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Research Article

Studies on combining ability and heterosis in rice (*Oryza sativa* L.)

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Abstract
Combining ability analysis was carried out in rice involving seven lines, four testers and 28 cross combinations. The combining ability variances revealed that SCA was greater than GCA indicating the preponderance of non-additive gene action for all the traits *viz.,* days to 50 per cent flowering, plant height, 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 L/B ratio. From standard heterosis, hybrids *viz*., STBN 4/ADT 45, STBN 3/ADT 45 and ADT 43/PMK 3 recorded significant standard heterosis for most of the traits. Among the parents ADT 43, STBN 3, STBN 4 among lines and ADT 45 among testers were good general combiners for grain yield per plant and other component traits. Among hybrids, STBN 3 x ATD 45, STBN 4 x ADT 45 and ADT 43 x PY 3 recorded significant and positive *sca* effects for grain yield per plant which indicated the involvement of additive type of epistasis for grain yield and other characters.

Key words
Rice, combining ability, gene action, heterosis.

Introduction

Rice (*Oryza sativa* L.) is the world's most important staple food crop. India is the second largest producer and consumer of rice in the world. Rice is the major source of calorie intake and also contributes to the total agricultural income in most of the Asian countries. Rice is grown throughout the world in 165 million hectares with the production of 740 million tonnes. In India, rice occupies an area of about 44 million hectares with a production of 159.2 million tonnes. In Tamil Nadu, it is cultivated in an area of 2.1 million hectares, with a production of 9.2 million tonnes. Demand for rice is expected to grow faster than production in most countries so much that by the year 2025, 800 million tones of it will be needed annually (Anon.,1994). Although many methods are in vogue for rice improvement, hybrid breeding to increase rice productivity has gained much importance nowadays.

Combining ability analysis is a powerful tool to discriminate good as well as poor combiner and selecting out appropriate parental material and type of gene action involved in the inheritance of various traits. Knowledge of type of *gca* effects and their magnitude is of fundamental importance to the plant breeder. To exploit heterosis, knowledge on choosing appropriate parents of good genetic potential is very essential. The parent involved in the improvement programme should possess good combining ability and wide genetic diversity for various economic traits many biometrical techniques are made available to the breeder for choosing desirable parents. With this background, combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis. Line × tester technique (Kempthorne *et al*. 1957) is useful in deciding the relative ability of female and male lines to produce desirable hybrid combinations.

Material and Methods

The experimental material used in the present investigation consisted of F_1 hybrids of 28 crosses and 11 parental lines *viz.*, STBN2, STBN3, STBN4, PY3, ADT43, ADT49 and TKM 9 (as lines) as well as ADT36, ADT45, IR64 and PMK3 (as testers). Crosses were made following L x T method. All the lines, testers and cross combinations were grown in randomized block design with three replications at the Plant Breeding Farm, Faculty of Agriculture, Annamalai University, Annamalainagar during July to October 2014 under transplanted condition. Twenty five days old seedlings were transplanted in the field. Each entry was raised in single row of 3 m length spaced 20 cm apart with 15 cm interplant distance. The standard agronomic packages of practices were followed to raise healthy crop. Ten quantitative characters were evaluated *viz.* days to 50 per cent flowering, 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), kernel breadth (mm) and kernel L/B ratio. About ten random plants per plot were used for measuring traits and mean values obtained were subjected to line x tester analysis. The standard procedures developed by Kempthorne (1957) were followed to estimate variances of SCA and GCA. Significance test for GCA and SCA effects were performed using t-test. Heterosis was estimated according to Shull (1914). The significance of different types of heterosis was carried out by adopting t-test as suggested by Nadarajan *et al.* (2016). The variety, IR 64, was used as a standard check to calculate standard heterosis.

Results and Discussion

Analysis of variance due to parents and hybrids for ten characters is presented in (Table 1). All the hybrids showed significance for all the characters. The lines and testers exhibited significance for all the characters. This indicated the presence of general combining ability effects among parents for these traits. The estimates of GCA and SCA variances revealed that the SCA variances were higher for all the characters which indicated the preponderance of non-additive gene action. Preponderance of non-additive variances in the expression of different characters in rice have also been reported by Abhinav Sao and Motiramani (2006).

