D2329 and HW741 x WH147 exhibited gnificant and positive sca effects for grain yield r plant in descending order of magnitude. These osses, except WH291 x WH147 and Sonalika x 'H147 also showed significant and desirable sca fects for one or more yield components. The cross D2428 x WH127 recorded high sca effects for rain yield per plant, tillers per plant, spike length, rains per spike and 100-grain weight. It also chibited high *per se* performance for grain yield nd tillers per plant involving high x high and low x w general combiners for grain yield and tillers per lant, respectively. There was no association etween sca effects and *per se* performance of the rosses.

Top three crosses with high sca affects for grain yield and its component (Table 4) showed that these crosses were involving all types of general combiners, *i.e.* high x high, high x low and ow x low. This shows the role of additive and nonadditive gene actions for the character studied and signify the importance of both the types of gene action for improvement in grain yield by following an appropriate method of recurrent selection. If the commercial production of wheat hybrids becomes feasible, wheat breeders will be able to take advantage of both additive and nonadditive gene actions. Under these circumstances there would be merit in selecting lines on the basis of high gca effects for grain yield and its components.

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HETEROSIS AND COMBINING ABILITY FOR GRAIN CHARACTERS IN RICE

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ABSTRACT

Heterosis and combining ability studies were made on ten grain characters *viz.*, kernel length, kernel breadth, kernel thickness, L/B ratio, kernel length after cooking, kernel breadth after cooking, linear elogation ratio, breadth wise elongation ratio, hulling per cent and milling per cent. The study revealed that the parents IR 50 and White Ponni possessed significant *per se* performance and gca effect for physical grain quality characters. The parents TKM 9 and ADT 37 are best adjuded for improving the cooking quality. The hybrid combinations ADT 37/White Ponni, TKM 9/White Ponni and ADT 39/ ADT 40 can be exploited for heterosis breeding. ADT 39 proved to be a good donor for improving the hulling and milling per cent. The high GCA variance for most of the characters indicate the predominance of additive gene action

KEY WORDS: Rice, Heterosis, Combining Ability

Heterosis breeding has been successfully utilised to enhance the productivity of rice crop. Besides yield, food consumption pattern has encouraged the attention of the grain quality characters. Detailed information about heterosis of quality characters is lacking. The information on grain characters could be better utilised for improving yield and quality of rice. Choice of parents for hybridisation programme is of prime importance in any breeding programme. Assessment of combining ability of parents in terms of their hybrid is a tool for the breeders in identifying those parents and hybrids that have superior combination of grain characters. The present investigation reports heterosis and combining ability on different grain characters in rice.

MATERIALS AND METHODS

Six popular rice varieties cultivated in Tamil Nadu *viz.*, IR 50, TKM 9, ADT 37, ADT 39, ADT 40 and White Ponni were crossed in all possible ways without reciprocals. The F1 hybrids along with the parents were raised at the Tamil Nadu Rice Research Institute, Aduthurai during 1993 *kharif* in randomised block design replicated thrice adopting a spacing of 20x10 cm and single seedlings per hill. The seeds were collected on randomly selected five plants in each replication and grain quality attributes were recorded. Four physical grain characters *viz.*,. kernel length, kernel breadth, kernel thickness and kernel L/B ratio, four cooking characters *viz.*, kernel length after cooking (KLAC), kernel breadth after cooking (KBAC), linear elongation ration (LER) and breadthwise elogation ratio (BER) and two milling characters *viz.*, hulling per cent and milling per cent were recorded. The physical grain characters before and after cooking were measured using Mitutoyo micrometer (Juliano and Perez, 1984). Mc.Gell huller and miller was utilised for hulling and milling. Heterosis was estimated based on Matzinger *et al.* (1962) and Fonseca and Patterson (1968) Combining ability analysis was carried out according to Griffing (1956) Method II and Model I.

RESULTS AND DISCUSSION

The analysis of variance revealed that there were significant differences among parents and hybrids for all the ten characters studied (Table 1). The mean value of the genotypes, the *gca* and *sca* effects and the level of heterosis in the hybrids are presented in Tables 2 to5.

