



## Choice of parents for developing two line hybrids in rice (*Oryza sativa* L.)

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**Abstract:** An investigation was carried out to evaluate two line hybrids in rice for yield traits. Four TGMS lines and eleven testers were crossed in line x Tester design. Greater proportion of *sca* variance was observed for all the characters which revealed that preponderance of non-additive gene action governing traits concerned and selection procedures based on the accumulation of additive effects would be successful in improving these traits. The line TS09 24 and testers *viz.*, T 2006, KDML 105, Improved white ponni and BPT 5204 were found to be good combiners for the yield and yield components. The best hybrids based on *sca* value, TNAU 27S x Improved white ponni was derived from low x low combiners for thousand grain weight and TS 29 X ADT 38 for the number of filled grains per panicle spikelet fertility. The best performing hybrid TS 29 x KDML 105 produced 54.25g of grain yield per plant in 128 days which was 92.89 and 85.47 per cent increase over the standard checks CORH 3 and Improved white ponni respectively. This hybrid also recorded 27.32 and 64.30 per cent increase CORH 3 and Improved white ponni for thousand grain weight. Hence, the two line hybrid breeding system, utilizing thermo sensitive genic male sterility is economically feasible as well as viable alternative to cytoplasmic male sterile (CMS) based three line breeding due to much simplified hybrid seed production.

**Keywords:** *Oryza sativa*, TGM lines, Two line hybrids, SCA variance, Seed production

### INTRODUCTION

Hybrid rice technology is the most promising approach to break yield barriers in rice, being practically feasible and readily exploitable. As rice is a self-pollinated species, use of male sterility is essential for hybrid rice breeding and seed production (Stephen *et al.*, 2016). To cope up with the ever increasing demand for rice it should be met with quantum jump in production in fixed cultivable area. This is a daunting task, in view of plateauing trend observed in yield potential of high yielding varieties declining natural resource base (Gopikannan and Ganesh, 2013).

The discovery and application of thermo sensitive genic male sterility has great potential for revolutionizing hybrid seed production technology in rice. In the tropics TGMS is more practical to use since day length difference is marginal (Virmani and Ilyas, 2001 and Dhivyapriya *et al.*, 2015). Male sterility in temperature sensitive genic male sterile (TGMS) lines is heritable. Higher temperature (> 30 °C) results in sterility while lower temperature (< 23 °C) results in fertility. (Yuan, 1990 and Arasakesary *et al.*, 2015).

The main advantages of two line heterosis breeding include the ability to use a wide range of genotypes as male parents, absence of negative effects associated

with sterility-inducing cytoplasm and no need for maintainer lines. These two line hybrids have 5-10 per cent yield advantage over the three line hybrids (Arasakesary *et al.*, 2015). Line x Tester analysis is a powerful tool to discriminate the good as well as poor combiners for choosing appropriate parental material in successful hybrid breeding programme. However, the success of hybrid rice programme depends upon the magnitude of heterosis which also helps in the identification of potential cross combinations to be used in the conventional breeding program to create wide array of variability in the segregating generations (Aker *et al.*, 2010). The present investigation was carried out to study the combining ability in order to identify good combiners and superior hybrid combinations.

### MATERIALS AND METHODS

Four TGMS lines and eleven testers were crossed in line x Tester design. The lines used for the experiments were TNAU 27S, TS09 24, TS09 26 and TS 29. Eleven testers *viz.* CO(R) 49, ADT 38, Improved white ponni (IWP), BPT 5204, KDML 105, WGL 14, G 14, T 2006, T 972, T 360 and CB 87R and the CORH 3 and Improved white ponni were used as the standard checks. An investigation was carried out at

Paddy Breeding Station, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore with the objective of developing two line hybrids in rice using Thermo sensitive genic sterility (TGMS) lines system and estimating the extent of heterosis in these hybrids. The four TGMS lines and eleven testers were raised in a crossing block for hybridization. Three staggered sowing of parental lines were taken up at 15 days interval for the synchronization of flowering. Crossing was done in line x tester mating design. During the hybridization period, the TGMS lines were sterile under high temperature regime, when the maximum and minimum temperature was 36.2°C and 26.2°C respectively. Based on the microscopic studies of the anthers 100 per cent sterile plants were identified and labelled. The spikelets of the unopened panicles were cut to one third of its length and the TGMS lines being male sterile, are not emasculated. They were bagged with butter paper cover to avoid contamination. This process was done at the beginning of anthesis time (7.00 A.M. to 9.00 A.M). During the time of anthesis (10.00 A.M. to 11.30 A.M.), partially opened panicles were selected from the testers (pollinators) and were churned over the panicles of the lines that were bagged earlier so that the pollen grains were dusted on it. The crossed panicles were covered and labelled. Twenty five days after pollination, the crossed seeds were collected and adequately dried.