The success of any breeding programme largely depends on the choice of parents used in hybridization. Gilbert (1958) suggested that parents with good *per se* performance would result in better hybrids. Genotypes with high *per se* performance and high *gca* effects could be useful in evolving desirable segregants in breeding programmes. The *gca* effect is due to additive gene action and is fixable (Sprague and Tatum, 1942). The term combining ability is defined as the relative ability of genotype to transmit its desirable characters to its progenies. Among lines, STBN 3 and STBN 4 were found to be good general combiners for grain yield per plant and all other characters (Table 2), followed by line ADT 43. Among the testers, ADT 45 was good general combiner for grain yield per plant and all other characters. Good general combiner for various traits were also been reported by Chakraborty *et al.* (2009), Waghmode *et al.* (2011), Utharasu and Anandakumar (2013) and Kolom *et al.* (2014).

The specific combining ability (*sca*) effects of the 28 F_1 crosses for 10 quantitative traits are presented in Table 4. Specific combining ability is the deviation from the performance predicted on the basis of general combining ability (Allard, 1956). Diwakar and Singh (1993) suggested that the crosses with high *gca* effects generally gave high *sca* effects. High *sca* effects were not only produced by high x high but also with high x low or low x high or low x low combination of *gca* effects. All the promising crosses *viz.* STBN 3 x ATD 45, STBN 4 x ADT 45 and ADT 43 x PY 3 recorded significant and positive *sca* effects for grain yield per plant (Table 3). The *gca* effects of parents are also significant and positive except PY 3. The parent, PY 3 had non-significant *gca* effect for grain yield per plant. Hence, it may be concluded that the gene action involved in these crosses are of additive type of epistasis. Similar trend was observed for other traits too. The present findings was also supported Biswas and Julfiquar (2006), Muhammad Rashid *et al* (2007), Gulzar *et al*. (2012), Satheesh Kumar and Saravanan (2013) and Satyapal Singh *et al.* (2014).

Heterosis in rice was first reported by Jones in 1926. Plant breeders have extensively explored and utilized heterosis for enhancing the yield in a number of crops. Information on the magnitude of heterosis is a pre-requisite for the development of any hybrid. A good hybrid manifests high amount of heterosis for commercial exploitation. The hybrid performance is assessed normally in terms of per cent increase over standard parent. Swaminathan *et al*. (1972) indicated the need for computing standard heterosis for commercial exploitation of hybrid vigour. Hence, for the evaluation of hybrids, standard heterosis is to be given importance rather than the other two types of heterosis (Table 4). Among the hybrids, significant and positive standard heterosis of more than 20 per cent was reported in three cross combinations *viz.*, STBN 4/ADT 45, STBN 3/ADT 45 and ADT 43/PMK 3. These hybrids also recorded significant standard heterosis for most of the traits.

In the present study, out of 11 parents, STBN 3, STBN 4 and ADT 45 were adjudged as good general combiners for grain yield per plant and other yield component traits. Among hybrids, STBN 3 x ADT 45, STBN 4 x ADT 45 and ADT 43 x PY 3 were high yielders with more than 20 per cent standard heterosis. Parents of these hybrids were good combiners for grain yield per plant and yield component traits. The specific combining ability effects of these hybrids indicated the involvement of additive type epistasis for grain yield and other characters of these promising hybrids. Hence, the present study indicated that good combiners need to be involved in heterosis breeding to exploit additive type of epistasis.

References

Abhinav Sao., and Motiramani, N.K., 2006: Combining ability analysis for yield and yield contributing traits using cytoplasmic male sterility-fertility restoration system in rice hybrids. *Jordan J. Agric. Sci,* **2**(1).

Annon., 1994: Hand book of hybrid rice breeding manual. International Rice Research Institute, Manila, Philippines.

Allard, R.W., 1956: Biometrical approach to plant breeding. Proceedings of Symposium on Genetics and Plant Breeding. Broahave, Nat. Laboratory, 66-68.

