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LINE × TESTER ANALYSIS USING CMS SYSTEM IN RICE (*ORYZA SATIVA* L.)

I. S. THAKARE*, A. L. PATEL AND A. M. MEHTA[1]
Department of Agricultural Botany,
B. A. College of Agriculture, Anand Agricultural University, Anand - 388 110, Gujarat, INDIA
[1]Main Rice Research Station, Anand Agricultural University, Nawagam - 387 540, Gujrat, INDIA
e-mail: isag2010@gmail.com

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***Corresponding author**

ABSTRACT
Eighteen rice (*Oryza sativa* L.) genotypes consisting three CMS lines were crossed in a line × tester mating design. The 45F1's and their parents were evaluated with three standard checks in a randomized complete block design with three replications at the Main Rice Research Station, Anand Agricultural University, Nawagam, Gujarat in *kharif* 2007. The estimates of gca effects indicated that, among females, IR 68886 A and IR 68897 A and among males IR-44, IR-60, IR-9761, IR-4266-29-4-2-2-2, IR-5638-139-2-2, IR-69701-9-3-1 and IR-71138-49-2-2 were found as good general combiners for grain yield per plant. High sca effects were observed in the crosses, IR 68886 A × IR-44, IR 68897 A × IET-15554, IR 68897 A × IR–56455-206-2, IR 68902 A × IR-4266-29-4-2-2-2 and IR 68897 A × IR–62161-184-3-1-3-2. They were found to be the best combinations for grain yield per plant and quality traits. The preponderance of non-additive type of gene actions clearly indicated that selection of superior plants should be use for further improvement.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the world's most important staple cereal food crop growing in at least 114 countries under diverse conditions (Anon., 2013). As population growth continues to boost demand for rice, production growth in all the ecosystems is approaching a plateau. Therefore, efforts to enhance rice productivity with keeping grain quality must receive top priority. Increasing rice production can be achieved by application of improved agronomic techniques, developing and adopting high yielding varieties. Major emphasis, in breeding program, is put on the development of improved varieties with superior qualitative and quantitative traits. Hence, there is an urgent need to test various cytoplasmic male sterile (CMS) lines and restorers for their combining ability to exploit the heterosis in rice.

However to breed high yielding varieties, breeders often face the problem of selecting appropriate genotypes as parents and crosses. In a systematic plant breeding programme, selection of parents with desirable characteristics having good gca effects for yield as well as high estimates of sca effects of hybrids are essential. In this context line × tester analysis method introduced by Kempthorne (1957) is one of the powerful tools available to estimate the combining ability effects and aids in selecting desirable parents and crosses for exploitation in pedigree breeding (Rashid *et. al.,* 2007). It provides a systematic approach to large scale studies of continuous variation and better disciplined analysis of the resulting data. Performances *per se* do not necessarily reveal which parents are good or poor combiners. To surmount this difficulty, it is necessary to gather information on the nature of gene actions. Line x tester analysis provides information about general combining ability (gca) and specific combining ability (sca) effects of parents and is helpful in estimating various types of gene actions governs the inheritance of characters. The knowledge of nature and magnitude of gene action controlling yield and yield components is very useful for crop improvement. Combining ability analysis provides information on two components of variance viz., additive and dominance variance. Its role is important to decide parents, crosses and adoption of appropriate breeding procedure to be followed to select desirable segregants (Salgotra *et. al.,* 2009).

The objectives of this study are to assess the combining ability for yield and yield related quality traits, to determine the nature and magnitude of gene actions in a line × tester mating design with a view to identify good combiners including CMS lines and restorers.

