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Research Article

Genetic variability and association studies for yield and floral traits in Temperature Sensitive Male Sterile lines (TGMS) of rice (*Oryza sativa* L)

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Abstract
One hundred and nineteen rice TGMS lines were evaluated for ten morphological traits in fertility favouring environment and eight floral traits in sterility favouring environment respectively. The analysis of variance exhibited significant difference among the TGMS lines for all the traits studied except sterile lemma length indicates large amount of genetic variability was present in the experimental material. The morphological traits *viz*., pollen fertility, number of grains per panicle, single plant yield and floral traits namely anther length, anther breadth, stigma length, stigma breadth, glume opening angle, stigma exertion and pollen sterility were recorded high phenotypic and genotypic coefficient of variation. High heritability with high genetic advance as per cent of mean was observed in morphological traits namely, days to 50 per cent flowering, pollen fertility, spikelet fertility, number of grains per panicle, single plant yield and in floral traits *viz*., anther length, anther breadth, stigma length, stigma breadth, stigma exertion, glume opening angle and pollen sterility reveals presence of additive gene action and further genetic improvement through direct selection would be effective for these traits. The single plant yield observed significant and positive correlation with plant height, number of productive tillers per plant and spikelet fertility shows importance of these characters for yield improvement. In floral traits, stigma breadth and glume opening angle had non significant and positive correlation with pollen sterility. Path analysis showed that plant height and number of productive tillers had positive direct effect on single plant yield. In floral traits, stigma breadth and glume opening angle had small positive effects on pollen sterility.

Key words
TGMS, variability, correlation, path, floral traits, morphological traits

Introduction

Rice (*Oryza sativa* L), belonging to the family of grasses (*Poaceae*) is diploid (2n=24), annual (potentially perennial), a short day plant, has a determinate inflorescence and normally self-fertilizes. It is an ancient grain crop and a staple sustenance for humans because of it being high in sugars, low in fat, and wealthy in proteins, vitamins and minerals. It has been utilized as noteworthy nourishment for more than ten thousand years. It is estimated that half of the total human population subsists entirely or in part on rice. Rice supplies 23 per cent of global human per capita energy and 16 per cent of per capita protein requirement. India ranks first in area and second in the production after China among other countries in the world rice production. Decreasing land area under rice makes the situation still worse and hence warrants higher productivity from unit land area. The hybridization program for varietal improvement in rice mainly depends on the selection of parents having high variability so that the desired combination of characters can be selected to improve the yield. Knowledge on nature and magnitude of genotypic and phenotypic variables present in any crop species play an important role in formulating successful breeding programme. The estimate of genetic variability helps to select potential benefits and enable to have a comparison of genetic variability in the quantitative traits. The extent of variability and heritability of characters among the genotypes is the basic source for the exploitation of potentiality of the genotypes. The variability for floral traits in TGMS lines is useful for breeding TGMS lines with good out crossing rate in rice.

Association among the traits is useful to know the suitability of various characters for selection, because of a particular trait selection induce desirable and undesirable changes in the associated characters. The efficiency of selection for yield mainly depends on the direction and magnitude of association between yield and its component characters. Character association provides information on the nature and extent of association between pairs of metric traits and helps in selection for the improvement of the character. Direct selection for yield is not effective since yield is a complex and indirect selection could be made for the component characters contributing to yield through character association as it provides information about the characters that are correlated with each other in improving dependent variable especially yield. With this aim, the present investigation was undertaken to assess the genetic

variability and association studies for yield in fertility favouring environment and floral traits in sterility favouring environment for 119 rice TGMS lines.

