Madras Agric. J., 100 (1-3): 36-41 March 2013
https://doi.org/10.29321/MAJ.10.001233

Character Association and Parent Progeny Regression Studies for Yield and its Related Traits in Segregating Generations of TGMS Rice (*Oryza sativa* L.)

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The aims of this study were to determine the response to selection for high grain yield and yield related components, to estimate the heritability of these traits, to compute the correlation of grain yield with yield components and to estimate the genetic potential transferred from one generation to other by using different segregating generations of rice (*Oryza sativa* L.). Various segregating populations (F_2, F_3 and F_4) of the cross, TS 29 / CO(R) 49 were evaluated for yield and its related traits. The results indicated that correlation studies in F_3 generation had positive association of single plant yield with fertility percentage, number of productive tillers per plant, panicle length, panicle exertion percentage, stigma exertion percentage and spikelet fertility percentage. Study on parent-progeny regression revealed positive significant regression and correlation coefficient estimates observed in F_3-F_4 generation for days to 50 per cent flowering, number of productive tillers per plant, panicle length, panicle exertion percentage and stigma exertion percentage which indicated that F_3 are good indicators of F_4 performance for all these traits. Narrow sense heritability increased with advancement of generation from F_2 to F_4 indicating the additivity of gene effects for number of productive tillers per plant, panicle length and panicle exertion percentage. It indicated the chances of selecting high yielding genotypes at early generations based on these characters are valuable.

Key words: TGMS rice, correlation, parent-progeny regression analysis, heritability, selection.

Today, rice is synonymous with food security in most parts of Asia. Recent progress in plant breeding research indicated that a significant shift in the yield frontier could be made possible through hybrid rice. Three-line breeding utilizing the cytoplasmic genic male sterility (CMS) system has been found to be effective in the development of commercial hybrids and will continue to play an important role in heterosis breeding. But this system has some constraints such as a plateauing yield, dependency on a single CMS source (WA), restriction on the choice of male parents due to problems associated with fertility restoration, complex seed production procedures and high seed cost. The application of thermo-sensitive genic male sterile (TGMS) lines has a great potential to exploit two-line hybrid rice technology. The two line hybrid breeding system, utilizing thermo-sensitive genic male sterility is economically feasible as well as a viable alternative to cytoplasmic male sterile (CMS) based three line breeding due to much simplified hybrid seed production (Shukla and Pandey, 2008). Here there is no need for a maintainer line for seed multiplication, thus making seed production simpler and more cost-effective.

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Any fertile line can be used as a pollen parent (PP); therefore, the frequency of heterotic hybrids is higher among two-line hybrids than among three-line hybrids, thereby increasing hybrid-breeding efficiency. Crop improvement for grain yield has been achieved in rice through effective use of various segregating populations and fixing desirable character combinations. However, there are still possibilities to increase the yield output through proper breeding technologies in rice. Grain yield is a complex trait and is the result of interaction of many variables. A knowledge of the association between yield and its component traits themselves can provide the efficiency of selection and parent progeny regression is a method commonly used for estimating the amount of genetic potential transferred from parent to progeny. Hence identification of high yielding TGMS lines with desirable floral traits is one of the important aspects that a breeder should keep in mind while selecting a line in hybrid breeding. Therefore, the present study was conducted to evaluate the inter relationship between yield and its contributing characters and how far the genetic potential is transferred from one generation to other for the cross TS 29 / CO(R) 49 .