MATERIALS AND METHODS

The experimental material comprising of three CMS lines (IR-68886 A, IR-68897 A, IR-68902 A) and fifteen testers (IR-40, IR-60, IR-9761, IR-4266-29-4-2-2-2, IR-5638-139-2-2, IR-56455-206-2, IR–60819-34-2, IR-62161-184-3-1-3-2, IR-69701-9-3-1, IR–71138-49-2-2-1-2, GAUR-1, Suraksha, IET-15554, IET-16555, IET-17162) were selected on the basis of the morphological differences. All These eighteen parents were crossed to produce 45 F1 hybrids according to the line × tester mating design developed by Kempthorne (1957). Crosses were made in a line x tester fashion by adopting the "Isolation Free System" design advocated by Virmani and Casal (1993), as well as by pollinating the CMS line by the respective donors. The resulting 45 hybrids along with 18 parents and three standard checks {Gurjari, GR-11 (Inbreds) and KRH-1 (Hybrid)} were grown in a randomized block design replicated thrice at the Main Rice Research Station, Anand Agricultural University, Nawagam, Gujarat in *kharif* 2006 and 2007. Each entry was planted in a 3 meter long row with inter and intra row spacing of 20 × 15 cm. One line of each entry was planted in each replication. All the recommended agronomic and plant protection practices were uniformly applied throughout the crop growth period to raise a good crop.

Five competitive plants were randomly selected to record the observations on grain yield and grain quality characters viz., grain length, grain breadth, length: breadth ratio, hulling percentage, milling percentage and head rice recovery percentage and their mean values were subjected to statistical analysis. Data recorded were subjected to analysis of variance according to Panse and Sukhatme (1978) to determine significant differences among genotypes. Combining ability effects are very effective genetic parameters in deciding the next phase of breeding programs. They were computed according to the line × tester method. Significance test for general combining ability and specific combining ability effects were performed using t-test. (σ^2gca/σ^2sca), and (σ^2D/σ^2A)$^{1/2}$ ratios were used to rate the relative weight of additive versus non-additive type of gene actions (Verma & Srivastava 2004).

RESULTS AND DISCUSSION

Analysis of variance for combining ability

The recorded data on yield and quality parameters were subjected to analysis of variance and mean square due to various sources of variation to confirm the differences among rice genotypes (Table 1). Analysis of variance for combining ability revealed that the mean squares due to females (lines) were significant only for character grain yield per plant. The

Table 1: Analysis of variance and variance estimates for combining ability for grain quality traits in rice

Source	d.f.	Grain yield/ plant (g)	Grain length (mm)	Grain breadth (mm)	Length:breadth ratio (%)	Hulling (%)	Milling (%)	Head rice recovery (g)
Replication	2	19.69*	0.01	0.03	1.60**	85.11**	18.60	108.65**
Hybrid	44	575.45**	1.54**	0.06**	0.45**	16.31**	171.31**	361.77**
Females	2	3615.49**	4.30	0.00	0.91	8.90	252.42	300.58
Males	14	325.01	1.47	0.09	0.61	18.19	161.90	241.09
F × M	28	483.52**	1.38**	0.06**	0.34**	15.90**	170.22**	426.48**
Error	88	5.88	0.02	0.03	0.17	3.362	6.62	5.49
σ^2 F		80.15	0.10	0.00	0.02	0.11	5.47	6.53
σ^2 M		35.15	0.16	0.01	0.05	1.59	17.30	26.06
σ^2 gca		72.65	0.11	0.00	0.02	0.36	7.44	9.79
σ^2 sca		158.29	0.45	0.01	0.07	4.02	54.66	139.98
σ^2A		290.61	0.42	0.00	0.09	1.44	29.77	39.16
σ^2D		633.15	1.81	0.05	0.27	16.07	218.65	559.93
σ^2A/σ^2D		0.46	0.23	0.07	0.34	0.09	0.14	0.07
Degree of dominance		1.48	2.07	3.89	1.71	3.34	2.71	3.78

* and ** indicate significance at 5% and 1% level, respectively

Table 2: Estimates of general combining ability (gca) effects of parents for grain quality traits in rice

