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Genetic Effects and Combining Ability for Yield and its Component Traits in Rice (Oryza sativa L.) Using Line X Tester

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Abstract: ***Combining ability analysis for yield and yield components in some important rice germplasm through Line X Tester analysis of 28 cross developed crossing 7 lines and 4 Testers. The variance due to sca were higher than the corresponding gca variance for ten characters as days to fifty percent flowering, plant height at maturity, number of productive tillers per plant, number of grain per panicle, panicle length, 100 grain weight, grain yield per plant, kernel length, kernel breadth, kernel length x breadth. Among the lines, based on mean performance studied ADT 41, ADT 45 and ADT 47 was adjudged as superior parents for grain yield per plant and most of the corresponding characters in testers ADT 36 and CO 51 were recorded high for grain yield and some of the characters. Among the hybrids ADT 41 × ADT 36, ADT 47 × ADT 36, ADT 41 × CO 51 and ADT 45 × ADT 36 were identified as best one since it had desirable per se performance for all the ten characters studied. The combining ability variance revealed the predominance of additive gene action for all the characters studied.***

Keywords: Combining ability, Line X Tester, Per se

1. Introduction

Rice is a most important food crop and most extensively grown cereal crop in tropical and sub tropical regions of the world. Rice (Oryza sativa L.) is a self pollinated cereal crop. It belongs to the family Poaceae with the chromosome number 2n=24. The worldwide production of rice grain is 483.9 million metric tonnes. The total consumption of milled rice in the world is 477.77 million metric tonnes (www.statista.com/2018). The production of rice in India is 1091.49 lakh million tones and in Tamil Nadu the production of rice in rabi season is 40.92 lakh million tones cultivated area is 2792 hectare (Indiastat 2017). The current levels of rice production do not meet the future demand. The world population has been projected at 8.27 billion by 2030, demanding an increased rice production of 771 million tonnes (Badawi, 2004). But it is highly impossible to increase the area under production as it has already attained the saturation level. Hence, it is imperative to increase the productivity of the crop.

This could be achieved through crop improvement strategies. Genetic manipulation is the only means of achieving this goal. Combining ability studies is one such technology to select the superior genotypes. It helps in identifying the best combiners that may be used in crosses either to exploit heterosis or to accumulate fixable genes and obtain desirable segregants. It helps to understand the genetic architecture of various characters that enables the breeder to design effective breeding plan for future up gradation of the existing materials. Line × Tester (Kempthorne 1956) matting design is one such technology which provides reliable information to study the combining ability of genotype.

2. Materials and Methods

The present study was carried out at the Plant Breeding Farm, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India during the year 2016-2018. The biological materials used for this study comprised of eleven genotypes, out of which eight genotypes were used as lines and four genotypes were used as testers. The details of the parental materials are presented in the Table 1.

Seven lines and four testers were crossed in a line x tester mating design resulting in twenty eight hybrids. Unpaired sowing of parents was taken up during Late Samba (March-May 2017) season. The seeds were sown in raised nursery beds at fifteen days interval for synchronizing in flowering. The experimental materials consisted of twenty eight hybrids with their eleven parents were transplanted in rows with spacing of 30 cm between rows and 20 cm between plants during Samba (July - October 2017). Twenty one days old seedlings were transplanted and one seedling per hill was maintained. The row length of 3 m was maintained for each genotype. The experiment was laid out in a randomized block design with three replications. Recommended cultural practices and need based plant protection measures were also adopted to raise the crop.

3. Observations Recorded

In this present study the observations recorded are days to fifty percent flowering, plant height at maturity, number of productive tillers per plant, number of grain per panicle, panicle length, 100 grain weight, grain yield per plant, kernel length, kernel breadth, kernel length x breadth.