Physical grain characters

Among the ten characters studies. kernel length, kernel breadth, kernel thickness and kernel L/B ratio are the four physical grain characters which determine the appearance and market value of the rice. The present investigation revealed that among the parents studied IR 50 possessed desirable values for kernel length, kernel breadth and kernel L/B ratio and White Ponni had desirable values for kernel thickness. The *gca* effect is utilised as one of the tools to analyse the parents for their ability to transmit the characters to the progeny. IR 50 exhibited highly desirable *gca* effects for the same three characters and White Ponni for kernel thickness. Since the *gca* effect is predominantly due to additive genes, these two parents can be useful for improving the physical grain characters of rice through pedigree breeding.

Among the 15 hybrids, highly desirable mean values for physical grain characters were observed in IR 50/While Ponni for kernel breadth and thickness, ADT 39/ADT 40 for kernel breath and

Table 1. Analysis of variance for different traits

Source of variation	df	Mean Squares									
		Kernel length (mm)	Kernel Breadth (mm)	Kernel thickness (mm)	Kernel L/B ratio	Kernel length after cooking (mm)	Kernel Breadth after cooking (mm)	Length wise elonga-tion ratio	Breadth wise elonga-tion ratio	Hulling %	Milling %
Genotype	20	0.132**	0.154**	0.070**	0.643**	1.117**	0.165**	0.032**	0.016**	8.761**	8.991**
Replication	2	0.091	0.011	0.006	0.003	0.126	0.044	0.009	0.014	0.95	1.40
Error	40	0.458	0.00	0.001	0.001	0.005	0.003	0.001	0.001	0.04	0.03

Table 2. Mean value of parents and hybrids for different traits

Parents/ Hybrids	Kernel length (mm)	Kernel Breadth (mm)	Kernel thickness (mm)	L/B ratio	Kernel length after cooking (mm)	Kernel Breadth after cooking (mm)	Length wise elonga tion ratio	Breadth wise expansion ratio	Hulling %	Milling %
IR 50	6.26*	1.96*	1.57*	3.42*	9.36*	3.14*	1.54*	1.60	75.97	70.79
ADT 37	5.37	2.74	1.81	1.88	8.03	3.59	1.62	1.37	78.41*	74.13*
TKM 9	5.85	2.69*	1.85*	2.19	8.39	3.00*	1.47	1.13*	75.59	70.22
ADT 39	5.81	2.32*	1.57*	2.41	8.69	3.18	1.60	1.45	78.82*	74.66
ADT 40	5.84	2.63*	1.78*	2.21	9.09*	3.40*	1.56	1.42	75.53	70.56
Improved White Ponni	5.97	2.13*	1.53*	2.66*	8.27	2.83	1.56	1.59	73.82	70.06
IR 50/ADT 37	5.78	2.27*	1.64	2.51	8.87*	3.10*	1.60	1.40	76.95	73.22*
IR 50/TKM 9	6.00	2.28*	1.68	2.62*	9.30*	3.20	1.59	1.45	76.62*	70.94
IR 50/ADT 39	5.93	2.24*	1.57*	2.66*	8.73	3.03*	1.51	1.38	76.77*	71.52
IR 50/ADT 40	5.88	2.27*	2.20*	2.60*	9.23*	3.06*	1.56	1.22*	71.17	67.49
IR 50/Improved White Ponni	5.47	2.14*	1.56*	2.76*	9.56*	3.47	1.64	1.36	76.80*	71.50
ADT 37/TKM 9	5.51	2.80*	1.82*	1.93	8.35	3.59	1.59	1.32	75.86	72.21*
ADT 37/ADT 39	5.59	2.51*	1.62	2.21	8.91*	3.73	1.70*	1.44	75.86	71.37
ADT 37/ADT40	5.86	2.70*	1.78*	2.14	9.26*	3.19	1.59	1.42	75.54	70.82
ADT 37/Improved White Ponni	5.91	2.28*	1.57*	2.59*	8.66	3.23	1.61	1.16*	74.27	68.86
TKM 9/ADT 39	5.83	2.47*	1.65	3.92*	8.63	3.26	1.56	1.33	76.69*	71.08
TKM 9/ADT 40	5.92	2.70*	1.79	2.18	9.20*	3.03*	1.57	1.25*	78.07*	72.73*
TKM 9/Improved White Ponni	5.85	2.50*	1.64	2.38	9.36*	3.03*	1.62	1.47	75.12	68.80
ADT 39/ADT 40	6.09	2.39*	1.70	2.59*	8.41	3.00	1.45	1.36	76.93*	71.38
ADT 39/Improved White Ponni	5.90	2.20*	1.60	2.67*	8.59	3.10*	1.52	1.41	77.98*	73.12*
ADT 40/Improved White Ponni	5.81	2.31*	1.65	2.55*	6.83	3.00*	1.17	1.35	75.39	71.42
Grand mean	5.83	2.41	1.69	2.53	8.75	3.20	1.55	1.38	76.10	71.28
CD (5%)	0.35	0.01	0.01	0.02	0.02	0.03	0.10	0.06	0.31	0.29