Source	Grain yield/ plant (g)	Grain length (mm)	Grain breadth (mm)	Length to breadth ratio (%)	Hulling (%)	Milling (%)	Head rice recovery (g)
Female parents							
IR 68886 A	5.72**	0.23**	-0.003	0.09	-0.44	1.48**	-2.23**
IR 68897 A	4.60**	-0.35**	0.01	-0.16**	-0.01	1.25**	2.83**
IR 68902 A	-10.33**	0.12**	-0.01	0.07	0.45	-2.73**	-0.59
S.Ed.	0.44	0.02	0.02	0.06	0.29	0.37	0.38
Male parents							
IR- 44	9.59**	-0.59**	0.084	-0.38**	-1.62 *	-10.99**	-11.92**
IR- 60	4.29**	-0.47**	0.09	-0.35**	1.43 *	2.19**	-2.16*
IR- 9761	3.41**	-0.15**	-0.09	0.06	1.05	2.50**	-6.84**
IR- 4266-29-4-2-2-2	9.23**	0.13**	0.00	0.07	-0.91	-1.01	-0.65
IR- 5638-139-2-2	4.08**	-0.24**	-0.07	0.00	-0.52	1.98*	3.15**
IR- 56455-206-2	-2.49*	0.57**	0.07	0.11	-0.84	-2.20**	8.66**
IR- 60819-34-2	-5.72**	0.16**	-0.056	0.183	0.5	4.36**	2.369**
IR- 62161-184-3-1-3-2	-1.05	-0.00	0.08	-0.13	-0.47	2.67**	-4.99**
IR- 69701-9-3-1	2.52*	-0.33**	0.07	-0.25*	-1.15	1.99*	-0.48
IR- 71138-49-2-2-1-2	2.65**	0.57**	-0.07	0.35**	3.03**	6.20**	4.99**
GAUR– 1	-1.40	-0.62**	-0.09	-0.13	-1.16	-1.53	1.00
Suraksha	-9.03**	0.24**	0.02	0.06	2.49**	-5.85**	-0.52
IET- 15554	-0.93	0.50**	-0.01	0.22	-1.25	-1.37	0.77
IET- 16555	-3.76**	-0.12*	0.18**	-0.32*	-0.70	1.68*	6.19**
IET- 17162	-11.39**	0.34**	-0.20**	0.50**	0.08	-0.61	0.44
S. Ed.	0.98	0.05	0.05	0.12	0.65	0.83	0.85

* and ** indicate level of significance at 5% and 1%, respectively

variance due to hybrids differed significantly for all the characters. The mean squares due to males (testers) were found non significant for all the characters. Thus, suggesting the importance of heterosis breeding for improvement of rice. Vanaja *et al*. (2003) reported similar results. A comparison of variances due to males (σ^2m) and females (σ^2f) indicated that the females showed higher magnitude of variability for the character grain yield per plant. The magnitudes of sca (average) variances were higher than the (σ^2gca) gca variances for almost all the characters indicated the predominance of non-additive gene action in the inheritance of all the traits. The presence of non-additive genetic variance is the primary justification for initiating the hybrid programme (Cockerham, 1961). The perusal of the data revealed lower σ^2 A/σ^2 D ratio for all the characters also suggested preponderance of non additive gene action. These observations are in accordance with the report of Saravanan *et al*. (2006), Anandkumar *et al*. (2004).

General combining ability

Variation in general combining ability (gca) effects was estimated among females and males for yield and quality traits to identify the best parent for subsequent hybrid development programme (Table 2). An overall appraisal of significant and positive gca effects revealed that among females IR 68886 A (5.72) and IR 68897 A (4.60) were good general combiners for grain yield per plant. Sanghera and Hussain (2012) observed similar good general combiner female parents for yield in rice. The parental line, IR 68886 A had also favorable

Table 3: Estimates of specific combining ability (sca) effects for grain quality traits in rice