Biswas, P.S., and Julfiquar, A.W., 2006: Heterosis in relation to combining ability in rice *(Oryza sativa* L.) involving cytoplasmic genetic male sterility system. *SAARC J. Agric,* **4**: 33-43.

Chakraborty, R., Supriyo Chakraborty., Dutta, B.K. and Paul, S.B., 2009: Combining ability analysis for yield and yield components in bold grained rice *(Oryza sativa* L.) of Assam. ACTA AGRON (PALMIRA). **58** (1)**:** 9-13.

Diwakar, N.C., and Singh, A.K., 1993: Combining ability for oil content and yield attributes in yellow seeded Indian mustard *(Brassica juncea* L. *Zern cross). Ann. Agric. Res.* **14**:194-198.

Gulzer, S., Sanghera, and Wassem Husssaian, 2012: Heterosis and combining ability estimates using line x tester analysis to develop rice hybrids for temperate conditions. *National Sci. Biol,* **50** (1): 52-57.

Gilbert, N.E.C., 1958: Diallel cross in Plant Breeding. *Heredity,* **12:** 477-498.

Jones, J.W., 1926: Hybrid vigour in rice. *J. American Soc. Agron,* **28**: 423-428.

Kempthorne, O., 1957: An introduction to genetic statistics, John Wiley and Sons, Inc., New York.

Kolom, R., Changkija, S., and Sharma, M.B., 2014: Combining ability analysis for yield and yield components in some important upland rice germplasms of Nagaland. *Indian J. Hill Farming,* **27** (1): 118-125.

Muhammad Rashid., Akbar Alicheema, and Muhammad Ashraf, 2007: Line x tester analysis in Basmati rice. *Pakistan J. Bot,* **39** (6): 2035 -2042.

Nadarajan N., Manivannan, N., and Gunasekaran, M., 2016: Quantitative genetics and biometrical techniques in plant breeding. Kalyani publishers, New Delhi, 132-143 p.

Satheesh Kumar, P., and Saravanan, K., 2013: Studies on combining ability for yield attributes in rice *(Oryza sativa* L.). IJCAR**, 2** (12): 56-58.

Satyapal Singh., Parmeshwar Ku. Sahu., Deepak Sharma., Hemant Sahu, and Fakeer Chand Sao, 2014: Studies on combining ability to develop medium slender and aromatic short grain rice hybrids. *Inter. J. Current. Agric. Res,* **3** (12): 89-96.

Shull G. H., 1914. Duplicate genes for capsule-form in Bursa pastoris. Zeitschrift ind. Abst. u. Verebsgl.**12:** 97–149.

Sprague, G.P. and Tatum, L.A., 1942: General vs specific combining ability in single crosses of corn. *J. American Soc. Agron,* **34** : 923-932.

Swaminathan, M.S., Siddiq, E.A., and Sharma, S.D., 1972: Outlook for hybrid rice in India. *In:* Rice breeding. Inter. Rice Res. Inst., Manila, Philippines. pp. 609-613.

Utharasu, S., and Anandakumar, C.R., 2013: Heterosis and combining ability analysis for grain and its component traits in aerobic rice *(Oryza sativa* L.) cultivars. Electronic Journal of Plant Breeding, **4** (4): 1271-1279.

Waghmode, B. D., Mehta, H.D., and Vashi, R.D., 2011: Combining ability studies using different CMS source in rice. Oryza, **48** (4): 304-313.

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Table 1. Analysis of variance for combining ability in rice

Source of variation	df	Days to 50 per cent flowering	Plant height (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
Replication	2	7.21	0.83	4.37	1.16	3.44	0.006	0.20	0.01	0.002	0.005
Hybrid	27	116.39**	297.10**	18.47**	22.16**	3314.10**	0.31**	61.59**	0.82**	0.22**	0.24**
Lines	6	214.99**	725.81**	35.30**	58.53**	10503.01**	0.62**	121.31**	1.53**	0.36**	0.60**
Testers	3	266.35**	406.45**	9.65**	23.02**	3447.59**	0.35**	45.009**	1.56**	0.43**	0.14**
L x T	18	58.53**	135.97**	14.34**	9.89**	895.55**	0.19**	44.45**	0.46**	0.14**	0.13**
Error	54	1.77	2.20	1.18	1.02	8.49	0.007	0.96	0.02	0.009	0.02
GCA		1.28	3.58	0.02	0.27	14.87	0.002	0.38	0.008	0.001	-0.0002
SCA		18.90	44.43	3.54	2.95	317.10	0.06	14.49	0.14	0.03	0.04
GCA/SCA		0.06	0.08	0.006	0.09	0.04	0.03	0.002	0.05	0.05	-0.004