* Significant at 5% level

and TKM 9/ADT 39 for kernel L/B ratio. Considering the *sca* effect, which measures the non-additive gene action of the parents, ADT 37, White Ponni for kernel breath and thickness and in TKM 9/ADT 39 for kernal L/B ratio. Considering all the there phenomena together i.e. *per se* performance *sca* effect and heterosis per cent, IR 50/White Ponni and ADT 37/While Ponni were identified as most desirable combination since they excelled others in atleast two physical grain characters. The additive and non-additive genes in these combinations could be exploited through heterosis and hybridisation and selection methods of breeding.

Table 3. Estimates of general combining ability (gca) effects of parents for different traits

Parents	Kernel length (mm)	Kernel Breadth (mm)	Kernel thickness (mm)	L/B ratio	Kernel length after cooking (mm)	Kernel Breadth after cooking (mm)	Linear elonga- tion ratio	Breadth wise expansion ratio	Hulling %	Milling %
IR 50	0.09*	-0.22**	-0.01**	0.29**	0.40**	-0.03*	0.01**	0.06**	-0.43**	-0.33**
ADT 37	-0.18**	0.15**	0.02**	-0.31**	-0.14**	0.21**	0.06**	-0.02**	0.37**	0.70**
TKM 9	0.01	0.16**	0.05**	-0.04**	0.05**	-0.04**	-0.01	-0.07**	0.03**	-0.34**
ADT 39	0.02	-0.05**	-0.07**	0.15**	-0.07**	0.01	0.01	0.02**	1.19**	1.08**
ADT 40	0.06	0.10**	0.10**	-0-.15**	-0.02	-0.04**	-0.05**	-0.02**	-0.52**	-0.49**
Improved White Ponni	0.01	-0.14**	-0.10**	0.07**	-0.21**	-0.11**	-0.02**	0.03**	-0.64**	-0.63**
SE (gi)	0.041	0.005	0.002	0.002	0.014	0.010	0.004	0.004	0.035	0.034

Table 4. Estimates of specific combining ability (sca) effects of hybrids for different traits