Source	Grain yield/plant (g)	Grain length (mm)	Grain breadth (mm)	Length: breadth ratio (%)	Hulling (%)	Milling (%)	Head rice recovery (g)
IR 68886 A × IR - 44	37.43**	1.24**	0.10	0.35	0.59	1.57	0.93
IR 68886 A × IR - 60	-4.74**	0.47**	0.07	0.09	-0.56	0.69	-3.77*
IR 68886 A × IR - 9761	5.00**	0.31**	0.03	0.10	0.08	-1.82	-1.06
IR 68886 A × IR - 4266-29-4-2-2-2	-7.54**	0.68**	-0.23*	0.71**	-0.07	-2.34	-1.19
IR 68886 A × IR - 5638-139-2-2	-0.83	0.04	0.03	-0.01	1.79	-2.54	-6.18**
IR 68886 A × IR - 56455-206-2	-11.66**	-0.51**	-0.05	-0.13	-2.2	-1.55	22.59**
IR 68886 A × IR - 60819-34-2	0.77	0.03	0.07	-0.13	0.18	0.07	-11.45**
IR 68886 A × IR - 62161-184-3-1-3-2	-4.43*	-0.71**	-0.10	-0.13	0.68	3.59*	-10.28**
IR 68886 A × IR - 69701-9-3-1	-1.06	-0.40**	-0.07	-0.05	0.62	-0.36	-0.15
IR 68886 A × IR - 71138-49-2-2-1-2	-4.68**	0.44**	0.10	0.01	-3.32**	-1.98	-4.40**
IR 68886 A × GAUR - 1	-0.78	0.38**	-0.01	0.19	1.81	-2.01	-2.26
IR 68886 A × SURAKSHA	-4.97**	-1.16**	0.08	-0.60**	-1.75	7.46**	11.69**
IR 68886 A × IET - 15554	-6.09**	-0.37**	0.09	-0.31	0.22	0.55	12.97**
IR 68886 A × IET - 16555	-4.46*	-0.02	-0.19*	0.27	1.54	-0.60	-8.12**
IR 68886 A × IET - 17162	8.03**	-0.41**	0.10	-0.36	0.39	-0.74	0.67
IR 68897 A × IR - 44	-17.83**	-0.31**	-0.17	0.12	1.91	11.98**	-2.91
IR 68897 A × IR - 60	-1.42	-0.44**	-0.14	0.03	1.55	-1.58	13.63**
IR 68897 A × IR - 9761	-14.34**	-0.85**	-0.17	-0.09	-1.35	0.56	3.84*
IR 68897 A × IR - 4266-29-4-2-2-2	-9.09**	-0.76**	-0.05	-0.28	0.48	1.39	6.12**
IR 68897 A × IR - 5638-139-2-2	-11.25**	-0.76**	-0.07	-0.23	-0.78	1.12	6.89**
IR 68897 A × IR - 56455-206-2	14.83**	0.66**	0.075	0.16	0.09	-2.28	-28.21**
IR 68897 A × IR - 60819-34-2	3.21	-0.45**	0.14	-0.43*	1.1	-0.67	11.41**
IR 68897 A × IR - 62161-184-3-1-3-2	11.50**	0.55**	0.16	-0.00	-0.80	-4.95**	5.94**
IR 68897 A × IR - 69701-9-3-1	6.12**	0.17*	0.12	-0.09	0.11	-2.79	-7.04**
IR 68897 A × IR - 71138-49-2-2-1-2	1.36	-0.21*	0.01	-0.11	-4.33**	-8.69**	-10.99**
IR 68897 A × GAUR - 1	6.66**	0.25**	0.01	0.09	-0.71	-3.293*	2.68
IR 68897 A × SURAKSHA	0.28	0.69**	-0.04	0.36	3.04**	15.75**	9.67**
IR 68897 A × IET - 15554	13.38**	0.76**	0.08	0.18	0.19	-5.63**	-16.02**
IR 68897 A × IET - 16555	6.94**	-0.02	0.10	-0.13	-0.49	-2.19	2.20
IR 68897 A × IET - 17162	-10.36**	0.72**	-0.05	0.42	-0.07	1.27	2.81
IR 68902 A × IR - 44	-19.60**	-0.93**	0.07	-0.47*	-2.49*	-13.55**	1.98
IR 68902 A × IR - 60	6.16**	-0.03	0.08	-0.13	-1.00	0.89	-9.86**
IR 68902 A × IR - 9761	9.34**	0.54**	0.14	-0.01	1.26	1.26	-2.78
IR 68902 A × IR - 4266-29-4-2-2-2	16.63**	0.08	0.28**	-0.43*	-0.40	0.95	-4.93**
IR 68902 A × IR - 5638-139-2-2	10.08**	0.72**	0.04	0.24	-1.02	1.42	-0.70
IR 68902 A × IR - 56455-206-2	-3.18	-0.15	-0.02	-0.03	2.11	3.83**	5.63**
IR 68902 A × IR - 60819-34-2	-3.98*	0.42**	-0.21*	0.56**	-1.33	0.59	0.03
IR 68902 A × IR - 62161-184-3-1-3-2	-7.07**	0.16	-0.05	0.13	0.12	1.36	4.345**
IR 68902 A × IR - 69701-9-3-1	-5.06**	0.23*	-0.04	0.14	-0.72	3.15*	7.20**
IR 68902 A × IR - 71138-49-2-2-1-2	3.32	-0.23**	-0.11	0.10	7.64**	10.67**	15.38**
IR 68902 A × GAUR - 1	-5.88**	-0.63**	0.00	-0.29	-1.10	5.29**	-0.42
IR 68902 A × SURAKSHA	4.69**	0.47**	-0.04	0.24	-1.28	-23.21**	-21.36**
IR 68902 A × IET - 15554	-7.29**	-0.39**	-0.17	0.13	-0.41	5.07**	3.05*
IR 68902 A × IET - 16555	-2.49	0.036	0.09	-0.14	-1.06	2.79	5.92**
IR 68902 A × IET - 17162	2.32	-0.30**	-0.04	-0.06	-0.33	-0.53	-3.48*
S. Ed.	1.70	0.09	0.09	0.21	1.13	1.44	1.48