Materials and Methods

The stable TGMS parental line, TS 29 was crossed with the improved rice variety CO(R) 49 for synthesis of segregating population. For making the cross, parental lines were raised in the summer season for getting complete sterility in the female line (TS 29) at Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore. Scheduled cultural operations and need based plant protection measures were carried out. The crossed F_1 seeds were raised along with parents in the next season (Kharif 2007) for studying the F_1 plant progenies and seeds were harvested during maturity stage and forwarded to F_2 generation (Late Rabi 2007-08). In the F_3 population, each progeny was raised during sterility inducing environment (Summer 2008) in paired rows and each row contains 12 plants. During the maturity stage, the sterile plants were observed. A total of 84 homogeneous progenies were identified and plants selected within the progenies were maintained as stubble under a separate nursery during cool season (Rabi 2008-
9) . The observed sterile plants from the F_3 population were uprooted and planted in the separate field for getting seeds during cool season and each stubble progeny contains nine stubble plants. Pollen fertility was observed in all the stubble derived plants. Some of the biometric observations were taken up in the stubble field for selecting desirable sterile lines. Matured seeds were collected after attaining physiological maturity. The F_4 generation were raised during fertility restricting season (Summer 2009) from the fertile seeds obtained by selfing of the selected sterile stubbles during the fertility favouring environment in the stubble nursery. Pollen fertility was observed in all the families during flowering stage. Complete and uniformly sterile lines were identified with desirable floral traits. These lines are grouped into early and medium duration lines and all the biometrical characters were observed. For biometrical studies the F_3 and F_4 generation were raised in three replications and five plants in each replication were observed and their mean values were used for calculating phenotypic and genotypic correlation coefficient, parent progeny regression analysis and heritability estimates. The correlation coefficient, regression analysis and heritability of F_2, F_3 and F_4 families were estimated for the traits *viz*., days to 50 per cent flowering, plant height, number of productive tillers per plant, pollen fertility percentage, pollen sterility percentage, panicle length, panicle exertion, stigma exertion percentage, spikelet fertility percentage, spikelet sterility percentage and single plant yield. The estimates of phenotypic and genotypic correlation coefficient values were calculated as explained by Singh and Chaudhary (1985), and narrow sense heritability was calculated based on parent-offspring regression (Smith and Kinman, 1965). The parent progeny regression analysis was carried out by regressing the mean values of a character in the progeny (F_3 and F_4) upon the value of a character in the parents ($F_2$and F_3). The regression coefficient b was calculated by using the formula suggested by Lush (1940).

Results and Discussion

The correlation coefficients which provide a good estimate of direction and strength of relationship among the characters are presented in the Tables 1 and 2. The genotypic correlation coefficients were marginally higher than the phenotypic correlation coefficients for most of the characters. The characters namely pollen fertility percentage (0.433 and 0.379), number of productive tillers per plant (1.019 and 0.928), panicle length (0.36 and 0.317), panicle exertion percentage (0.381 and 0.350), stigma exertion percentage (0.375 and 0.365) and spikelet fertility percentage (0.411 and 0.371) had a highly significant positive genotypic and phenotypic correlation with single plant yield in the F_3 generation. However, the characters, days to 50 per cent flowering (0.067 and 0.056) and plant height (0.014 and 0.015) had non-significant positive correlation with yield. In the F_4 generation (studied in sterility favouring environment) single plant yield

Table 1. Genotypic and phenotypic correlatio coefficient among yield and important characters for TGMS in F_3 population

Characters		DFF	PF %	PH	NP	PL	PE %	SE %	SF %	SPY
Days to 50%	G	1.000	0.221**	0.309**	0.086	0.366**	0.326**	0.134	0.182*	0.067
flowering	P	1.000	0.186	0.291**	0.083	0.304**	0.285**	0.124	0.165	0.056
Pollen fertility %	G		1.000	0.131	0.379**	0.508**	0.538**	0.944**	1.030**	0.433**
	P		1.000	0.113	0.333**	0.390**	0.435**	0.832**	0.848**	0.379**
Plant height	G			1.000	0.024	0.333**	0.273**	0.089	0.133	0.014
	P			1.000	0.023	0.285**	0.257**	0.088	0.127	0.015
No. of productive	G				1.000	0.370**	0.377**	0.334**	0.374**	1.019**
tillers/ plant	P				1.000	0.311**	0.340**	0.308**	0.321**	0.928**
Panicle length	G					1.000	0.97**1	0.409**	0.533**	0.365**
	P					1.000	0.871**	0.370**	0.416**	0.317**
Panicle exertion	G						1.000	0.458**	0.553**	0.381**
percentage	P						1.000	0.438**	0.464**	0.350**
Stigma exertion	G							1.000	0.921**	0.375**
percentage	P							1.000	0.859**	0.365**
Spikelet fertility percentage	G								1.000	0.411**
	P								1.000	0.371**
Single plant yield	G									1.000
	P									1.000

