows. Single seedling was planted per hill with a spacing of 20 × 15 cm. Standard package of practices was adopted to raise the crop. Observations were recorded from five randomly selected plants in each plot for 13 characters *viz.*, days to 50 per cent flowering, plant height (cm), number of productive tillers per plant, panicle exsertion (cm), panicle length (cm), number of grains per panicle, spikelet fertility (%), 100 grain weight (g), harvest index, single plant yield (g), kernel L/B ratio, kernel elongation at cooking and amylose content. Amylose content was estimated as per the method suggested [7].

Results and discussion

Analysis for combining ability for thirteen characters revealed significant differences among the genotypes. The variances due to lines, testers and Line × Tester interaction were highly significant for all the traits. In the present investigation, high σ^2A than σ^2D obtained for the traits days to 50 per cent flowering, plant height, number of productive tillers per plant, panicle exsertion, 100 grain weight and kernel L/B ratio indicated the predominance of additive gene action (Table 1). Similar results were reported earlier for days to 50 per cent flowering and number of productive tillers per plant [8], plant height and 100 grain weight [9], panicle exsertion [10], and kernel L/B ratio [11]. The traits panicle length, number of grains per panicle, spikelet fertility, harvest index, single plant yield, kernel elongation at cooking and amylose content were highly influenced by non additive gene action as evidenced from the very low σ^2A/σ^2D ratio (Table 1). Similar results of non additive gene action governing various traits were reported for panicle length, number of grains per panicle, spikelet fertility and single plant yield, and harvest index [32], kernel elongation at cooking [13] and amylose content [14].

Table 1. Magnitude of additive and dominance variance for different traits in two line rice hybrids

S. No.	Characters	σ^2A	σ^2D	σ^2A/σ^2D
1.	Days to 50 per cent flowering	22.40	9.50	2.35
2.	Plant height	106.50	26.60	4.00
3.	No. of productive tillers/plant	2.06	0.96	2.14
4.	Panicle length	1.18	1.46	0.80
5.	Panicle exsertion	1.16	0.84	1.38
6.	Number of grains per panicle	36.40	947.90	0.04
7.	Spikelet fertility	23.26	61.30	0.38
8.	100 grain weight	0.02	0.01	2.00
9.	Harvest index	5.38	10.93	0.49
10.	Single plant yield	7.28	16.86	0.43
11.	Kernel L/B ratio	0.06	0.03	2.00
12.	Kernel elongation	0.01	0.06	0.17
13.	Amylose content	0.66	2.69	0.25

The success of any plant breeding programme largely depends on the appropriate choice of parents. The parents chosen for the present study were assessed based on their mean performance and combining ability effects. Among the parents, CB 97033 was the best as it showed superior mean for the maximum of six traits *viz.*, number of productive tillers per plant, panicle length, number of grains per panicle, spikelet fertility, single plant yield and kernel L/B ratio.

The estimate of *gca* effects (Table. 2) revealed that the line GD 98014 had significant and desirable *gca* effects for six characters *viz.*, number of productive tillers per plant, number of grains per panicle, spikelet fertility, single plant yield, kernel elongation at cooking and amylose content. Among the testers, IR 72 had good *gca* effects for 11 traits *viz.* days to 50 per cent flowering, plant height, number of productive tillers per plant, panicle length, panicle exsertion, number of grains per panicle, spikelet fertility, 100 grain weight, harvest index, single plant yield and kernel L/B ratio, followed by CB 97033 which has shown high *gca* effects for six traits.

Among the parents used, the tester CB 97033 exhibited superior mean and good *gca* effects for number of productive tillers per plant, panicle length, number of grains per panicle, spikelet fertility, single plant yield and kernel L/B ratio, followed by IR 72, GD 98014 and GD 98049 for different yield contributing traits besides grain quality. Hence these parents could be utilized in crossing programme for yield besides kernel quality.

Among the 32 crosses generated, the hybrid GD 98049/IR 72 recorded high mean values for all the traits except kernel elongation at cooking and amylose content, followed by the three hybrids namely GD 98013/CB 97033, GD 98014/IR 72 and GD 98049/CB 97033 which showed high mean values for seven different yield and yield contributing traits.

The *sca* effect is an useful index to determine the usefulness of a particular cross combination for exploitation of heterosis [15]. Among the 32 hybrids, the cross combination GD 98014/ADT 45 showed desirable *sca* effects for nine different traits *viz.*, days to 50 per cent flowering, number of productive tillers per plant, panicle length, panicle exsertion, number of grains per panicle, 100 grain weight, harvest index, single plant yield and kernel L/B ratio. The hybrids GD 98014/PMK 2, GD 98029/ASD 16, GD 98029/TRY 2 and GD 97013/CB 97033 performed equally good and showed the next best *sca* effects for different yield attributing traits.