**Hybridization and production of F<sub>1</sub>:** The forty four hybrids and fifteen parents were raised during 2011 at *Kharif* season in randomized block design with two replications by adopting a spacing of 20 x 15 cm accommodating ten plants per replication. Single seedling per hill was planted.

**Biometric observations in F<sub>1</sub>s and parents:** At flowering, in each replication five competitive plants in the middle of rows were selected in each treatment at random and tag labeled. Nine biometrical observations *viz.*, days to fifty per cent flowering, plant height, number of productive tillers per plant, panicle length, number of grains per panicle, number of filled grains per panicle, spikelet fertility, thousand grain weight and grain yield per plant were recorded at the time of maturity on all tagged plants. The mean values recorded for nine characters in the parents and F<sub>1</sub> generations were used for statistical analysis. The analysis was done using the INDOSTAT statistical package (INDOSTAT services, Hyderabad). Analysis of variance of four lines, eleven testers and forty four hybrids were carried out for the quantitative characters following the procedure outlined by Panse and Sukhatme (1964). The combining ability analysis was done by using Line x Tester mating design as described by Kempthorne (1957). The performance of F<sub>1</sub> hybrids was evaluated on the basis of heterosis estimates (Fonseca and Patterson, 1968). Significance of heterosis was tested using the formula given by Snedecor and

Cochran (1967).

## RESULTS AND DISCUSSION

**Analysis of variance:** In the estimate of variances, the mean squares due to lines, testers, hybrids, line x tester in interactions and general and specific combining ability variances are presented in Table 1. The lines and the testers showed higher positively significant differences for all the characters studied. In genetic analysis, it is presumed that *gca* and *sca* reflect additive gene action and the non additive gene action respectively. In the present study, greater proportion of *sca* variance was observed for all the characters which revealed that preponderance of non-additive gene action governing the traits concerned and selection procedures based on the accumulation of additive effects would be successful in improving these traits. This is in accordance with findings of Utharasu and Anandakumar (2013) for days to fifty per cent flowering, plant height, number of productive tillers per plant, panicle length, number of grains per panicle, spikelet fertility, hundred grain weight and grain yield per plant. Dhivyapriya and Kalaiyarasi (2014) recorded higher *sca* for the characters *viz.*, days to fifty per cent flowering, plant height, number of productive tillers per plant, panicle length, number of grains per panicle, number of filled grains per panicle, spikelet fertility, thousand grain weight and grain yield per plant and Sasikala *et al.* (2015) for days to fifty per cent flowering, plant height, number of productive tillers, panicle length, number of spikelets per panicle, number of filled spikelets per panicle, spikelet fertility percentage, 1000 grain weight and single plant yield.

**Per se performance:** The mean performances of parents are presented in Table 2. High mean value remains as the main selection index in the choice of parents. Gilbert (1958) pointed out that the parents with high *per se* performance will result in superior hybrids. Among the lines, TNAU 27S exhibited significantly high *per se* performance for maximum six characters *viz.*, plant height (negative direction), number of productive tillers, panicle length, spikelet fertility, thousand grain weight and the grain yield per plant. Among the testers, T 972 exhibited high *per se* performance for the characters *viz.*, days to fifty per cent flowering (negative direction), spikelet fertility and thousand grain weight. Hence these parents can be utilized in hybrid breeding programmes. The general and specific combining ability effects of the parents and the hybrids are presented in the Tables 3 and 4.