***, ****Significant at 5 and 1 per cent level respectively

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Table 2. Estimates of general combining ability effects of parents in rice

Name of parents	Days to 50 per cent flowering	Plant height (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										
STBN 2	8.50**	7.57**	0.23	-1.73**	-25.75**	-0.02	-1.02**	-0.19**	0.09	0.01
STBN 3	-1.04**	-4.15**	1.16**	2.52**	21.04**	0.26**	3.09**	0.33**	-0.07	-0.01
STBN 4	-4.01**	-10.88**	1.03**	2.45**	17.95**	0.21**	2.16**	0.45**	-0.07	0.01
PY 3	0.74	3.77**	-1.16**	-1.25**	-5.07**	-0.05*	-1.96**	-0.45**	0.09	-0.05
ADT 43	-4.13**	-8.24**	0.80**	2.04**	9.24**	0.14**	4.07**	-0.30**	-0.18**	-0.03
ADT 49	0.43	8.87**	-0.62*	2.00**	-7.98**	-0.39**	-1.62**	-0.13**	-0.04	0.23**
TKM 9	-0.50	3.0**	-1.45**	-2.04**	-9.44**	-0.16**	-4.72**	-0.32**	0.18**	-0.15**
Testers										
ADT 36	1.58**	3.69**	-0.69**	-1.57**	-14.74**	-0.20**	1.62**	-0.39**	-0.20**	0.04
ADT 45	-3.68**	-3.39**	0.84**	0.58*	6.47**	0.05**	1.93**	0.05	0.07**	-0.05
IR 64	-2.10**	-4.21**	0.69**	0.43	6.61**	0.07**	-0.27	0.11**	0.06**	-0.01
PMK 3	4.20**	3.91**	-0.85**	0.55*	1.66*	0.07**	-0.05	.23**	0.07**	0.03
SE(lines)	**0.38**	**0.47**	**0.26**	**0.29**	**0.84**	**0.02**	**0.28**	**0.04**	**0.02**	**0.03**
SE (testers)	**0.29**	**0.35**	**0.20**	**0.22**	**0.63**	**0.01**	**0.21**	**0.03**	**0.02**	**0.02**

, * Significant at 5 and 1 per cent level respectively

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Table 3. Estimates of specific combining ability effects for hybrids in rice