Table 1: List of Parents used in the Study

S. No	Parents	Parentage	Origin
Lines			
L1	ADT-37	BG 280-12 X PTB 33	Tamil Nadu Rice Research Institute (TRRI), Aduthurai
L2	ADT-41	Mutant of Basmati 378	Tamil Nadu Rice Research Institute (TRRI), Aduthurai
L3	ADT-42	AD 9246 X ADT 29	Tamil Nadu Rice Research

			Institute (TRRI), Aduthurai
L4	ADT-45	IR 50 X ADT 37	Tamil Nadu Rice Research Institute (TRRI), Aduthurai
L5	ADT-47	ADT 43 X Jeera ga samba	Tamil Nadu Rice Research Institute (TRRI), Aduthurai
L6	ADT-48	IET 11412 X IR 64	Tamil Nadu Rice Research Institute (TRRI), Aduthurai
L7	ADT-43	IR 50 X White Ponni	Tamil Nadu Rice Research Institute (TRRI), Aduthurai
Testers			
T1	IR-50	IR 2153-14 X IR 28 X IR 36	International Rice Research Institute (IRRI), Philippines
T2	CO-51	ADT 43 / RR 272 – 1745	Tamil Nadu Agriculture university (TNAU), Coimbatore.
T3	ADT-36	Triveni X IR 20	Tamil Nadu Rice Research Institute (TRRI), Aduthurai
T4	TKM-9	TKM 7 X IR 8	International Rice Research Institute (IRRI), Philippines

4. Results and Discussion

The analysis of variance revealed significant differences among the parents for all the ten characters studied. The mean sum of squares due to general combining ability and specific combining ability for all the characters were also significant is represented in Table 2.

The analysis of variance indicated that there were significant differences among the crosses for the traits viz., days to 50 per cent flowering, plant height at maturity, number of productive tillers per plant, panicle length (cm), number of grains per panicle, 100 grain weight (gm), grain yield per plant (gm), kernel length (mm), kernel breadth (mm) and kernel length × breadth. The partitioning of variance due to crosses into its components revealed that there were differences among crosses due to lines (females) for days to 50 per cent flowering, plant height at maturity, 100 grain weight (gm), grain yield per plant (gm), kernel length (mm), kernel breadth (mm) and kernel length × breadth recorded significant values. The differences due to testers (males) were also significant for grain yield per plant, kernel length, kernel breadth and kernel length × breadth. The interaction between lines and testers was significant for days to 50 per cent flowering, plant height at maturity, number of productive tillers per plant, panicle length, number of grains per panicle, hundred grain weight, grain yield per plant kernel length, kernel breadth and kernel length × breadth. This showed both general and specific combining ability variances were important for the traits that showed significant differences. A perusal of estimates of combining ability variances revealed that specific combining ability variance was predominant for days to 50 per cent flowering, plant height at maturity, number of productive tillers per plant, panicle length, number of grains per panicle, hundred grain weight, grain yield per plant kernel length, kernel breadth and kernel length × breadth. The nature of genetic variance could be revealed by estimates of additive and dominance variance components. Relative importance of additive and dominance variance based on absolute quantities revealed the predominance of non-additive variance than additive variance for all the characters studied. These results were in agreement with the studies of Rukumini devi et al (2018) Thirumalai et al (2017) Gayathri (2015) in rice.

Among the lines studied, ADT 41 recorded the highest mean value for the traits viz., days to 50% flowering, plant height at maturity, panicle length, hundred grain weight, grain yield per plant and kernel length. Also, genotype ADT 41 registered the high grain yield per plant. The line, ADT 45 also had significant high mean for days to 50% flowering, plant height, number of productive tiller per plant, panicle length, number of grains per panicle, 100 grain weight, grain yield, kernel length, kernel breadth and kernel length × breadth characters. This genotype recorded significantly high mean value for number of productive tillers per plant.

Among the testers, ADT 36 recorded high per se performance for the all the traits viz., days to 50% flowering, plant height at maturity, number of productive tiller per plant, panicle length, number of grains per panicle, 100 grain weight, grain yield, kernel length, kernel breadth and kernel length × breadth. The tester, CO 51 recorded significant and showed lower plant height among all the testers. Thus, based on the per se performance the lines, ADT 41, ADT 45 and ADT 47 and the testers ADT 36 and CO 51 have been estimated as superior parents and they might be useful for the incorporation of the respective traits in hybridization programme.