**gca effects:** Dhillon (1975) pointed out that combining ability of parents gives useful information on the choice of parents in terms of expected performance of their progenies in maize. Among the lines TS09 24 was found to be good combiner for the panicle length, number of grains per panicle, number of filled grains

**Table 1.** Analysis of variance for combining ability for different traits in rice.

Source of variation	Degrees of freedom	Mean squares									
		Days to 50% flowering	Plant height	Number of productive fillers	Panicle length	Number of grains / panicle	Number of filled grains / panicle	Spikelet fertility	1000 grain weight	Grain yield per plant	
Replication	1	3.284	11.019	27.832	4.682	231.725	173.349	3.508	0.007	216.565	
Hybrids	43	90.998**	527.947**	29.146**	5.769**	3372.617**	2202.782**	154.454**	26.261**	157.973**	
Lines	3	201.011**	40.3363**	91.0948**	5.6137**	18047.960**	14367.560**	387.473**	62.901**	158.397**	
Testers	10	21.531**	1639.151*	27.251**	12.198**	4142.751**	2132.580**	142.706**	33.458**	259.634**	
L X T	30	69.8197**	206.307**	23.583**	3.641**	1648.371**	1009.705**	135.069**	20.199**	24.044**	
Error	43	0.237	6.540	2.474	0.939	284.994	294.373	30.088	0.745	15.911	
$\sigma^2 GCA$		0.479	7.286	0.126	0.048	39.063	27.029	0.439	0.137	0.769	
$\sigma^2 SCA$		34.791	99.883	10.554	1.351	681.688	357.665	52.490	9.727	54.066	
$\sigma^2 GCA / SCA$		0.013	0.073	0.012	0.036	0.058	0.076	0.008	0.014	0.014	

\*, \*\* Significant at 5 % and 1 % levels of probability respectively

**Table 2.** *Per se* performance of parents in rice.

Characters Parents	Days to 50% flowering	Plant height (cm)	Plant height	Number of productive fillers	Panicle length (cm)	Panicle length	Number of grains / panicle	Number of filled grains / panicle	Spikelet fertility (%)	1000 grain weight (g)	Grain yield per plant (g)
<b>Lines</b>											
TNAU 27S	84.00	65.40	65.40	29.00	22.36	22.36	106.17	156.00	145.33	18.48	27.25
TS09 24	97.00	93.17	93.17	18.50	21.10	21.10	216.33	162.83	74.82	17.70	22.50
TS09 26	105.00	91.92	91.92	15.50	21.17	21.17	184.00	115.00	65.91	17.05	19.38
TS 29	79.50	94.83	94.83	16.33	20.92	20.92	215.00	153.67	70.43	17.90	21.25
<b>Testers</b>											
CO(R) 49	105.00	88.25	88.25	10.34	22.35	22.35	189.67	106.00	56.64	16.27	19.66
ADT 38	105.00	88.42	88.42	15.66	22.23	22.23	153.17	100.00	65.47	18.10	25.17
Improved white ponnai	107.50	105.58	105.58	14.50	23.57	23.57	197.00	154.17	76.76	16.92	29.25
BPT 5204	105.00	73.25	73.25	11.00	23.97	23.97	143.33	111.67	79.76	18.70	24.75
KDML 105	104.00	122.33	122.33	14.84	23.88	23.88	169.17	111.00	66.07	22.10	35.14
WGL 14	105.00	90.50	90.50	9.33	23.95	23.95	189.50	149.50	78.92	15.90	37.33
G 14	102.00	103.67	103.67	13.16	24.23	24.23	123.75	104.00	84.12	23.15	28.25
T 2006	89.00	115.75	115.75	12.50	24.95	24.95	174.75	114.25	65.85	21.45	24.5
T 972	89.00	134.74	134.74	11.00	23.35	23.35	140.83	128.00	91.05	25.98	24.63
T 360	94.00	72.00	72.00	12.50	24.55	24.55	119.00	91.17	77.01	24.48	26.38
CB 87R	87.50	85.42	85.42	11.00	23.02	23.02	130.83	98.83	75.90	22.25	24.25

Table 3. *gca* effects of lines and testers in rice.