Significant heterosis over the standard variety IR 72 was observed in the hybrid GD 98049/IR 72 for the following ten traits *viz.*, days to 50 per cent flowering, number of productive tillers per plant, panicle length, panicle exsertion, number of grains per panicle, spikelet fertility, harvest index, single plant yield, kernel L/B ratio and kernel elongation at cooking. Three hybrids *viz.*, GD 98014/IR 72, GD 98029/TRY 2 and GD 98029/IR 72 had recorded significant standard heterosis for nine traits each. The hybrids GD 98029/ADT 45, GD 98049/ADT 45, GD 98049/PMK 2 and GD 98049/CB 97033 recorded standard heterosis for a maximum of eight different traits each including yield and quality parameters. Similar results of standard heterosis for various characters in two line hybrids were observed in earlier study also [16].

Out of 32 crosses evaluated, the hybrids GD 98049/CB 97033, GD 98013/CB 97033, GD 98014/ADT 45, GD 98014/PMK 2, GD 98013/CO 47and GD 98049/ADT 39 (Table 3) had superior values for different characters based on *per se*, *sca* effects and standard heterosis and hence these hybrids were suitable for commercial exploitation of hybrid vigour through heterosis breeding.

Table 2. Mean performance and combining ability of parents for yield contributing traits in rice

Parents	Number of productive tillers/plant	Panicle length (cm)	Number of grains per panicle	Spikelet fertility (%)	100 grain weight (g)	Single plant yield (g)	Kernel elongation	Amylose content (%)
Lines								
GD 98013	13.20	22.40	-	-	1.98	-	1.53	20.10
	_0.48*_	_0.06_	_−16.42*_	_1.26*_	_−0.01*_	_−0.19_	_0.01*_	_−0.62*_
GD 98014	13.00	22.50	-	-	2.10*	-	1.51	20.50*
	_0.62*_	_−0.28*_	_10.05*_	_4.79*_	_−0.08*_	_2.63*_	_0.01*_	_0.24*_
GD 98029	13.10	20.80	-	-	1.99	-	1.53	19.70
	_−0.65*_	_−0.55*_	_2.36*_	_−4.95*_	_0.11*_	_−2.49*_	_0.01*_	_0.46*_
GD 98049	12.70	24.40*	-	-	2.08	-	1.67*	18.80
	_0.52*_	_0.77*_	_4.01*_	_−1.11*_	_−0.03*_	_0.05_	_−0.02*_	_−0.08_
Mean	13.00	22.50	-	-	2.04	-	1.56	19.80
SEd	0.37	0.39	-	-	0.02	-	0.02	0.30
	_0.12_	_0.12_	_0.71_	_0.21_	_0.05_	_0.26_	_0.05_	_0.09_
CD (0.05)	0.74	0.78	-	-	0.04	-	0.04	0.60
Testers								
ASD 16	10.90	26.00*	135.00	81.60	2.23*	21.10	1.47*	24.10*
	_−0.00_	_0.88*_	_15.24*_	_−2.20*_	_0.11*_	_−1.57*_	_−0.001_	_−0.23_
ADT 39	11.60	21.20	170.30*	89.40*	1.70	21.70	1.63*	23.90*
	_0.31_	_0.50*_	_−13.49*_	_−3.53*_	_−0.15*_	_−0.52_	_−0.01_	_−2.06*_
ADT 45	13.00*	21.50	158.30	90.40*	1.61	17.30	1.56*	22.40
	_−2.30*_	_−2.40*_	_2.38*_	_3.14*_	_−0.28*_	_−4.43*_	_0.04*_	_1.20*_
PMK 2	10.00	24.90*	125.90	76.90	2.37*	19.00	1.30	24.80*
	_−2.58*_	_0.08_	_−7.35*_	_−11.76*_	_0.09*_	_−2.16*_	_0.03*_	_2.46*_
TRY 2	9.80	25.40*	148.50	93.80*	2.34*	21.00	1.39	22.10
	_−0.01_	_−0.24_	_−17.84*_	_2.26*_	_0.22*_	_−0.15_	_0.01_	_0.37*_
IR 72	10.30	24.40*	127.60	87.20	2.34*	22.20	1.29	22.60
	_1.58*_	_0.57*_	_6.80*_	_3.25*_	_0.18*_	_5.66*_	_−0.05*_	_−0.21_
CO 47	12.10*	22.20	143.60	89.80*	1.83	23.10	1.29	22.30
	_1.67*_	_−1.45*_	_−14.56*_	_6.04*_	_−0.12*_	_−0.87_	_0.04_	_−0.48*_
CB 97033	12.30*	25.20*	257.60*	91.30*	1.72	30.80*	1.18	22.40
	_1.31*_	_2.06*_	_28.84*_	_2.79_	_−0.04*_	_4.04*_	_−0.02*_	_−1.06*_
Mean	11.30	23.60	158.20	87.60	2.02	22.00	1.39	23.10
SEd	0.35	0.37	2.14	0.62	0.02	0.77	0.02	0.30
	_0.16_	_0.17_	_1.01_	_0.29_	_0.01_	_0.36_	_0.01_	_0.13_
CD (0.05)	0.70	0.74	4.26	1.23	0.04	1.53	0.04	0.60