Combining ability is one of the important parameters commonly used by plant breeders to evaluate the genetic potential of the materials handled. Dhillon (1975) pointed out that the combining ability gives useful information on the choice of parents. Singh and Nanda (1976) suggested to select at least one parent with high gca effect as a selection index for parental evaluation. The gca effect is considered as intrinsic genetic value of the parent for a trait which is due to gene additive effect and it is fixable (Simmonds, 1979). The gca effects of parents has been attributed to additive gene action where selection would be very efficient because additive gene effects are readily transmitted from one generation to another (Gravois and Mc New, 1993). Therefore, it is better to choose parents possessing significant gca effects for hybridization rather than parents with low gca effects or merely based on mean performance.

In the present investigation, the gca effects of the lines indicated that the line ADT-43 was positive and significant for all the yield attributing characters viz., number of number of productive tillers per plant, panicle length, number of grains per panicle, 100 grain weight, grain yield per plant, kernel length, kernel breadth and kernel length × breadth with negative significant gca effect for days to 50 per cent flowering and plant height at maturity. The line ADT 45 also had significant and positive gca effects for the traits viz., number of productive tillers per plant, panicle length, number of grains per panicle, 100 grain weight, grain yield per plant, kernel length, kernel breadth and kernel length × breadth with negative significant gca effects for days to 50 per cent flowering and plant height at maturity. The line, ADT 47 had significant and positive gca effects for the traits namely, number of grains per panicle,100 grain weight and grain yield per plant with negative significant gca effects for days to 50 per cent flowering and plant height at maturity.

Among the testers, ADT 36 possessed desirable gca effects for all the yield attributing characters ., number of number of productive tillers per plant, panicle length, number of grains per panicle, hundred grain weight, grain yield per plant, kernel length, kernel breadth and kernel length × breadth and negative significant for days to 50 per cent flowering and plant height at maturity. The above results indicated that different parents recorded significant gca results for different traits. Based on the gca effects recorded, among the lines, ADT 41, ADT 45 and ADT 47 in the testers, ADT 36 could be found suitable in hybridization programme for subsequent improvement in grain yield.

The mean performance is the primary principle for evaluation of a hybrid. Nadarajan (1986) and Ramalingam et al. (1993) indicated the per se performance as a useful index to evaluate the hybrids. In the present learning, the hybrid ADT 41 × ADT 36 rated as the best for all the nine traits viz., number of productive tillers per plant, panicle length, hundred grain weight, grain yield per plant, kernel length, kernel breadth and kernel length × breadth. This cross also recorded high significant mean values for less number of days to 50 per cent flowering with short tallness plant except number of grains per panicle is not significant. The next best cross combination ADT 47 × ADT 36 had high significant mean values for number of productive tillers per plant, number of grains per panicle, hundred grain weight, grain yield per plant, kernel length, kernel breadth and kernel length × breadth. This cross also recorded high significant mean values for less number of days to 50 per cent flowering with short height plant except panicle length is not significant in this cross. Apart from this, the cross, ADT 41 x CO 51 recorded significantly high mean values for number of productive tillers per plant, panicle length, number of grains per panicle, grain yield per plant, kernel length, kernel breadth and kernel length × breadth in this hybrid hundred grain weight recorded as non-significant traits. This cross also recorded high significant mean values for less number of days to 50 per cent flowering with short height plant. This cross showed superior performance for the plant height and days to 50 per cent flowering. The other hybrid, ADT 45 × ADT 36 also had significantly high mean values for almost all the yield attributing characters but not in the plant height and recorded as the superior performer for panicle length. These hybrids showed best performance, resulted from the combination in which both the parents of a cross had higher mean values when compared to others for most of the traits studied.

As suggested by Savery (1998) in rice, the above hybrid combinations had combined all the desirable parents with high mean performance and it is concluded that the superiority of the hybrids were dependent on the parents selected based on per se performance.

The specific combining ability is the variation from the performance predicted on the basis of gca (Allard, 1960). According to Sprague and Tatum (1942), the specific combining ability is controlled by non-additive gene action. The specific combining ability of any cross is helpful in predicting the performance of a particular hybrid in relation to the gca of its parents (Peng and Virmani, 1990). Hence, the sca effect is an important criterion for the evaluation of hybrids.