Materials and Methods

One hundred nineteen rice TGMS lines were evaluated at two locations *viz*., (i) study of morphological traits at fertility favouring environment at Hybrid Rice Evaluation Centre, Gudalur of The Nilgiris district which is located at high altitude of 1500 m above mean sea level during *Kharif* 2017 and (ii) for floral traits at sterility favouring environment at low altitude of 426.7 m above mean sea level in Department of Rice, TNAU, Coimbatore during *Rabi* 2017-18. The experiment was carried out by planting the 119 TGMS lines in a Randomized Block Design with three replications adapting a spacing of 20 cm x 20 cm in one row of 4 m each. Normal cultural practices were followed as per standard recommendations to get a good crop stand. The observations for quantitative and floral traits were recorded in five randomly selected plants in a genotype and mean values are arrived for statistical analysis. The traits namely days to 50 per cent flowering, plant height, number of productive tillers, panicle length, panicle emergence, flag leaf length, pollen fertility, spikelet fertility, number of grains per plant and single plant yield were recorded in fertility favouring environment. The floral characters *viz*., anther length, anther breadth, stigma length, stigma breadth, glume opening angle, stigma exertion, sterile lemma length and pollen sterility were studied at sterility favouring environments. The traits, anther length, anther breadth, stigma length, stigma breadth, stigma colour, pollen fertility, pollen sterility were measured by using a digital microscope with help of imaging software tool SCOPE IMAGE V 9.1 build 90225p. Pollen grains from the well matured anthers were observed using one per cent iodine potassium iodide solution and the pollen sterility and fertility was worked out. The data were analysed for variability as per procedure given by Panse and Sukhatme (1985), Genotypic coefficient of variation (GCV) and Phenotypic coefficient of variation (PCV) by Burton and DeVane (1953) and heritability and genetic advance by Johnson *et al*. (1955). The path and correlation coefficient analysis was worked out following the method suggested by Dewey and Lu (1959).

Results and Discussion

The analysis of variance for morphological traits at fertility favouring environment revealed that there existed highly significant difference for all characters studied (Table 1). The analysis of variance at sterility favouring environment for floral traits exhibited significant differences for all characters studied except sterile lemma length (Table 2) indicates large amount of genetic variability present in the experimental material.

Variability parameters for morphological traits at fertility favouring environment and floral traits at sterility favouring environment are presented in Table 3 and Table 4 respectively. High phenotypic and genotypic coefficient of variation was observed in morphological (Table 3) traits *viz*., pollen fertility, number of grains per panicle, single plant yield and in floral (Table 4) traits *viz*., anther breadth, stigma length, stigma breadth, glume opening angle, stigma exertion and pollen sterility which indicates that these traits are least influenced by the environment. Similar findings were reported by Sheeba *et al.*, (2006) for pollen fertility per cent and Devi *et al*., (2016) for single plant yield, Singh *et al*., (2014a) for anther breadth, Savitha and Kumar (2014) for stigma breadth, Sheeba *et al.*, (2006) for glume opening angle. The morphological (Table 3) traits namely days to 50 per cent flowering, number of productive tillers per plant, spikelet fertility and anther length of floral (Table 4) trait had moderate phenotypic and genotypic coefficient of variation. These results were similar to the findings of Bomare *et al*., (2014) and Singh *et al*., (2014b). Moderate phenotypic coefficient of variation and low genotypic coefficient of variation was observed (Table 3) for panicle length, panicle exertion, flag leaf length which infers that these traits are highly influenced by the environment. These results are in accordance with findings of Devi *et al*., (2016). Sterile lemma length was recorded low phenotypic coefficient of variation and genotypic coefficient of variation (Table 4) .

High heritability coupled with high genetic advance a per cent of mean was observed in fertility favouring environment for morphological (Table 3) traits *viz*., days to 50 per cent flowering, number of productive tillers, pollen fertility, spikelet fertility, number of grains per panicle, single plan yield as well as in sterility favouring environment for floral (Table 4) traits namely, anther length, anther breadth, stigma length, stigma breadth, stigma exertion, glume opening angle and pollen sterility revealed the predominance of additive gene action for these traits, thereby phenotypic selection can be practiced for crop improvement through direct selection. Similar results were reported by Hemant *et al*., (2017) for days to 50 per cent flowering, Devi *et al*., (2016) for number of grains per panicle, Singh *et al*., (2014a) for pollen fertility, Ekka *et al*., (2015) for spikelet fertility per cent, Bornare *et al*., (2014) for anther length, Singh *et al*., (2014a) for anther breadth, Rajkumar *et al*., (2015) for stigma

breadth. Moderate heritability and low genetic advance as per cent of mean was recorded for sterile lemma length. Low heritability and low genetic advance as per cent of mean was observed for flag leaf length indicated the predominance of non additive gene action which could be exploited through heterosis breeding.