Characters / lines & testers	Days to 50% flowering	Plant height	Number of productive tillers	Panicle length	Number of grains / panicle	Number of filled grains / panicle	Spikelet fertility	1000 grain weight	Grain yield per plant
<b>Lines</b>									
TNAU 27S	-0.97**	1.25*	2.94**	0.3	-31.55**	-23.39**	2.07	-0.24	-0.44
TS09 24	-1.51**	0.16	-0.55	0.54*	36.68**	36.40**	4.02**	-0.66**	-3.46**
TS09 26	4.49**	0.50	-0.64	-0.30	4.77	-5.40	-5.68**	-1.51**	2.9**
TS 29	-2.01**	-1.91**	-1.75**	-0.54*	-9.89**	-7.61*	-0.41	2.41**	1.00
<b>Testers</b>									
CO(R) 49	-0.10	-9.71**	-2.85**	-1.66**	-14.26*	-12.34*	-0.08	-1.88**	-7.41**
ADT 38	0.08	-7.01**	-2.47**	0.52	-7.28	-12.65*	-4.47*	-0.85**	0.84
IWP	8.83**	13.36**	2.41**	0.48	8.50	6.55	-0.78	0.15*	6.04**
BPT 5204	3.95**	-15.91**	-0.16	-1.67**	27.7**	21.57**	-0.28	-1.23**	-2.53
KDML 105	1.95**	22.93**	1.53**	2.31**	8.80	0.57	-3.88	2.33**	10.19**
WGL 14	-0.55**	-12.47**	0.32	-0.68	39.49**	15.68*	-7.53**	-2.58**	-8.22**
G 14	-4.3**	2.68**	1.03	0.20	6.68	10.45	2.39	0.25	3.06*
T 2006	-5.05**	12.29**	2.32**	1.41**	-3.30	6.43	4.71*	-0.63*	4.71**
T 972	-1.92**	18.08**	-0.64	0.32	-2.65	5.20	4.81*	4.53**	-2.31
T 360	-2.55**	-9.5**	0.61	-0.09	-45.11**	-37.49**	-0.75	-1.25**	-0.19
CB 87R	-0.30**	-14.73**	-2.09**	-1.1**	-18.63**	-3.97	5.85**	1.18**	-4.2**

per panicle and the spikelet fertility, while TNAU 27S showed *gca* effects for productive tillers and days to fifty per cent flowering. The line TS 29 showed higher negatively significant *gca* effect for days to fifty per cent flowering and higher positive significant for thousand grain weight. Among the testers, T 2006 was the good combiners for the number of productive tillers per plant, panicle length, spikelet fertility, grain yield per plant and (negative direction); KDML 105 for the characters panicle length, and the grain yield per plant; BPT 5204 for the number of grains per panicle, number of the filled grains per panicle and plant height (negative direction); CB 87R for the plant height (negative direction) and days to fifty per cent flowering. The tester Improved white ponni was the good combiner for the number of productive tillers, thousand grain weight and grain yield per plant. The *gca* effect is generally associated with additive gene action in the inheritance of a particular character.

Hence line TS09 24 and testers *viz.*, T 2006, KDML 105, Improved white ponni and BPT 5204 were found to be good general combiners for the yield and yield components and also can be used as potential donors for improvement of yield potential or yield with early maturity in rice as suggested by Singh *et al.* (2013), Dhivyapriya and Kalaiyarasi (2014) and Sasikala *et al.* (2015).

***sca* effects:** The *sca* effect is an index to determine the usefulness of a particular cross combination (Peng and Virmani, 1990). Among the hybrids, TNAU 27S x KDML 105 showed higher *sca* effects for days to fifty per cent flowering, number of productive tillers and panicle length. The hybrid, TNAU 27S x Improved white ponni had shown highly positive significant *sca* effects for three characters *viz.*, panicle length, spikelet fertility and grain yield per plant. The hybrid, TS09 24 x T 2006 had higher negative *sca* effects for days to fifty per cent flowering and had higher positive *sca* effects for number of productive tillers; TS 29 x BPT 5204 for the number of grains per panicle and number of filled grains per panicle; TS09 24 x Improved white ponni reported highly positive significant for the spikelet fertility and the grain yield per plant. Hence these hybrids were found to have specific combiners for most of the yield and yield component traits.