Among the hybrids studied, the hybrid ADT 47 x ADT 36 identified with positive significant sca effects for the characters viz., number of productive tillers per plant, number of grains per panicle, hundred grain weight, grain yield per plant, kernel length, kernel breadth and kernel length × breadth and negative significant sca effects for days to 50 per cent flowering and plant height for panicle length it recorded as non significant trait. The cross, ADT 41 x CO 51 registered positive significant effects for the traits viz., number of productive tillers per plant, panicle length, number of grains per panicle, grain yield per plant, kernel length, kernel breadth and kernel length × breadth and negative significant values for days to 50 per cent flowering and plant height for hundred grain weight significant negative sca were observed. Similar results were obtained by Upadhyay and Jiswal (2015) and Vadivel (2015) in their studies on rice.

The cross, ADT 41 x ADT 36 registered negative non significant sca effects for all the traits studied except for days to 50 per cent flowering, plant height and number of grains per panicle since they were recorded with positive non-significant sca effects. Also the cross, ADT 45 x ADT 36 recorded positive non significant sca effects for the traits viz., 50 per cent flowering and plant height and negative non significant sca effects for number of productive tillers per plant, panicle length, hundred grain weight, grain yield, kernel length, kernel breadth and kernel length × breadth in number of grains per panicle positive significant sca effects in this trait. Similar results were found by Souresh and Rabiei(2010) and Gayathri (2015) in their studies on rice.

The consistency between gca and sca effects might be due to complex interaction of genes as suggested by Matzinger and Kempthorne (1954). It is a well known phenomenon that the crosses involving high gca parents generally evolve high sca effects of hybrids. In the present study the hybrids, ADT 47 x ADT 36 and ADT 41 x CO 51 exhibited high mean performance and significant sca effects with high x high gca combinations for grain yield per plant and all its component traits studied. Such high x high gca combinations resulting in highly significant sca effects may be attributed due to interaction between positive x positive alleles that is additive x additive type of gene action between favorable alleles contributed by both the parents which is fixable and hence may be utilized to develop superior hybrids as these hybrids also combine high per se performance for almost all the characters studied including grain yield per plant. Similar results were obtained by Ravi Kishore (2017) and Thirumalai et al. 2018. Hence these two hybrids could be exploited for heterosis breeding.

The other two hybrids viz., ADT 41 x ADT 36 and ADT 45 x ADT 36 recorded non significant sca effects for all the traits studied. These two crosses also had superior mean performance for grain yield and all its component traits studied. This indicated that these genotypes were governed by additive gene action which is fixable and were found to be suitable for recombination breeding.

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Table 4: General combining effects of parents for different traits in rice genotypes

	Days to 50 per cent flowering (days)	Plant height at maturity (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of grains per panicle	100 grain weight (g)	Grain yield per plant (g)	Kernel Length (mm)	Kernel Breadth (mm)	Kernel L/B ratio
Lines										
ADT-37	7.97**	3.89**	-1.12**	-2.68**	-5.51	0.02	-3.68**	-0.10*	-0.23**	0.11
ADT-41	-3.68**	-6.81**	4.40**	4.46**	12.70**	0.45**	10.64**	0.34**	0.47**	0.18**
ADT-42	7.92**	-0.69	-7.34**	-3.39**	0.25	-0.49**	-1.62**	-0.43**	-0.28**	0.06
ADT-45	17.45**	20.66**	0.36	-0.49	1.25	-0.05*	-7.17**	0.13**	-0.08**	-0.04
ADT-47	-9.13**	-7.40**	2.61**	3.43**	1.61*	0.15**	5.03**	0.30**	0.22**	0.17**
ADT-48	-9.98**	-11.40**	2.09**	-1.59**	-28.26**	-0.11**	1.51**	0.23**	0.05*	-0.37**
ADT-43	-10.55**	1.76**	-1.01**	0.25	17.96	0.04	-4.71**	-0.47**	-0.05	-0.11
Testers										
IR-50	-0.1	-0.85	-0.12	0.11	-7.91**	-0.07**	-4.76**	-0.50**	-0.06**	-0.32**
CO-51	2.50**	0	-2.47**	-0.17	-7.91**	0.05*	1.30**	0.13**	0.13**	0.09*
ADT-36	-5.34**	-1.88**	2.94**	1.62**	-7.91**	0.07**	4.13**	0.25**	0.13**	-0.03
TKM-9	2.94**	2.73**	-0.34	-1.56**	-7.91**	-0.04*	-0.67**	0.12**	-0.19	0.26**