* and ** indicate level of significance at 5% and 1 %, respectively

genes grain length (0.23) and milling percentage (1.48), whereas line IR 68897 A possessed desirable genes for quality traits milling percentage (1.25) and head rice recovery (2.83). On the other hand, for the trait grain length the line IR 68902 A (0.12) was found significant. Grain yield/plant, being the ultimate objective, is very important to rice breeders. Among the males IR-44 (9.59), IR-60 (4.29), IR-9761 (3.41), IR-4266-29-4-2-2-2 (9.23), IR 5638-139-2-2 (4.08), IR-69701-9-3-1 (2.52) and IR-71138-49-2-2-1-2 (2.65) were good general combiners as indicated by significant and positive gca effects for grain yield per plant. Similar results reported by Bagheri and Jelodar (2010).

For quality traits male parent IR-4266-29-4-2-2-2 (0.13), IR-71138-49-2-2-1-2 (0.57) exhibited significant positive estimates of gca effects and thus possessed favorable genes for long grain length. However IET-17162 (-0.20) indicated significant negative estimate of gca effect and hence, identified as good general combiner for the trait grain breadth as supported by earlier findings of Kumar *et al.* (2007). Significant and positive gca effect for length to breadth ration were given by males IR-71138-49-2-2-1-2 (0.35) and IET-17162 (0.50) and therefore, considered as good general combiners for this trait. Similar results reported by Singh *et al.* (2001). Apart from these, significant and positive gca effects are registered in male parents, IR-60 (1.43), IR-71138-49-2-2-1-2 (3.03) and Suraksha (2.49) for hulling percentage; IR-60 (2.19), IR-9761 (2.50), IR-5638-139-2-2 (1.98), IR-60819-34-2 (4.36), IR- 62161-184-3-1-3-2 (2.67), IR-69701-9-3-1 (1.99), IR-71138-49-2-2-1-2 (6.20), and IET 16555 (1.68) for milling percentage; whereas, IR-5638-139-2-2 (3.15), IR-56455-206-2 (8.66), IR-60819-34-2 (2.369), IR-71138-49-2-2-1-2 (4.99), and IET-16555 (6.19) considered as good general combiners. The present results fall in the same line with Raju *et al.* (2001) and Babu and Reddy (2002). Identification of such superior combiners helps the breeders in selecting appropriate parents to be used in the breeding programmes to develop superior varieties.

Specific combining ability

Specific combining ability effect estimates revealed a very wide range of variation for all the characters (Table 3). The results of grain yield per plant revealed that 14 crosses exhibited significant positive sca effects. High sca effect results mostly from dominance and interaction effects existed between the hybridizing parents. Out of them, positive significant sca effect for grain yield per plant was exhibited by 5 promising specific crosses viz., IR 68886 A × IR-44, IR 68897 A × IET-15554, IR 68897 A × IR-56455-206-2, IR 68902 A × IR-4266-29-4-2-2-2 and IR 68897 A × IR-62161-184-3-1-3-2 indicated the preponderance of non additive gene action involving good x good and good × poor combining parents. These results coincide with the findings of Sanghera and Hussain (2012) and Bagheri and Jelodar (2010). Of these five combinations, in addition to grain yield per plant, the cross combinations IR 68886 A × IR-44, IR 68897 A × IET-15554 and IR 68897 A × IR-56455-206-2 registered high and positive sca effects for grain length; cross IR 68902 A × IR-4266-29-4-2-2-2 for grain breadth was earlier reported by Kumar *et al.* (2007); whereas, cross IR 68897 A × IR-62161-184-3-1-3-2 for grain length and head rice recovery. These results are in conformity with the earlier findings of Sarma *et al.* (2007).