The hybrids *viz.*, TNAU 27S x Improved white ponni, TNAU 27S x T 2006 and TS09 26 x CB 87R involved low x high combiners and this may be due to interaction between dominant alleles from the good combiner and recessive alleles from the poor combiners (Hasan *et al.* 2013). The hybrid, TS09 26 x T2006 involved both the parents, which were good combiners. This would involve interaction between positive x positive alleles and are fixable in subsequent generation in rice. Kalitha and Upadhaya (2000), Shivani *et al.* (2009) and Salgotra *et al.* (2009) also reported about interaction between positive and positive alleles in crosses

Table 4. *sca* effects of hybrids for yield components in rice.

Hybrids	Days to fifty per-cent flowering	Plant height	Number of productive tillers	Panicle length	Number of grains/ panicle	Number of filled rains/ panicle	Spikelet fertility	1000 grain weight	Grain yield/ plant
TNAU27S/ CO(R)49	-0.28	-7.12**	1.14	0.79	-14.95	-3.52	5.21	2.73**	3.02
TNAU 27S/ ADT 38	5.47**	-10.97**	-6.90**	-3.01**	0.07	-9.04	-7.90*	-4.95**	-11.97**
TNAU27S/IWP	7.22**	11.14**	3.06**	2.78**	26.11*	13.08	-5.38	1.74**	13.5**
TNAU27S/BPT 5204	2.09**	-4.01*	6.54**	0.95	19.59	2.89	-8.23*	0.18	-2.72
TNAU27S/KDML 105	-7.41**	5.57**	0.60	0.71	21.30	16.56	-1.83	0.92	3.93
TNAU27S/WGL 14	0.59	-0.69	2.64*	2.12**	11.30	-1.04	-7.25	1.78**	3.47
TNAU27S/G14	3.84**	25.91**	-2.9*	-1.21	-26.14*	-12.98	6.03	1.1	7.06*
TNAU27S/ T2006	-0.91*	-6.89**	-3.02**	-0.99	6.09	15.71	6.35	-0.62	-9.00**
TNAU27S/T972	-5.03**	6.08**	-0.07	-1.01	-42.22**	-24.40*	9.23*	-2.50**	-0.39
TNAU27S/T360	-3.91**	-14.25**	-1.98	-0.78	-13.09	-1.71	7.31	0.94	-3.56
TNAU27S/CB87R	-1.66**	-4.77*	0.89	-0.35	11.93	4.44	-3.53	-1.33*	-3.34
TS09 24/ CO(R) 49	-2.24**	4.22*	1.47	-0.47	66.15**	36.02**	-8.60*	-1.22	8.56**
TS0924/ ADT 38	-2.49**	-1.40	0.09	1.50*	22.10	-2.42	-8.82*	0.86	-1.69
TS09 24/IWP	-5.74**	5.85**	2.22	-1.28	-3.45	17.62	8.48*	1.21	4.11
TS09 24/BPT 5204	0.64**	5.48**	-0.39	-0.41	-27.8*	0.77	14.33**	-1.50*	9.18**