Hybrids	Days to 50 per cent flowering	Plant height (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
STBN 2/ADT 36	-0.04	-1.58	0.65	1.90**	21.02**	0.46**	2.85**	-0.21*	0.09	-0.17*
STBN 2/ADT 45	4.37**	6.28**	-1.16*	-0.37	-9.41**	-0.12*	-2.84**	-0.02	-0.16**	0.17*
STBN 2/IR 64	-0.58	-10.24**	0.41	-0.93	-17.19**	-0.10*	-1.08	0.17*	0.13*	-0.09
STBN 2/PMK 3	-3.74**	5.54**	0.10	-0.60	5.58**	-0.24**	1.07	0.06	-0.06	0.09
STBN 3/ADT 36	4.72**	8.92**	-1.68**	-1.14	-22.35**	-0.12*	-0.31	-0.55**	-0.07	-0.12
STBN 3/ADT 45	-5.67**	-4.50**	1.70**	2.21**	21.68**	0.26**	5.07**	0.37**	0.19**	-0.06
STBN 3/IR 64	-2.54**	-0.70	0.00	-0.59	6.55**	-0.11*	-2.76**	0.22**	-0.11*	0.20**
STBN 3/PMK 3	3.49**	-3.71**	-0.03	-0.48	-5.88**	-0.03	-2.00**	-0.05	-0.01	-0.02
STBN 4/ADT 36	2.06**	8.87**	-1.45**	-2.06**	-36.17**	-0.27**	-7.38**	-0.03	-0.07	0.09
STBN 4/ADT 45	-3.06**	-1.01	2.38**	3.06**	26.87**	0.42**	7.72**	0.36**	0.27**	-0.15*
STBN 4/IR 64	-2.32**	-2.98**	-0.90	0.32	11.99**	0.01	1.64**	-0.10	0.05	-0.12
STBN 4/PMK 3	3.32**	-4.88**	-0.03	-1.31*	-2.69	-0.15**	-1.98**	-0.23**	-0.25**	0.18*
PY 3/ADT 36	0.94	3.23**	1.32*	1.65**	20.27**	0.10	2.98**	0.17*	0.09	-0.07
PY 3/ADT 45	-4.12**	-2.14*	-1.88**	-1.17*	-31.56**	-0.19**	-0.50	-0.14	-0.15**	0.13
PY 3/IR 64	2.61**	-3.08**	-0.47	-0.23	4.76**	0.16**	-1.64**	-0.20*	-0.10	-0.03
PY 3/PMK 3	0.57	1.99*	1.03	-0.25	6.53**	-0.07	-0.84	0.17*	0.15**	-0.10
ADT 43/ADT 36	1.41	1.34	-3.05**	-2.04**	2.43	0.30**	-2.49**	-0.31**	-0.18**	0.10
ADT 43/ADT 45	5.60**	0.01	-0.05	-1.66**	1.54	-0.13**	-2.89**	0.02	-0.27**	0.30**
ADT 43/IR 64	1.34	0.75	0.19	1.57**	-0.69	0.18**	1.40*	0.15	0.18**	-0.15*
ADT 43/PMK 3	-8.35**	-2.10*	2.91**	2.13**	-3.28	0.25**	3.98**	0.14	0.28**	-0.25**
ADT 49/ADT 36	-6.79**	-9.32**	1.96**	-0.75	9.42**	-0.06	3.93**	0.68**	-0.04	0.25**
ADT 49/ADT 45	5.60**	0.01	-0.05	-1.66**	1.54	-0.13**	-2.89**	0.02	-0.27**	0.30**
ADT 49/IR 64	1.34	0.75	0.19	1.57**	-0.69	0.18**	1.40*	0.15	0.18**	-0.15*
ADT 49/PMK 3	-8.35**	-2.10*	2.91**	2.13**	-3.28	0.25**	3.98**	0.14	0.28**	-0.25**
TKM 9/ADT 36	-6.79**	-9.32**	1.96**	-0.75	9.42**	-0.06	3.93**	0.68**	-0.04	0.25**
TKM 9/ADT 45	5.60**	0.01	-0.05	-1.66**	1.54	-0.13**	-2.89**	0.02	-0.27**	0.30**
TKM 9/IR 64	1.34	0.75	0.19	1.57**	-0.69	0.18**	1.40*	0.15	0.18**	-0.15*
TKM 9/PMK 3	-8.35**	-2.10*	2.91**	2.13**	-3.28	0.25**	3.98**	0.14	0.28**	-0.25**
SE (hybrids)	**0.77**	**0.94**	**0.53**	**0.58**	**1.68**	**0.04**	**0.56**	**0.08**	**0.05**	**0.07**

, * Significant at 5 and 1 per cent level respectively

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Table 4. Estimates of standard heterosis in rice