From this study it is observed that parental lines IR 68886 A and IR 68897 A among females, parents IR-44, IR-9761, IR-4266-29-4-2-2-2, IR-5638-139-2-2, IR-69701-9-3-1 and IR-71138-49-2-2 among males and cross combinations, IR 68886 A × IR-44, IR 68897 A × IET-15554, IR 68897 A × IR-56455-206-2, IR 68902 A × IR-4266-29-4-2-2-2 and IR 68897A × IR-62161-184-3-1-3-2 could be exploited beneficially in future rice breeding programme by adopting appropriate breeding technique in order to evolve high yielding hybrid varieties.

REFERENCES

Anandkumar; Singh, N. K. and Chaudhary, V. K. 2004. Line × tester analysis for grain yield and related characters in rice. *Madras Agric. J.* **91**(**4-6**)**:** 211-214.

Anonymous, 2013. http://www.irri.org.

Babu, S. S. and Reddy, P. S. 2002. Combining ability analysis in rice (*Oryza sativa* L.). *Research on Crops*. **3**(**3**)**:** 592-598.

Bagheri, N. and Jelodar, N. B. 2010. Heterosis and combining ability analysis for yield and related-yield traits in hybrid rice. *Intern J. Biol.* **2**(**2**)**:** 222-231.

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

Kumar, S.; Singh, H. B. and Sharma, J. K. 2007. Gene action for grain yield, its components and quality traits in hill rice (*Oryza sativa* L.) varieties. *Indian J. Genet.* **67**(**3**)**:** 275-277.

Panse, V.G. and Sukhatme, P.V. 1978. 'Statistical methods for agriculture workers' I.C.A.R., New Delhi.

Raju, C. S., Rao, M. V., Reddy, G. L., Rao, J. S. and Reddy K. S. 2003. Heterosis and combining ability for some qualitative traits in rice (*O. sativa* L.). *Ann. Agric. Res.* **24**(**2**)**:** 227-233.

Rashid, M., Cheema, A. A., and Ashraf, M. 2007. Line x tester analysis in basmati rice. *Pakistan Journal of Botany*. **39**(**6**)**:** 2035–2042.

Salgotra, R. K., Gupta, B. B. and Praveen Singh 2009. Combining ability studies for yield and yield components in Basmati rice. *Oryza.* **46**(**1**)**:** 12-16.

Sanghera, G. S. and Hussain, W. 2012. Heterosis and combining ability estimates using line × tester analysis to develop rice hybrids for temperate conditions. *Not Sci Biol*. **4**(**3**)**:** 131-142.

Saravanan, K.; Ramya, B.; Satheesh Kumar, P. and Sabesan. T. 2006. Combining ability for yield and quality characters in rice (*Oryza sativa* L.). *Oryza.* **43**(**4**)**:** 274-277.

Sarma, M. K., Sharma, R. K., Agrawal, R. K. and Richharia, A. K. 2007. Combining ability and gene action for yield and quality traits in *Ahu* rices of Assam. *Indian J. Genet.* **67**(**3**)**:** 278-280.

Singh, A. K., Tikle, A. N. and Yadava, H. S. 2001. Combining ability for grain quality traits in rice (*Oryza sativa* L.*). Flora and Fauna.* **7**(**2**)**:** 81-82.

Vanaja, T.; Babu, L. C.; Radhakrishnan, V. V. and Pushkaran, K. 2003. Combining ability for yield and yield components in rice varieties of diverse origin. *Journal of Tropical Agriculture*. **41**(**1/2**)**:** 7-15.

Verma, O. P. and Srivastava, H. K. 2004. Genetic component and combining ability analyses in relation to heterosis for yield and associated traits using three diverse rice-growing ecosystems, *Field Crops Research*. **88**(**2-3**)**:** 91-102.

Virmani, S. S. and Casal, C. 1993. Isolation-free system for producing experimental hybrid rice seed for preliminary evaluation. *IRRN*. **18**(**3**)**:** 6-7.