Hybrids	Kernel length (mm)	Kernel Breadth (mm)	Kernel thickness (mm)	L/B ratio	Kernel length after cooking (mm)	Kernel Breadth after cooking (mm)	Length wise elonga tion ratio	Breadth wise expansion ratio	Hulling %	Milling %
IR 50/ADT 37	0.04	-0.07**	-0.07**	0.01*	-0.14**	-0.28**	-0.02*	0.02*	0.96**	1.58**
IR 50/TKM 9	0.08	-0.07**	-0.06**	-0.16**	0.11**	0.07**	0.03**	0.08**	-0.02	0.33**
IR 50/ADT 39	-0.01	0.10**	-0.04**	-0.30**	-0.34**	-0.15**	-0.07**	-0.08**	-0.04	-0.51**
IR 50/ADT 40	-0.10	-0.02	0.42**	-0.07**	0.10**	-0.07**	0.05**	-0.19**	-3.93**	-2.96**
IR 50/Imp. White Ponni	-0.51**	0.09**	-0.03**	-0.13**	0.63**	0.41**	0.10**	-0.12**	1.83**	1.19**
ADT 37/TKM 9	-0.15	0.09**	0.05**	-0.24**	-0.30**	0.22**	-0.02	0.03**	-0.59**	0.57**
ADT 37/ADT 39	0.09	0.01	-0.03**	-0.15**	0.38**	0.32**	0.08**	0.06**	-1.75**	1.92**
ADT 37/ADT40	0.15	0.05**	0.04**	0.09**	0.67**	-0.17**	-0.03**	0.09**	0.36**	0.66**
ADT 37/Imp. White Ponni	0.25**	-0.13**	-0.05**	0.31**	0.27**	-0.06**	0.02*	-0.23**	-1.51**	2.48**
TKM 9/ADT 39	-0.02	-0.05**	-0.02**	1.28**	-0.09**	0.08**	-0.01	-0.01	-0.57**	0.94**
TKM 9/ADT 40	0.03	0.04**	-0.06**	-0.16**	0.42**	-0.10**	0.07**	-0.03**	2.52**	2.29**
TKM 9/Imp. White Ponni	0.02	0.08**	-0.01	-0.18**	0.78**	-0.02	0.09**	0.13**	-0.31**	1.50**
ADT 39/ADT 40	0.19**	-0.06**	-0.02**	0.06**	-0.25**	-0.18**	-0.06**	-0.02**	0.21**	0.48**
ADT 39/Imp. White Ponni	0.04	-0.01	0.08**	-0.08**	0.13**	0.01	-0.01	-0.02**	1.38**	1.40**
ADT 40/Imp. White Ponni	-0.08	-0.05**	-0.05**	0.10**	-1.69**	-0.05**	-0.30	-0.04**	0.50**	1.28
SE (sij)	0.093	0.012	0.004	0.005	0.031	0.002	0.009	0.010	0.079	0.077

* Significant at 5% level; ** Significant at 1% level

Cooking characters

The cooking characters *viz.*, KLAC, KBAC LER and BER are important from the consumer point of view. Higher values for KLAC and LER and less values for KBAC and BER are the requirements for cooking quality. Among the parents, the most desirable mean values were observed in IR 50 for KLAC, in White Ponni for KBAC, in ADT 37 for LER and in TKM 9 for BER. The parental performance was similar for *gca* effects also, and the same four parents were found to possess most desirable *gca* effects for the characters listed. The parents ADT 37 and TKM 9 which possess highly desirable values for LER and BER are rated more suitable for involving in breeding programmes. Such short bold grains possessing desirable cooking characters revealed that short grain generally elongate more than medium and long slender types. Similar results were reported by Sunithakumari and Padmavathi (1991)

The mean values, *sca* effects and heterosis for the cooking characters in the hybrids revealed that every character required different combinations of parents for high expansion. For KLAC, highest mean value was observed in IR 50/White Ponni while high *sca* effects and heterosis was expresse in TKM 9/ White Ponni. For KBAC least mea value as well as well as heterosis was observed i ADT 39/ADT 40 while the least *sca* effect wa exhibited in IR50/ADT 37. For LER, mean valu was high in ADT 37/ADT 39, *sca* in IR 50/Whit Ponni and heterosis in TKM 9/ White Ponni. Onl for BER, a single combination *viz.*, ADT 37/ Whit Ponni possessed least mean value, *sca* effect an heterosis. In over all rating the hybrids TKM 9/White Ponni, ADT 39/ADT 40 and AD 37/White Ponni were found superior owing to thei high desirable values for two characters in eac methods of evaluation. These combinations can b exploited for the non-additive genetic componen through heterosis or hybridisation and selection.