Table 2. Genotypic and phenotypic correlation coefficient between important characters for TGMS in F_4 sterile population

Characters		DFF	PS %	PH	NP	PL	PE %	SE %	SS %
Days to 50%	G	1.000	-0.401**	0.147	0.163	0.281**	0.503**	-0.002	-0.431**
flowering	P	1.000	-0.399**	0.139	0.162	0.253**	0.451**	-0.002	-0.393**
Pollen sterility	G		1.000	-0.110	-0.085	-0.353**	-0.317**	0.291**	0.980**
percentage	P		1.000	-0.093	-0.084	-0.352**	-0.316**	0.287**	0.750**
Plant height	G			1.000	0.986**	0.084	0.296**	0.151	-0.144
	P			1.000	0.875**	0.063	0.273**	0.097	-0.083
No. of	G				1.000	0.081	0.296**	0.185	-0.136
productive tillers per plant	P				1.000	0.080	0.295**	0.184	-0.133
Panicle length	G					1.000	0.513**	0.498**	-0.381**
	P					1.000	0.510**	0.473**	-0.370**
Panicle exertion	G						1.000	0.306**	-0.250*
percentage	P						1.000	0.292**	-0.240*
Stigma exertion	G							1.000	0.285*
percentage	P							1.000	0.244*
Spikelet sterility	G								1.000
percentage	P								1.000

could not be recorded. Only intercorrelations among other traits were studied. Regarding the interrelation of yield components in the F_3 generation, days to 50 per cent flowering had high significant positive correlation with plant height (0.309 and 0.291), panicle length (0.366 and 0.304) and panicle exertion percentage (0.326 and 0.285) for both the correlation coefficients. Pollen fertility percentage (0.221) and spikelet fertility percentage (0.182) had high significant positive correlation with days to 50 per cent flowering. Pollen fertility percentage had high significant positive correlation with number of productive tiller per plant (0.379 and 0.333), panicle length (0.508 and 0.390), panicle exertion percentage (0.944 and 0.832), spikelet fertility (1.030 and 0.848) and single plant yield (0.433 and 0.379). Pollen fertility percentage was found to be non-significantly associated with plant height.The highly positive significant inter correlation was noticed between panicle length (0.333 and 0.285), and panicle exertion percentage (0.273 and 0.257) with plant height. The rest of the characters showed non-significant association. Number of productive tiller had highly significant association with panicle length, panicle exertion percentage, stigma exertion percentage, spikelet fertility percentage and single plant yield. High positive inter correlation was observed between panicle exertion percentage, stigma exertion percentage, spikelet fertility percentage and single plant yield with panicle length. Panicle exertion percentage had high positive association with stigma exertion percentage, spikelet fertility percentage and single plant yield. Spikelet fertility percentage and single plant yield showed a high positive relationship with stigma exertion percentage.

Table 3. Intergeneration correlation coefficient (r) regression coefficient (b) between F_2-F_3 and F_3-F_4 and narrow sense heritability (h_2N) estimates

Trait	F_2- F_3			F_3- F_4		
	Correlation coefficient (r)	Regression coefficient (b)	Narrow sense heritability (h_2N)	Correlation coefficient (r)	Regression coefficient (b)	Narrow sense heritability (h_2N)
Days to 50% flowering(DFF)	0.78**	0.93**	0.61	0.99**	0.95**	0.48
Pollen fertility percentage	0.63**	0.82**	0.65	n.d	n.d	n.d
Plant height (PH)	0.96**	1.64**	0.85	0.02	0.02	0.50
No. of productive tillers/ plant(NP)	0.97**	1.04**	0.54	0.91**	0.90**	0.50
Panicle length(PL)	0.97**	0.97**	0.50	0.44**	0.62**	0.70
Panicle exertion % (PE)	0.98**	1.11**	0.57	0.91**	1.02**	0.56
Stigma exertion % (SE)	0.95**	1.04**	0.55	0.87**	0.68**	0.39
Spikelet fertility percentage(SPK)	0.99**	0.94**	0.47	n.d	n.d	n.d
Single plant yield (SPY)	0.99**	0.93**	0.47	n.d	n.d	n.d