Hybrids	Days to 50 per cent flowering	Plant height (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
STBN 2/ADT 36	5.27**	10.17**	-6.82*	-10.13**	-9.55**	10.29**	-7.53*	-5.28**	-5.25	0.00
STBN 2/ADT 45	-4.17**	11.09**	-8.07*	-10.65**	-17.02**	-4.41	-15.99**	4.42*	-4.42	9.11*
STBN 2/IR 64	-0.18	-9.42**	-1.75	13.71**	-23.21**	-2.94	-17.70**	8.14**	7.04*	0.97
STBN 2/PMK 3	3.86**	18.84**	-9.98**	-11.76**	-8.76**	-8.82**	-8.34**	8.20**	-0.69	8.99*
STBN 3/ADT 36	-0.90	8.72**	-13.03**	-4.94	-6.77**	-2.94	-3.72	-2.56	-3.73	1.22
STBN 3/ADT 45	-21.10**	-15.54**	8.82*	18.54**	46.12**	24.71**	31.60**	18.10**	18.23**	-0.12
STBN 3/IR 64	-15.03**	-12.00**	0.58	5.92	33.96**	9.12**	-8.10*	16.69**	5.25	10.81**
STBN 3/PMK 3	-0.89	-5.96**	-6.39	6.92	19.88**	12.94**	-4.19	14.48**	9.81**	4.25
STBN 4/ADT 36	-8.17**	0.70	-12.65**	-9.20*	-20.48**	-11.76**	-35.37**	7.14**	-2.07	9.60**
STBN 4/ADT 45	-21.56**	-19.37**	11.24**	21.87**	47.82**	29.56**	38.41**	19.86**	22.79**	-2.31
STBN 4/IR 64	-18.56**	-22.65**	-4.03	9.51**	35.87**	12.06**	5.63	13.73**	13.54**	0.12
STBN 4/PMK 3	-3.17*	-15.31**	-7.00*	3.09	19.96**	5.29	-7.82*	13.52**	1.10	12.27**
PY 3/ADT 36	-3.48*	11.37**	-10.02**	-9.13*	6.61**	-7.35*	-10.70**	-3.47	-7.60*	1.58
PY 3/ADT 45	-16.80**	-3.37*	-17.44**	-12.02**	-18.21**	-8.82**	-10.42**	-1.41	-6.49*	5.71
PY 3/IR 64	-6.07**	-5.43**	-11.85**	-8.64*	11.35**	7.35*	-23.63**	-1.46	-4.70	3.40
PY 3/PMK 3	-0.58	10.16**	-12.03**	-8.17*	8.77**	-2.94	-19.63**	5.98**	5.94	0.12
ADT 43/ADT 36	-9.18**	-5.08**	-20.74**	-10.85**	3.75	-16.18**	-8.45**	0.65	-7.04*	8.38*
ADT 43/ADT 45	-10.54**	-15.03**	-0.59	-0.06	20.22**	2.35	4.01	12.37**	0.00	12.39**
ADT 43/IR 64	-14.01**	-15.11**	-0.19	13.10**	18.52**	17.06**	12.25**	15.23**	18.37**	-2.67
ADT 43/PMK 3	-18.38**	-8.89**	5.09	16.01**	12.42**	19.85**	23.33**	16.79**	22.79**	-4.86
ADT 49/ADT 36	-13.86**	2.55	-4.76	-22.63**	-4.54*	-23.53**	-5.58	9.15**	-17.82**	23.57**
ADT 49/ADT 45	-9.69**	3.95*	-4.49	-15.55**	0.81	-30.88**	-26.27**	-8.14**	0.83	-8.63*
ADT 49/IR 64	-5.26**	12.02**	-1.14	-10.27**	1.43	-11.76**	-10.31**	10.11**	-8.98**	21.26**
ADT 49/PMK 3	0.28	-18.33**	-31.29**	-2.44	1.38	-4.41	-16.78**	8.09**	-6.77*	16.16**
TKM 9/ADT 36	-9.27**	-6.87**	-7.24*	-9.17*	-9.00**	-13.24**	-31.81**	-0.30	2.35	-2.43
TKM 9/ADT 45	-11.56**	1.18**	-16.98**	-13.91**	0.64	0.00	-26.14**	7.29**	4.42	2.67
TKM 9/IR 64	-13.70**	8.80**	-13.83**	-12.18**	3.24	-13.24**	-23.90**	-3.92*	2.07	-5.83
TKM 9/PMK 3	-1.17	6.22**	-18.53**	-16.23**	-0.53	-4.41	-26.27**	4.22*	2.62	1.46

, * Significant at 5 and 1 per cent level respectively