The phenotypic and genotypic correlation coefficients for morphological traits are given in Table 5. In the study, single plant yield was positively and significantly correlated with plant height, number of productive tillers per plant and spikelet fertility at both genotypic and phenotypic level. Hence, for yield improvement plants with these characters could be selected. The result was in accordance with the findings of Singh *et al.*, (2014b). It is obvious that improvement of one character results in simultaneous improvement of all positively associated component character. The trait days to 50 per cent flowering exhibited significant and negative association with plant height at genotypic level. Significant and positive correlation was observed for plant height with flag leaf length, panicle length and spikelet fertility, panicle length with panicle exertion, panicle exertion with spikelet fertility and pollen fertility with spikelet fertility. Similar results were previously reported by Kole *et al.*, (2008) for plant height with panicle length. The flag leaf length showed significant positive correlation with panicle length and negatively significant with pollen fertility at genotypic level. Panicle emergence showed non significantly negative correlation with pollen fertility and number of grain per panicle. Spikelet fertility was negatively correlated with number of grains per panicle. Negative correlation among the yield components may be due to negative linkage and that needs to be broken through recombination breeding.

The genotypic and phenotypic correlation coefficient for floral traits are given in Table 6. The anther breadth have negatively significant correlation with pollen sterility per cent at both phenotypic and genotypic level. Plant with floral morphology of reduced anther breadth could be used for indirect selection of plants with high pollen sterility. Anther length had positively significant with sterile lemma length at genotypic level and positively non significant with stigma length and stigma breadth. Anther length and anther breadth are important components that attributed to proper pollen quantity and pollen shedding. Stigma breadth had positively significant with glume opening angle and negatively significant correlation with sterile lemma length. Similar results was reported by Singh *et al*., (2014a) and Salgotra *et al.*, (2012)..

Path coefficient analysis was further partitioned as direct and indirect effect to know the inter-relationship of various traits on single plant yield are presented in Table 7. Path analysis indicated that plant height and number of productive tillers had high positive direct effect on single plant yield. Similar findings reported by Ekka *et al.*, (2013) for number of productive tillers. Therefore direct section on these characters would be rewarding for improvement of single plant yield. The trait flag leaf length had low and negative direct effect on single plant yield. Also single plant yield had low and positive direct effect contributed by spikelet fertility and number of grains per panicle. Whereas Ravindra babu *et al.*, (2012) reported spikelet fertility had low and negative direct effect on single plant yield. Plant height had low and negative indirect effect on single plant yield *via* days to 50 per cent flowering whereas it had moderate and low positive indirect effect on single plant yield via flag leaf length and panicle length respectively. Similar reports was given by Ratna *et al*., (2015) via days to 50 per cent flowering and panicle length. Number of productive tillers had low and positive indirect effect through days to 50 per cent flowering on single plant yield. Similar result was reported by Ratna *et al*., (2015). Number of productive tillers and flag leaf length had low and negative indirect effect via plant height towards single plant yield. A similar result was reported by Ratna *et al*., (2015) for number of productive tillers. It was observed that flag leaf length had negative indirect and direct effect on single plant yield through plant height and number productive tillers. The traits plant height, flag leaf length and number of productive tillers found to have direct and indirect contribution towards single plant yield. Thus, these traits could be considered as selection indices for rice yield improvement.

Path analysis on pollen sterility traits presented in Table 8 revealed that anther breadth was the only trait which had high and negative direct effect on pollen sterility whereas, all the other traits found to have negligible effect on pollen sterility in genotypic and phenotypic level. The genetic variability and association analysis revealed that plant height, number of productive tillers per plant, spikelet fertility, stigma breadth and glume opening angle were important contributing traits for selection to improve grain yield and floral traits in rice TGMS lines in fertility favouring environment.