TS0924/KDML 105	-1.36**	4.52*	-2.07	-0.08	-48.59**	-59.23**	-10.25*	0.93	-12.27**
TS0924/WGL 14	0.64	2.06	-0.70	-0.23	9.57	12.83	4.84	-0.90*	0.12
TS0924/G14	-0.11	5.25**	-1.24	0.45	-8.61	7.39	4.83	1.76	1.84
TS0924/ T2006	-1.36**	-9.93**	3.80**	0.28	-33.3**	-22.09	1.86	1.45*	-1.06
TS0924/T972	0.51	-9.46**	0.76	1.54*	24.47*	20.73	-1.39	-2.97**	-4.71
TS0924/T360	6.14**	1.24	-1.99	-0.48	31.51*	8.16	-8.76*	2.56**	-2.54
TS0924/CB87R	5.39**	3.89*	-1.95	-0.81	-32.05**	-19.77	3.49	-1.17	-1.53
TS09 26/ CO(R) 49	1.76**	2.20	-2.78*	-0.08	-29.27*	-25.52*	-3.83	-2.80**	-6.31*
TS0926/ ADT 38	-0.99**	4.60*	4.35**	0.14	-26.25*	-14.71	2.96	2.10**	5.56
TS09 26/IWP	-9.74**	-9.10**	-2.52*	-1.19	8.71	-8.58	-6.56	-0.39	-8.51**
TS09 26/BPT 5204	-5.86**	-1.50	-3.63**	0.41	-26.22*	-23.77	-1.33	3.10**	-0.19
TS0926/KDML 105	1.64**	-8.06**	-0.32	-1.12	22.15	26.40*	5.54	-1.57*	-2.16
TS0926/WGL 14	10.14**	-3.69*	0.89	-1.79*	0.48	8.04	4.79	2.15**	-3.50
TS0926/G14	6.39**	-5.06**	-3.32**	1.37	13.30	13.02	1.45	2.05**	-0.28
TS0926/ T2006	-0.86*	7.80**	2.39*	-0.10	17.77	10.29	-1.61	2.05**	6.82*
TS0926/T972	-2.49**	-0.94	-0.48	0.59	-0.37	-19.48	-11.06**	-4.57**	-7.40*
TS0926/T360	1.14**	3.68*	4.93**	-0.05	-4.41	11.12	7.49	-1.19	7.22*
TS0926/CB87R	-1.11**	10.07**	0.48	1.83*	24.11*	23.19	2.16	-0.92	8.73**
TS 29/ CO(R) 49	0.76**	0.71	0.17	-0.24	-21.94	-6.97	7.21	1.29*	-5.27
TS 29/ ADT 38	-1.99**	7.76**	2.45*	1.38*	4.08	26.17*	13.77**	1.99**	8.10**
TS 29/IWP	8.26**	3.81*	-2.75*	-0.31	-31.38*	-22.12	3.46	-2.56**	-9.10**
TS 29/BPT 5204	3.14**	0.03	-2.52*	-0.95	34.43**	20.11	-4.76	-1.77**	-6.28*
TS 29/KDML 105	7.14**	-2.02	1.79	0.49	5.14	16.27	6.54	-0.29	10.50**
TS 29/WGL 14	-11.36**	2.32	-2.84*	-0.10	-21.36	-19.83	-2.37	-3.02**	-0.09
TS 29/G14	-10.11**	-26.11**	7.46**	-0.60	21.45	-7.43	-12.31**	-3.91**	-8.62**
TS 29/ T2006	3.14**	9.01**	-3.17**	0.81	9.43	-3.91	-6.61	-2.87**	3.23
TS 29/T972	7.01**	4.33*	-0.21	-1.12	18.12	23.15	3.22	10.04**	12.51**
TS 29/T360	-3.36**	9.33**	-0.96	1.31	-14.00	-17.58	-6.04	-2.31**	-1.12
TS 29/CB87R	-2.61**	-9.19**	0.58	-0.67	-3.98	-7.85	-2.12	3.41**	-3.86