DFF- Days to 50% flowering, PH- Plant height, NP- Number of productive tillers/ plant, PF %- Pollen fertility percentage, PS %- Pollen sterility percentage, PL- Panicle length, PE %- Panicle exertion, SE %- Stigma exertion percentage, SF %- Spikelet fertility percentage, SS %- spikelet sterility percentage and SPY- single plant yield, n.d-not determined.

In the F_4 generation, days to 50 per cent flowering had high positive interrelationship with panicle exertion percentage (0.503) and highly significant negative correlation with pollen sterility percentage (- 0.401) and spikelet sterility percentage (- 0.431). Stigma exertion percentage (- 0.002) had negative non significant association with days to flowering. Pollen sterility percentage had high significant association with stigma exertion percentage and spikelet sterility and high negative significant correlation with panicle length (- 0.353) and panicle exertion percentage (- 0.317). Spikelet sterility percentage had negative association with most of the characters except and positive intercorrelation with pollen sterility percentage (0.980) and stigma exertion percentage (0.287). Number of productive tillers had recorded high significant correlation with plant height and non-significant relation with days to 50% flowering and negative non significant association with pollen sterility percentage. Stigma exertion percentage had high positive significant association with pollen sterility percentage (0.291) panicle length (0.498) and panicle exertion percentage (0.306).

Knowledge on association of traits would further help in identifying traits to be given importance during selection. It also reveals the effect of one character on the other related character particularly during selection. So correlation coefficients between yield and other important traits as well as *inter se* correlations among the traits have been calculated for F_3 and F_4 generations. Significant positive association of pollen fertility percentage, number of productive tillers per plant, panicle length, panicle exertion percentage, stigma exertion percentage and spikelet fertility percentage with yield emphasized the importance of these traits in improving the grain yield. These results are in confirmity with earlier reports of Suman *et al.* (2006). The information on the inter correlation among the yield components showed the nature and extent of relationship with each other. This will help in the simultaneous improvement of different characters along with grain yield in the breeding programmes. In the F_3 generation, inter correlation was observed between most of the characters. The important traits like pollen fertility percentage had highly significant positive correlation with number of productive tillers, panicle length, panicle exertion percentage, stigma exertion percentage, spikelet fertility and single plant yield. Borkakati *et al.* (2005) also obtained the similar results. Ali *et al.* (2008) reported 50 per cent natural out crossing rate with more than 70 % panicle exertion in the case of TGMS lines. F_4 generation was raised during summer season and hence single plant yield could not recorded. Only inter correlation among the plant and floral morphological characters could be studied. Some of the characters recorded negative association with other traits in F_4 generation. Pollen sterility had highly significant negative association with panicle length, panicle exertion percentage and high significant positive correlation with stigma exertion and spikelet sterility percentage. Non significant negative correlation was observed between days to 50% flowering and stigma exertion percentage. Comparison of performance of F_3 and F_4 revealed a considerable decrease in variance in F_4 for important traits like number of productive tillers per plant, panicle length and panicle exertion percentage due to reduction in heterozygosity. Correlation studies in F_3 generation had the positive association of single plant yield with fertility percentage, number of productive tillers per plant, panicle length, panicle exertion percentage, stigma exertion percentage and spikelet fertility percentage. A total of 84 complete sterile plants were selected from the F_3 population and stubble planted in separate field for getting selfed seeds. Some of the progenies were selected for good yield and desirable floral traits. In F_4 generation inter correlation among the traits was studied. Pollen sterility percentage had high significant association with stigma exertion percentage and spikelet sterility. Stigma exertion percentage had high positive significant association with pollen sterility percentage, panicle length and panicle exertion percentage. F_4 population was raised during summer season for assessing the level of sterility in the selected individual progenies. Most of the lines were identified as uniform and completely pollen and spikelet sterile.