*Significant at 5% level; Values in italicised indicate general combining ability of parents; Note: Since TGMS lines were sterile at Madurai condition, parental seed materials were used for recording 100 seed weight, kernel L/B ratio, kernel elongation and amylose content.

Table 3. Mean performance Specific combining ability and Standard heterosis of promising hybrids for yield contributing traits

Hybrid	Number of productive tillers/plant	Panicle length (cm)	Number of grains per panicle	Spikelet fertility (%)	100 grain weight (g)	Single plant yield (g)	Kernel elongation	Amylose content (%)
GD 98013/CO 47	18.10*	23.90	150.10	92.90*	1.98	37.40*	1.45	20.50
	_−0.13_	_−0.06_	_4.24*_	_1.69*_	_−0.03*_	_4.02*_	_−0.02*_	_0.17_
	74.84*	**−1.91**	**17.66***	**6.58***	**−15.36***	**68.66***	**12.11***	**−9.14***
GD 98013/CB 97033	18.80*	27.40*	206.40*	95.30*	2.08	41.40*	1.39	22.00
	_1.00*_	_−0.15_	_17.11*_	_7.29*_	_−0.01_	_3.10*_	_−0.05*_	_2.22*_
	82.10*	**12.16***	**61.75***	**9.28***	**−11.09***	**86.65***	**7.47***	**−2.65***
GD 98014/ADT 45	16.40	23.50	209.30*	91.00*	1.87	39.50*	1.46	19.60
	_1.09*_	_0.76*_	_19.95*_	_−0.88_	_0.09*_	_6.84*_	_−0.05*_	_−3.31*_
	58.71*	**−3.82***	**64.00***	**4.36***	**−20.20***	**77.97***	**12.89***	**−13.60***
GD 98014/PMK 2	16.30	25.50	168.00	83.20	2.01	36.80*	1.57*	25.10*
	_1.24*_	_0.28_	_−11.60*_	_6.32*_	_−0.14*_	_1.88*_	_0.07*_	_0.90*_
	57.42*	**4.37***	**31.64***	**−4.47***	**−14.22***	**65.87***	**21.39***	**10.91***
GD 98049/ADT 39	18.90*	26.70*	189.20*	73.90	1.96	41.90*	1.36	19.10
	_1.12*_	_0.08_	_21.80*_	_−5.40*_	_0.004_	_7.93*_	_−0.06*_	_−0.26_
	83.23*	**9.56***	**48.28***	**−15.25***	**−16.36***	**88.89***	**5.41***	**−15.63***
GD 98049/CB 97033	18.10*	31.20*	228.10*	81.70	2.17	41.00*	1.44	20.10
	_−0.69*_	_3.05*_	_18.41*_	_−3.89*_	_0.10*_	_2.43*_	_0.03*_	_−0.19_
	75.90*	**28.14***	**78.79***	**−6.27***	**−7.25***	**84.68***	**11.59***	**−10.91***
Grand mean	17.00	25.40	176.90	83.90	2.14	34.50	1.46	21.50
SEd	0.33	0.35	2.04	0.60	0.02	0.74	0.02	0.26
CD (0.05)	0.66	0.70	4.06	1.19	0.04	1.47	0.04	0.52
SE	_0.33_	_0.35_	_2.01_	_0.58_	_0.01_	_0.73_	_0.01_	_0.27_

*Significant at 5% level; Values in italicised indicate specific combining ability of hybrids; Values in bold indicate standard heterosis of hybrids

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