\*, \*\* Significant at 5 % and 1 % levels of probability respectively

**Table 4.** Standard heterosis for yield and yield component traits in rice.

Hybrids	Days to fifty percent flowering	Plant height	Number of productive tillers	Panicle length	Number of grains/panicle	Number of filled grains/ panicle	Spikelet fertility	1000 grain weight	Grain yield/plant
TNAU27S/ CO(R)49	6.55**	9.04**	-15.65	7.31	-15.71	21.57	43.60**	9.69*	-1.39
TNAU 27S/ ADT 38	13.69**	7.65*	-55.65**	-0.07	-0.57	14.89	14.83	-20.77**	-25.33
TNAU27S/IWP	26.19**	59.22**	21.76*	26.11**	28.21*	62.22**	25.03**	14.5**	83.7**
TNAU27S/BPT 5204	14.29**	5.30	26.53**	7.99	36.93**	67.75**	21.16*	0.98	-4.44
TNAU27S/KDML 105	0.60**	64.07**	4.36	25.06**	25.11*	59.36**	25.77**	20.68**	64.44**
TNAU27S/WGL 14	7.14**	13.49**	8.71	17.82**	39.33**	56.50**	10.86	2.13	-2.67
TNAU27S/G14	6.55**	64.17**	-16.51	6.69	-9.00	36.84	48.99**	11.98**	50.22**
TNAU27S/ T2006	0.50	36.03**	-10.44	13.2**	6.31	65.09**	53.34**	0.07	-1.03
TNAU27S/T972	-1.19	58.80**	-10.44	8.13	-26.49*	17.75	58.24**	15.07**	4.60
TNAU27S/T360	-0.60	0.64	-13.91	7.35	-35.67**	-5.15	45.93**	4.42	0.89
TNAU27S/CB87R	4.76**	5.81	-13.04	4.62	-0.23	40.27*	38.97**	5.11	-12.59
TS09 24/ CO(R)49	3.57**	21.48**	-32.17**	2.66	87.04**	135.31**	24.09**	-10.3*	7.56
TS0924/ ADT 38	3.57**	17.94**	-37.39**	21.56**	61.52**	90.94**	16.51	3.96	0.44
TS09 24/IWP	10.12**	37.26**	-0.86	8.72	54.81**	135.80**	51.00**	10.14*	39.56**
TS09 24/BPT 5204	11.9**	15.49**	-27.84**	2.89	51.26**	133.79**	61.42**	-8.63*	27.11
TS0924/KDML 105	7.14**	61.47**	-27.81**	22.54**	23.97*	41.03*	15.12	18.85**	-3.91
TS0924/WGL 14	6.55**	15.51**	-26.95**	8.22	85.09**	140.85**	33.92**	-12.07**	-25.33
TS0924/G14	1.19**	37.77**	-26.09**	15.32**	50.00**	128.63**	50.22**	8.54*	20.89
TS0924/ T2006	-1.19**	31.01**	6.97	20.05**	26.15	90.27**	49.15**	7.63	16.44
TS0924/T972	4.76**	38.62**	-24.34**	20.81**	66.34	137.89**	43.97**	11.06**	-21.51
TS0924/T360	10.71**	18.13**	-32.17**	9.79*	41.97	74.62**	22.72*	9.92*	-6.22
TS0924/CB87R	12.5**	14.99**	-46.07**	3.57	16.46	81.02**	53.70**	3.96	-16.89
TS09 26/ CO(R)49	15.48**	19.44**	-54.79**	0.61	-0.57	16.99	16.00	-21.46**	-22.67
TS0926/ ADT 38	12.5**	25.63**	-15.63	11.54*	6.31	29.02	19.93*	5.72	48.89**
TS09 26/IWP	12.5**	33.72**	-26.06**	5.33	41.23**	58.02**	10.36	-1.08	17.33
TS09 26/BPT 5204	11.31**	7.42*	-45.21**	2.82	30.39*	57.83**	19.77*	8.54*	16.44
TS0926/KDML 105	17.86**	46.6**	-19.12*	13.98**	50.69**	91.23**	25.14**	3.50	54.67**
TS0926/WGL 14	25.00**	8.94**	-19.12*	-2.73	56.88**	87.51**	17.91	-1.99	-15.56
TS0926/G14	16.07**	25.67**	-37.39**	15.71**	43.12**	87.22**	28.73**	10.58**	36.00*
TS0926/ T2006	6.55**	52.94**	-0.86	14.5**	39.33**	79.49**	27.52**	6.48	67.11**
TS0926/T972	8.33**	49.36**	-31.28**	12.68**	27.29*	43.99*	12.16	-0.16	-8.44
TS0926/T360	11.9**	21.48**	3.47	7.90	-4.70	30.16	33.49**	-11.15**	51.11**
TS0926/CB87R	11.9**	22.9**	-33.89**	11.77*	33.14**	82.35**	35.58**	1.21	42.22**
TS 29/ CO (R)49	6.55**	14.71**	-45.21**	-1.21	-5.62	35.69	42.8**	15.25**	-25.78
TS 29/ ADT 38	3.57**	26.54**	-31.31**	16.09**	17.08	73.29**	46.36**	23.2**	51.11**
TS 29/IWP	26.19**	46.47**	-33.03**	8.19	3.55	39.99*	35.48**	6.94	8.44
TS 29/BPT 5204	14.29**	6.36*	-45.21**	-4.46	62.04**	105.54**	22.78*	4.19	-12
TS 29/KDML 105	16.67**	51.02**	-13.91	20.19**	28.90*	71.1**	35.44**	27.32**	92.89**
TS 29/WGL 14	-8.33**	13.31**	-44.35**	3.89	31.76**	53.06**	14.80	-7.72	-10.22
TS 29/G14	-11.31**	-2.80	13.04	5.62	38.65**	61.26**	14.78	1.21	-0.44
TS 29/ T2006	3.57**	51.48**	-35.66**	17.53**	23.51*	60.69**	27.96**	1.90	47.56**
TS 29/T972	11.9**	52.84**	-35.64**	3.80	29.93*	90.27**	44.27**	84.66**	55.56**
TS 29/T360	-1.19	25.43**	-33.06**	13.00**	-21.39	-5.24	19.91*	1.67	14.67
TS 29/CB87R	2.38**	-3.4	-39.11**	-0.68	3.73	44.28	37.21**	39.00**	-9.33