Parent–progeny regression and heritability of traits

Results on the regression of yield and other traits of F_2 on F_3 and F_3 on F_4 and narrow sense heritability estimated from regression coefficient values are shown in Table 3. The intergeneration (F_2 and F_3) correlation and regression were positive and highly significant for the traits viz., days to 50 per cent flowering (0.78 and 0.93), pollen fertility percentage (0.63 and 2.71) plant height (0.96 and 1.64), number of productive tillers per plant (0.97 and 1.04), panicle length (0.97 and 0.97), panicle exertion percentage (0.98 and 1.11), stigma exertion percentage (0.95 and 1.04), spikelet fertility percentage (0.99 and 0.94) and single plant yield (0.99 and 0.93). In between F_2 and F_3 correlation regression were positive and highly significant for most of traits studied. However, plant height was not significant. Negative non significant estimate was noticed in pollen sterility and spikelet sterility percentage. The estimated narrow sense heritability values in F_2 generation were 0.61, 0.65, 0.85, 0.54, 0.50, 0.57, 0.55, 0.47 and 0.47 for the traits viz., days to 50 per cent flowering, pollen fertility percentage, plant height, number of productive tillers, panicle length, panicle exertion percentage, stigma exertion percentage, spikelet fertility percentage and single plant yield respectively. The F_3 generation heritability values were higher than F_2 for the trait panicle length (0.70). F_3 heritability of the pollen fertility percentage was 0.65 and that of spikelet fertility percentage was 0.47.

Parent progeny regression analysis is one of the efficient tools for estimating heritability to understand whether selection will be effective in the base population. There are different methods of estimating heritability among which heritability based on parent progeny regression is the best (Smith and Kinman, 1965). Heritability estimates from regression analysis are more conservative whereas heritability estimates from variancecovariance analysis are overestimates. In the early generation like F_2 where scrambling of genes had occurred due to segregation, the heritability is expected to be very low or even negative. However as generation advances, the interfamily variance gets increased while intrafamily variance decreases and the additive genetic variability will be fixed and the heritability will increase. After complete segregation is over, there will not be any more increase in the heritability and this is the best stage for exercising selection.

The selection of the plants is effective only when the performance of progeny is more dependable on the performance of the parent. Lush (1940) suggested that selection of best strains based on its genetic potentiality can be ascertained by regression of the progeny mean over the value of corresponding parent.

Table 4. List of superior Progenies identified for future exploitation

Line No.	DFF	PF %	PS %	PH	NP	PL	PE %	SE %	SF %	SS %	SPY
7S	81	65.77	100.00	95.00	13	27.15	82.87	64.09	76.18	100.00	24.50
17S	86	63.67	100.00	92.00	13	26.00	82.10	61.69	74.37	100.00	24.77
18S	78	65.77	100.00	91.00	14	25.40	80.55	64.90	75.97	100.00	29.00
27S	96	71.43	100.00	95.00	18	26.80	83.92	64.51	78.66	100.00	37.50
36S	89	74.37	100.00	85.00	13	27.00	84.24	70.31	81.25	100.00	28.13
50S	89	64.67	100.00	90.33	14	25.75	82.58	63.67	74.82	100.00	25.43
51S	84	70.63	100.00	92.00	20	26.20	83.08	68.92	79.68	100.00	40.23
52S	82	76.20	100.00	87.00	17	27.25	85.31	73.76	82.47	100.00	36.33
72S	93	60.37	100.00	92.10	12	24.50	77.54	62.27	70.19	100.00	25.57
73S	79	73.40	100.00	102.00	19	26.40	83.29	72.54	80.51	100.00	40.47
TS 29	70	61.67	100.00	69.92	10	19.58	71.00	65.05	69.84	100	29.17
CO(R) 49	104	95.33	4.07	102.00	18	27.28	90.74	52.36	90.12	7.63	49.70