References

Bornare, S. S., Mittra, S. K., and Mehta, A. K. 2014. Genetic variability, correlation and path analysis of floral, yield and its component traits in CMS and restorer lines of rice (*Oryza sativa* L.). *Bangladesh J. of Botany*.

https://doi.org/10.3329/bjb.v43i1.19745

Burton, G. W. and De Vane, E. H. 1953. Estimating heritability in tall fescue, *Festuca arundinaceae* from replicated clonal material. *Agron. J.* **45** : 578-81.

Devi, K. R., Parimala, K., Venkanna, V., Lingaiah, N., Hari, Y., and Chandra, B. S. 2016. Estimation of variability for grain yield and quality traits in rice (*Oryza sativa* L.). *Int. J. Pure App. Biosci*, **4**(2): 250–255.

Dewey, D.R. and Lu. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agro. J.* **15***:* 515-518.

Ekka, R. E., Sarawgi, K. and Kanwar, R. R. 2013. Characterization and evaluation of traditional rice accessions in Chhattisgarh, India. *Plant Archives*, **13**(2): 1129–1133.

Hemant, S., Saxena, R. R. and Verulkar, S. B. 2017. Genetic variability and character association study for different morphological traits and path analysis for grain yield of rice under irrigated and rainfed condition. *Electronic J. of Plant Breeding*, **8**(1), 38–45.

Johnson, H. W., Robinson, H. E. and Comstock, R. E. 1955. Estimates of genetic and environmental variability in soybean. *Agron.J.* **47** : 314-18.

Kole, P.C., Chakraborty, N.R. and Bhat, J.S. 2008. Analysis of variability, correlation and path coefficients in induced mutants of aromatic non basmati rice. *Tropical Agric. Res. and extension.* **11** : 60-64.

Panse, V. G. and Sukhatme, P. V. 1985. *Statistical Methods for Agricultural Workers, 4th edn.* ICAR, New Delhi.

Rajkumar, A., Badri, J., Bhadana, V. P., Priyanka, C., Ansari, N. A., Dey, S. and Chary, D. S. 2015. Original research article open access. *J. Rice Res.*, **8**(1): 33.

Ratna, M., Begum, S., Husna, A., Dey, S. and Hossain, M. 2015. Correlation and path coefficients analyses in Basmati rice. *Bangladesh J. Agric. Res.*, **40**(1):153. https://doi.org/10.3329/bjar.v40i1.23768

Ravindra Babu, V., Shreya, K., Singh Dangi, K., Usharani, G. and Shankar, A. S. 2012. Correlation and path analysis studies in popular rice hybrids of India. *International J. Scientific and Res. Publications*, **2**(1): 2250–3153.

Salgotra, R. K., Gupta, B. B. and Ahmed, M. I. 2012. Characterization of thermo-sensitive genic male sterility (TGMS) rice genotypes (*Oryza sativa* L.) at different altitudes. *Australian J. Crop Sci*, **6(**6): 957–962.

Savitha, P. and Kumari, R. U. 2014. Morphological and variability studies on androecium and gynoeceium in rice landraces and hybrids (*Oryza sativa* L.). *Trends in Biosciences*, **7**(17): 2365–2369.

Sheeba, A., Vivekanandan, P. and Ibrahim, S. M. 2006. Genetic variability for floral traits influencing outcrossing in the *cms* lines of rice. *Indian J. Agric. Res.*: **40**(4), 272–276.

Singh, R., Singh, B., Sahoo, S. K. and Srivastava, R. P. 2014a. Genetic analysis of cyto-sterile lines in rice (*Oryza sativa* L). *International J. Sci. and Res.*, **3(**12) :2012–2015.

Singh, A.K., R. Nandan and P.K. Singh. 2014b. Geneitic variability and association analysis in rice germplasm under rainfed conditions. *Crop Res.*, **47**(1,2&3): 7-11.