\*, \*\* Significant at 5 % and 1 % levels of probability respectively

involving high × high combiners which can be fixed in subsequent generations if no repulsion phase linkages are involved. In other hybrids, the parental combinations had either medium × medium or low × medium *gca* effects indicating a complementary gene action leading to superior F<sub>1</sub> hybrids.

The best hybrids based on *sca* value, TNAU 27S × Improved white ponni was derived from low × low combiners for thousand grain weight and TS 29 × ADT 38 for the number of filled grains per panicle spikelet fertility. This may be due to the non-additive gene action such as epistasis (Hasan *et al.*, 2013). Therefore no relationship could be established between *gca* effects of parents and *sca* effects of hybrids since some minor gene effects may also deviate the expected results. These cross combinations can be used for exploitation of heterosis in further hybrid breeding programme.

**Heterotic vigour of hybrids:** The estimates of heterosis based on standard checks are given in Table 5. Negative heterosis for days to fifty per cent flowering and plant height is a desirable trait as it confers earliness and resistance to lodging respectively. TNAU 27S × Improved white ponni recorded highly positive heterosis for grain yield per plant, number of grains per panicle, panicle length, number of filled grains per panicle, thousand grain weight, days to fifty per cent flowering (negative direction), plant height (negative direction) and spikelet fertility. The hybrid, TS 29 × KDML 105 showed highly negative significant standard heterosis for plant height and days to fifty per cent flowering and highly positive significant heterosis for grain yield per plant, number of grains per panicle, thousand grain weight, panicle length, spikelet fertility, and number of filled grains per panicle; The cross combination, TS09 26 × T 2006 had shown higher positive standard heterosis for grain yield per plant, number of grains per panicle, panicle length, plant height, number of filled grains per panicle, spikelet fertility and days to fifty per cent flowering (negative heterosis); TNAU 27S × KDML 105 had exhibited highly positive significant heterosis for grain yield per plant, number of grains per panicle, plant height, panicle length, spikelet fertility, days to fifty per cent flowering (negative heterosis), number of filled grains per panicle and thousand grain weight. Hence, the above said hybrids are highly suitable for commercial exploitation of heterosis. This is in accordance with findings of Dhivyapriya and Kalaiyarasi (2014) for days to 50 percent flowering (negative heterosis), plant height (negative heterosis), number of productive tillers, number of grains per panicle and thousand grain weight and Sasikala *et al.* (2015) for 50 percent flowering (negative heterosis), number of spikelets per panicle, number of filled spikelets per panicle and thousand grain weight.

## Conclusion

The best performing hybrid TS 29 × KDML 105 produced 54.25g of grain yield per plant in 128 days which was 92.89 and 85.47 per cent increase over the standard checks CORH 3 and Improved white ponni respectively. This hybrid also recorded 27.32 and 64.30 per cent increase CORH 3 and Improved white ponni for thousand grain weight. This was followed by TNAU 27S × Improved white ponni, TS09 26 × T 2006 and TNAU 27S × KDML105. These hybrids can be utilized for commercial exploitation since they recorded at least 10 per cent more grain yield than standard checks CORH 3 and Improved white ponni. Many scientists have advocated that two line hybrids have 5-10 per cent of yield advantage over three line hybrids can be released for cultivation, as three line hybrids have their own limitations. Breeders are looking for less complex and more efficient system of hybrid breeding which will attract large scale adoption of the technology by the farmers. Since two line hybrids have many advantages, the hybrids with on par performance to three line hybrids could also be recommended for commercial cultivation.

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