DFF- Days to 50% flowering, PH- Plant height, NP- Number of productive tillers/ plant, PF %- Pollen fertility percentage, PS % - Pollen sterility percentage, PL- Panicle length, PE %-Panicle exertion, SE %- Stigma exertion percentage, SF %- Spikelet fertility percentage, SS %- spikelet sterility percentage and SPY- single plant yield

To evaluate how F_3, F_4 values have a bearing on F_2, F_3 values respectively, and whether such parameters can be relied upon for selection, standardized regression coefficient and narrow sense heritability were estimated. Standardization of variables to eliminate the errors due to seasonal or environmental effects has been recommended by Falconer (1960), if two generation like F_3 and F_4, are raised in different seasons or years or environments, in this each variable is divided by respective standard deviation values and then the regression is calculated. The positive significant regression and correlation coefficient estimates observed in F_3-F_4 generation for days to 50% per cent flowering, number of productive tillers per plant, panicle length, panicle exertion percentage and stigma exertion percentage indicated that F_3 were good. Number of productive tillers, panicle length, panicle exertion percentage and stigma exertion percentage are the main contributors for increase in yield of TGMS lines. The selection importance of these traits had been already suggested by Ganesan *et al.* (1998) for panicle length; Smalley *et al.* (2004) for plant height; Kole (2006) for number of tillers per plant. Increase in heritability estimates for yield traits with advancement of generation indicates the increase in additivity of gene effects in F_4 as compared to their respective populations for these characters due to increase in homozygosity. The enhancement of additive effects due to increase in homozygosity has been hypothesized by Mather (1949). Relatively higher heritability estimates recorded by floral traits showed that these are the good selection indices for parental line development.

Study on parent- progeny regression revealed positive significant regression and correlation coefficient estimates observed in F_3 -F_4 generation for days to 50% flowering, number of productive tillers per plant, panicle length, panicle exertion percentage and stigma exertion percentage which indicated that F_3 are good indicators of F_4 performance for all these traits. Anilkumar *et al* (2011) found out plant height, panicle length, number of grains per panicle, 100 grain weight were to be the yield determinants. The selection strategy for less complex traits with consistently higher magnitude of heritability and good correlation with grain yield may facilitate the selection in early generations (Mukul Kumar *et al* ., 2009). Narrow sense heritability estimates computed from regression analysis increased with advancement of generation from F_2 to F_4 indicating the additivity of gene effects for number of productive tillers per plant, panicle length and panicle exertion percentage. The selection of highly heritable traits in early generations was also emphasized by some workers (Sun, 1979; Vivekanandan *et al*., 1992; Subhramanyan *et al*., 1986). From this study some of the superior progenies were identified viz., 7S, 17S, 18S, 27S, 36S, 50S, 51S, 52S, 72S and 73S exceeded for days to 50 per cent flowering over the parental line TS 29 (Table 4). Out of the 10 superior lines,four progenies namely 27S, 51S, 52S and 73S had excellent stigma exertion percentage (> 70 per cent) over TS 29 (63 percent) and single plant yield was recorded more than 35 g comparied to CO(R) 49 (30 g). These four lines possess the desirable traits along with medium slender grain type. Thiyagarajan *et al.* (2010) explained the importance of characters viz., pollen sterility, panicle exertion, stigma exertion, angle of glume opening and natural out crossing while selecting the desirable parents for two line hybrids with superior yield. Studies on stability and heterotic potential of these new TGMS lines will help to develop new high yielding hybrids through two-line breeding. The results of selection conducted for low and high values of the yield components, correlations between grain yield and yield components and heritability values revealed that the number of productive tillers per plant, panicle length and panicle exertion percentage could be used as selection criteria in early generations.

Acknowledgement

The financial assistance received from the Government of India – Department of Biotechnology Project is duly acknowledged.

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Received: August 02, 2012; Accepted: March 8, 2013