Milling character

The study revealed that the hulling and millin percentages among the genotypes exhibited simila trend. ADT 39 proved to be the best donor paren for increasing the hulling, and milling per cen owing to its highest mean values and *gca* effects Since ADT 39 grain is medium in length an slender in shape, the high hulling and millin recovery may be due to thin husk.

Table 5. Estimates of relative heterosis (di) per cent for different traits

Hybrids	Kernel length	Kernel Breadth	Kernel thickness (mm)	L/B ratio	Kernel length after cooking	Kernel Breadth after cooking	Length wise elongation ratio	Breadth wise expansion ratio	Hulling %	Milling %
IR 50/ADT 37	-0.63	-3.34**	-3.05**	-5.57**	1.95**	-8.06**	1.47	-8.10**	-0.20	1.04**
IR 50/TKM 9	-0.94	-1.79**	-1.56**	-6.87**	4.77**	4.23**	5.86**	3.69**	-0.09	0.61**
IR 50/ADT 39	-1.71	4.83**	-0.01	-9.00**	-3.29**	-4.21**	-4.24**	-11.63**	-0.70**	-1.66**
IR 50/ADT 40	-2.78	-1.09	31.48**	-7.90**	-0.01	-6.41**	1.18	-20.69**	-5.94**	-4.51**
IR 50/Improved White Ponni	-11.40**	4.82**	0.54	-9.51**	8.49**	16.05**	5.79**	-16.56**	2.67**	1.52**
ADT 37/TKM 9	-1.90	3.32**	-0.45	-4.99**	1.75**	9.04**	3.12**	5.18**	-1.48**	0.04
ADT 37/ADT 39	-0.12	-0.86	-4.24**	2.71**	6.58**	10.17**	5.37**	2.00	-3.50**	-4.38**
ADT 37/ADT40	4.55	0.62	-1.11**	4.63**	8.14**	-8.71**	0.10	1.67	-1.86**	-2.11**
ADT 37/Imp. White Ponni	4.17	-6.16**	-5.78**	13.99**	6.32**	0.57	1.05	-21.80**	-2.43**	-4.48**
TKM 9/ADT 39	-0.01	-1.13	-3.31**	70.48**	1.05	5.39**	1.41	2.84**	-0.66**	-1.88*
TKM 9/ADT 40	1.23	1.76*	-1.37*	-1.06**	5.26**	-5.31**	3.74**	-1.69	3.32**	3.32**
TKM 9/Improved White Ponni	-1.02	4.02**	-2.66**	-1.79**	12.42**	4.00**	6.70**	-7.96**	0.56**	-1.92**
ADT 39/ADT 40	4.66	-3.16**	1.49**	11.80**	-5.36**	-9.00**	-8.13**	-5.45**	-0.32**	-1.69**
ADT 39/Improved White Ponni	0.11	-0.82	3.33*	5.25**	1.36*	2.99**	-3.58**	-7.34**	2.17**	1.05**
ADT 40/Improved White Ponni	-1.55	-2.95**	-0.20	4.64**	-21.29**	3.85**	-24.49**	-10.18**	0.95**	1.59**

* Significant at 5% level; ** Significant at 1% level

Among the hybrid combinations, TKM 9/ADT 40 recovered highest man value, *sca* effect and heterosis. These high values due to the short bold grain types of the parents since short bold grains possess less surface area compared to medium and long slender grains. However, high milling recovery due to shape and size of the grain is not usefull to breeders. Hence ADT 39 is more preferable than other parents and hybrid combinations for improving the hulling and milling recovery in rice

The study revealed that the parents IR 50 and White Ponni and the hybrid combinations IR50/White Ponni and ADT 37/White Ponni are suitable for improving the physical grain quality traits. TKM 9 and ADT 37 are suitable for improving the cooking quality traits. The hybrid combinations ADT 37/White Ponni, TKM 9/White Ponni and ADT 39/ADT 40 can be exploited through non-additive genes for quality traits. The parents ADT 39 proved to be a good donor for improving the hulling and milling per cent.

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