Table 5: Specific combining effects of parents for different traits in rice genotypes

	Days to 50 per cent flowering (days)	Plant height at maturity (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of grains per panicle	100 grain weight (g)	Grain yield per plant (g)	Kernel Length (mm)	Kernel Breadth (mm)	Kernel L/B ratio
ADT-37 x IR-50	1.41**	8.19**	6.02**	1.95**	16.63**	0.16**	-2.06**	0.37**	-0.03	0.22
ADT-37 x CO-51	1.41**	12.03**	2.41**	4.09**	-4.27**	0.09	0.58	0.06	-0.01	-0.02
ADT-37 x ADT-36	1.24**	9.13**	-3.50**	-1.91**	-8.22**	-0.07	1.66**	-0.08	0.02	-0.01
ADT-37 x TKM-9	-4.05**	2.61**	-4.94**	-4.13**	-4.15**	-0.06	-3.97**	-0.19*	0.02	0.02
ADT-41 x IR-50	4.69**	-4.17**	6.58**	-3.87**	3.94**	-0.13**	1.67**	-0.05	-0.23**	0.2
ADT-41 x CO-51	-1.73**	-2.72**	7.81**	7.06**	41.01**	0.18**	3.13**	0.42**	0.21**	0.14
ADT-41 x ADT-36	0.31	1.22	-0.46	-1.01	0.22	-0.02	-0.82	-0.09	0.02	-0.23
ADT-41 x TKM-9	0.90*	-3.95**	-3.59**	-1.08	-10.80**	-0.02	-0.2	-0.42**	0.12*	-0.32**
ADT-42 x IR-50	-9.75**	6.19**	-13.22	1.15*	19.68**	-0.20**	-1.50**	-0.07	0.09	-0.64**
ADT-42 x CO-51	-21.71**	5.66**	5.10**	0.06	-12.74**	0.06	1.01*	0.33**	0.02	0.16

ADT-42 x ADT-36	17.20**	-6.60**	2.98**	2.12**	-12.06**	0.05	-1.83**	-0.39**	-0.19	0
ADT-42 x TKM-9	14.26**	-5.25**	5.15**	-2.26**	5.12**	-0.04	2.31**	0.13	-0.15**	0.2
ADT-45 x IR-50	1.23**	-23.03**	2.76**	2.56**	-7.74**	-0.10*	-1.67**	0.33**	-0.20**	0.09
ADT-45 x CO-51	3.71**	7.70**	-8.34**	2.93**	9.78**	-0.18**	-2.37**	-0.22*	-0.06	-0.01
ADT-45 x ADT-36	-6.69**	12.89**	5.74**	0.84	20.55**	0.06	-1.75**	0.24*	0.05	-0.42**
ADT-45 x TKM-9	1.75**	2.44**	-0.16	-3.17**	-22.58**	-0.10*	-0.23	-0.01	-0.06	0.12
ADT-47 x IR-50	-5.90**	7.01**	5.31**	-3.07**	-15.78**	-0.06	0.08	-0.48**	0.17**	-0.34**
ADT-47 x CO-51	5.47**	3.54**	-2.54	1.21*	-49.04**	-0.06	-1.55**	-0.46**	-0.06	0.32
ADT-47 x ADT-36	0.47	1.4	-0.71	-0.23	23.81**	0.05	-0.43	-0.1	-0.05	-0.06
ADT-47 x TKM-9	-3.76**	-11.96**	-2.05**	1.34*	6.64**	0.08	1.89**	0.36**	0.03	0.09
ADT-48 x IR-50	4.85**	2.28**	-5.06**	-3.74**	-13.27**	-0.06	0.04	-0.26**	0.10*	-0.13
ADT-48 x CO-51	4.95**	-6.10**	-1.39**	-4.69**	-27.10**	0.13**	-1.03*	0.37**	0.10*	0.03
ADT-48 x ADT-36	-1.19**	-1.65*	12.34**	8.49**	52.61**	0.23**	5.79**	0.70**	0.31**	0.31*
ADT-48 x TKM-9	-6.04**	5.48**	-5.34**	-2.23**	-12.24**	0.02	1.21**	-0.47**	-0.25**	0.01
ADT-43 x IR-50	-0.71	3.51**	4.17**	5.02**	-3.46*	0.07	2.19**	0.17	-0.03	0.1
ADT-43 x CO-51	5.86**	2.24**	-6.43**	-4.01**	3.44*	-0.11*	0.22	-0.34**	-0.09	-0.02
ADT-43 x ADT-36	-2.55**	-3.03**	-5.55**	-2.97**	-3.61*	-0.09	2.31**	-0.09	-0.07	0.03
ADT-43 x TKM-9	-5.62**	-1.02	-2.53**	1.96**	3.64*	0.12*	-4.72**	0.26**	0.19**	-0.11