Table 1. Analysis of variance for morphological traits at fertility favouring environments in rice TGMS lines

Sources of variation	df	Days to 50% flowering	Plant height (cm)	Number of productive tillers	Panicle length (cm)	Panicle exertion (%)	Flag leaf length (cm)	Pollen fertility (%)	Spikelet fertility (%)	No. of grains per panicle	Single plant yield (g)
Replication	2	25.62	49.188	0.252	22.693	30.39	31.82	2.65	0.573	14.04	23.86
Treatment	118	206.17*	100.51*	25.538*	11.142*	96.32*	17.32*	425.35*	245.36*	6817.69*	322.91*
Error	236	9.218	15.276	0.170	2.06	6.81	9.413	2.66	2.160	7.14	7.05

*Significant at 5 % level

Table 2. Analysis of variance for floral traits at sterility favouring environments in rice TGMS lines

Sources of variation	df	Anther length (mm)	Anther breadth (mm)	Stigma length (mm)	Stigma breadth (mm)	Glume opening angle (º)	Stigma exertion (%)	Sterile Lemma length (mm)	Pollen sterility (%)
Replication	2	0.007	0.0003	0.001	0.0005	2.15	0.0005	0.004	3.38
Treatment	118	0.185*	0.0474*	0.491*	0.0202*	107.84*	0.0802*	0.056	1196.76*
Error	236	0.004	0.0002	0.002	0.0005	2.03	0.0005	0.026	2.13

*Significant at 5 % level

Table 3. Variability parameters for morphological traits at fertility favouring environment in rice TGMS lines

Parameters	Days to 50% flowering	Plant height (cm)	No.of productive tillers	Panicle length (cm)	Panicle exertion (cm)	Flag leaf length (cm)	Pollen fertility (%)	Spikelet fertility (%)	No. of grains per panicle	single plant yield (g)
PV	75.68	43.68	8.62	5.08	53.03	12.01	301.69	83.230	2282.85	119.02
GV	66.46	28.41	8.45	3.03	19.84	2.59	289.08	81.07	2267.60	102.50
PCV	11.38	7.930	18.85	10.49	11.32	12.27	25.88	16.060	28.98	40.13
GCV	10.66	6.395	18.66	8.09	6.92	5.70	25.34	15.850	28.88	37.24
h^2	87.8	65.00	98.0	59.5	37.40	21.60	95.80	97.40	99.30	86.10
GA as % mean	20.59	10.62	38.06	12.86	8.72	5.47	51.10	32.22	59.29	71.19

Table 4. Variability parameters for floral traits at sterility favouring environment in rice TGMS lines

Parameters	Anther length (mm)	Anther breadth (mm)	Stigma length (mm)	Stigma breadth (mm)	Glume opening angle (º)	Stigma exertion (%)	Sterile Lemma length (mm)	Pollen sterility (%)
PV	0.064	0.011	0.165	0.007	36.60	125.922	0.034	402.045
GV	0.061	0.010	0.163	0.007	36.40	125.469	0.011	397.463
PCV	13.01	35.05	23.72	22.48	29.44	27.866	9.26	24.44
GCV	12.74	34.71	23.57	22.28	29.36	27.816	5.36	24.30
h^2	95.9	98.10	98.70	98.20	99.50	99.60	33.50	98.90
GA as %of mean	25.69	70.80	48.25	45.49	60.33	57.19	6.39	49.78

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Table 5. Phenotypic and genotypic correlation coefficients of yield traits at fertility favouring environment in rice TGMS lines