Table 3: Means of the measured traits for parents and their hybrids

	Days to 50 per cent flowering (days)	Plant height at maturity (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of grains per panicle	100 grain weight (g)	Grain yield per plant (g)	Kernel Length (mm)	Kernel Breadth (mm)	Kernel L/B ratio
Lines										
ADT-37	68.8	98.1	23.22	19.09	130.83**	1.42	26.58	4.7	2.03	1.62
ADT-41	63.32**	75.65**	28.73**	34.84**	151.62**	2.69**	33.29**	7.23**	2.90**	4.07**
ADT-42	85.81	99.34	22.42	17.1	112.84	1.45	28.04	6.23	2.07	3.51
ADT-45	67.72*	82.27**	25.92	20.15	86.5	1.57	26.89	5.97	1.47	3.46
ADT-47	65.74**	81.40**	26.39*	26.08**	143.77**	2.66**	30.94**	7.03**	1.87	3.34
ADT-48	66.63**	81.81**	23.98	21.54	139.08**	2.36**	29.87*	4.97	1.77	2.93
ADT-43	66.94**	83.35	24.62	19	104.74	1.98**	29.04	6.03	1.93	3.13
Testers										
IR-50	73.64	69.67	19.38	20.42	91.12	1.07	22.71	6.16	2.09	2.94
CO-51	69.36	79.95**	21.2	22.87	111.27	1.61	25.88	5.9	1.93	3.06
ADT-36	60.35**	75.37**	33.52**	24.71**	140.94**	2.01**	36.29**	7.01**	1.87	3.77**
TKM-9	73.58	107.9	26.25	17.56	120.43	1.05	23.78	6.96**	2.01	3.45
Hybrids										
	Days to 50 per cent flowering (days)	Plant height at maturity (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of grains per panicle	100 grain weight (g)	Grain yield per plant (g)	Kernel Length (mm)	Kernel Breadth (mm)	Kernel L/B ratio
ADT-37 x IR-50	71.73**	89.74**	39.95**	22.21	212.85**	2.01**	48.22	6.27	2.33**	2.69
ADT-37 x CO-51	88.33	98.84	30.94	19.29	173.08	1.7	49.33	6.43*	2.15**	2.66
ADT-37 x ADT-36	74.16**	86.34**	27.38	23.49	181.51	1.69	41.8	6.57**	2.38**	2.76
ADT-37 x TKM-9	69.30**	83.11**	25.72	24.43	171.36	1.81	40.27	6.32	2.05	2.93
ADT-41 x IR-50	74.43**	88.45**	34.29**	19.27	133.93	1.58	55.89**	5.08	1.94	2.63
ADT-41 x CO-51	66.45**	81.14**	41.31**	30.65**	215.83**	2.22**	58.74**	6.81**	2.79**	3.12*
ADT-41 x ADT-36	61.27**	70.37**	41.68**	33.13**	219.30**	2.33**	65.55**	6.95**	2.98**	3.32**
ADT-41 x TKM-9	73.67**	85.96**	23.97	21.54	178.33	1.72	49.22	5.32	1.98*	2.69
ADT-42 x IR-50	78.46**	98.44	26.23	21.39	209.99**	1.14	49.59	5.1	2.34**	2.18
ADT-42 x CO-51	70.00**	98.76	39.14**	18.95	165.79	1.4	49.28	6.13	1.96	2.98
ADT-42 x ADT-36	108.01	89.22**	39.37**	20.7	178.54	1.31	40.38	5.53	1.94	2.84
ADT-42 x TKM-9	105.51	85.96**	29.59	19.49	181.81	1.32	48.61	5.91	1.76	2.7
ADT-45 x IR-50	98.98	90.57**	38.17**	18.17	192.87**	2.00**	56.07**	6.07	2.13*	2.85
ADT-45 x CO-51	96.22	122.15	21.66	27.58**	189.3	1.47	52.54**	6.13	2.08	2.94
ADT-45 x ADT-36	93.66	130.06	38.09**	21.27**	212.45**	1.74	47.11	6.39*	2.21**	2.41
ADT-45 x TKM-9	102.54	115	31.97	26.43**	155.1	1.7	51.97**	6.34	1.96	2.37
ADT-47 x IR-50	86.54	103.84	36.94**	17.88	181.97	1.8	45.63	5.02	2.53**	1.98
ADT-47 x CO-51	88.5	101.22	29.7	19.46	127.62	2.12**	41.16	5.66	2.11*	2.67
ADT-47 x ADT-36	66.48**	97.19	40.97**	29.01**	215.06**	1.68	56.78**	6.82**	2.64**	3.08*
ADT-47 x TKM-9	90.12	81.96**	32.33	23.79	191.19*	1.96**	40.32	6.49**	2.07	2.99
ADT-48 x IR-50	76.01**	87.83**	28.44	18.29	156.47	1.65	48.04	5.57	2.20**	1.86
ADT-48 x CO-51	70.88**	87.46**	39.91**	28.82**	201.27**	2.10**	44.14	5.94	2.07	2.44
ADT-48 x ADT-36	64.81**	80.29**	41.32**	21.31	216.00**	2.29**	60.74**	6.82**	2.93**	3.24**
ADT-48 x TKM-9	68.16**	89.98**	25.42	30.87**	134.58	1.72	44.42	5.97	2.31**	2.58
ADT-43 x IR-50	75.91**	98.21	19.76	28.90**	213.86**	2.04**	43.27	6.11	2.59**	2.35
ADT-43 x CO-51	77.24**	97.79	25.3	19.59	199.68**	1.75	38.88	6.22	2.34**	2.65
ADT-43 x ADT-36	79.70*	95.24	28.54	19.25	205.00**	1.8	38.55	6.6	2.55**	2.58

ADT-43 x TKM-9	74.03**	90.94*	21.06	27.35**	198.03**	1.82	53.84**	6.18	2.50**	2.72

Table 2: Analysis of variance for combining ability analysis in rice

Source of variation		MSS									
	df	Days to 50 per cent flowering (days)	Plant height (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of grains per panicle	Hundred grain weight (g)	Grain yield per plant (g)	Kernel Length (mm)	Kernal Breadth (mm)	Kernal L × B
Replication	2	1.63	3.37	0.68	1.2	1.39	0.0005	0.34	0.04	0.005	0.14
Genotype	38	482.37**	500.54**	148.76**	66.72**	4516.42**	0.45**	371.16**	1.17**	0.35**	0.73**
Cross	27	519.19**	482.71**	149.26**	63.68**	2118.77**	0.26**	149.99**	0.88**	0.29**	0.35**
Line	6	169.01**	247.32**	13.84**	112.23**	1664.50**	0.93**	16.88**	2.69**	0.58**	1.74**
Tester	3	117.15**	864.87**	120.22**	28.79**	1282.97**	0.64**	116.15**	0.94**	0.02**	0.43**
L×T	18	235.68**	259.42**	148.63**	54.14**	1857.66**	0.05**	22.42**	0.46**	0.08**	0.17**
Error	76	0.6	1.87	0.77	0.79	6.6	0.006	0.53	0.02	0.007	0.04
GCA Variance		6.3	4.96	0.01	0.21	5.8	0.004	2.83	0.009	0.004	0.004
SCA Variance		78.35	85.85	49.28	17.78	617.01	0.01	7.29	0.14	0.02	0.04
GCA/SCA Variance		0.08	0.05	0.0002	0.01	0.009	0.4	0.38	0.06	0.2	0.1