		Days to 50% flowering	Plant height	No of productive tillers	Flag leaf length	Panicle length	Panicle emergence	Pollen fertility	Spikelet fertility	No. of grains per panicle	Single plant yield
Days to 50% flowering	**P**	**1.0000**	-0.1742	0.2031*	-0.0610	-0.1190	-0.0837	0.1495	-0.0737	-0.0318	-0.0294
	G	**1.0000**	-0.2287*	0.2192*	-0.1503	-0.1430	-0.1491	0.1696	-0.0794	0.0363	-0.0197
Plant height	**P**		**1.0000**	-0.1654	0.3390*	0.1836*	0.0105	-0.0121	0.1936*	0.0988	0.2037*
	G		**1.0000**	-0.2053*	0.6676*	0.3380*	0.0133	-0.0136	0.2249*	0.1199	0.2871*
No of productive tillers	**P**			**1.0000**	0.0110	-0.0511	0.0411	-0.1153	0.1468	-0.0701	0.3552*
	G			**1.0000**	0.0743	-0.0683	0.0731	-0.1152	0.1474	-0.0701	0.3793*
Flag leaf length	**P**				**1.0000**	-0.0008	0.1241	-0.1447	0.1142	0.0463	0.0946
	G				**1.0000**	0.1928*	0.0286	-0.3160*	0.2460	0.1114	0.1948*
Panicle length	**P**					**1.0000**	-0.0528	0.0728	-0.0568	0.0252	0.1356
	G					**1.0000**	0.2218*	0.0930	-0.0617	0.0357	0.1715
Panicle emergence	**P**						**1.0000**	-0.0949	0.1675	-0.1454	0.0543
	G						**1.0000**	-0.1678	0.2725*	-0.2441*	0.1151
Pollen fertility	**P**							**1.0000**	0.7493*	-0.0070	0.0517
	G							**1.0000**	0.7702*	-0.0068	0.0615
Spikelet fertility	**P**								**1.0000**	-0.0915	0.2274*
	G								**1.0000**	-0.0940	0.2430*
No. of grains per panicle	**P**									**1.0000**	0.1006
	G									**1.0000**	0.1113
Single plant yield	**P**										**1.0000**
	G										**1.0000**

***Significant at 5% level**

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Table 6. Phenotypic and genotypic correlation coefficients of floral traits at sterility favouring environment in rice TGMS lines

		Anther length	Anther Breadth	Stigma length	Stigma Breadth	Glume opening angle	Stigma exertion	Sterile Lemma length	Pollen sterility
Anther length	**P**	**1.0000**	-0.0703	0.0583	0.0316	-0.0174	-0.0576	0.1142	-0.0724
	G	**1.000**	-0.0748	0.0577	0.0318	-0.0179	-0.0581	0.1839*	-0.0752
Anther Breadth	**P**		**1.0000**	-0.0155	0.1135	0.0301	-0.0623	-0.0133	-0.3044*
	G		**1.0000**	-0.0151	0.1169	0.0314	-0.0633	-0.0172	-0.3064*
Stigma length	**P**			**1.0000**	0.1137	-0.0243	-0.0351	-0.0524	-0.0621
	G			**1.0000**	0.1138	-0.0241	-0.0353	-0.0935	-0.0632
Stigma Breadth	**P**				**1.0000**	0.1931*	-0.0041	-0.1105	0.0315
	G				**1.0000**	0.1968*	-0.0045	-0.1834*	0.0320
Glume opening angle	**P**					**1.0000**	-0.1622	-0.0861	0.0818
	G					**1.0000**	-0.1625	-0.1432	0.0829
Stigma exertion	**P**						**1.0000**	0.0107	-0.0469
	G						**1.0000**	0.0155	-0.0473
Sterile Lemma length	**P**							**1.0000**	-0.0302
	G							**1.0000**	-0.0500
Pollen sterility	**P**								**1.0000**
	G								**1.0000**

***-Significant at 5% level**

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Table 7. Phenotypic and genotypic path coefficients of traits for single plant yield at fertility favouring environment in rice TGMS lines

Traits		DFF	PH	NPT	FLL	PL	PE	PF	SF	NGP	SPY
DFF	**P**	**-0.0553**	0.0116	-0.0115	0.0053	0.0076	0.0059	-0.0103	-0.0067	-0.0017	-0.0160
	G	**-0.0855**	0.0199	-0.0210	0.0101	0.0122	0.0100	-0.0165	-0.0107	-0.0027	-0.0208
PH	**P**	-0.0540	**0.2561**	-0.0428	0.0976	0.0567	0.0012	0.0038	0.0114	0.0273	0.2338
	G	-0.0837	**0.3604**	-0.0835	0.1841	0.1030	0.0063	0.0038	0.0194	0.0404	0.2626
NPT	**P**	0.0830	-0.0665	**0.3974**	0.0187	-0.0207	0.0132	-0.0309	-0.0122	-0.0229	0.3264
	G	0.1270	-0.1197	**0.5169**	0.0307	-0.0429	0.0310	-0.0455	-0.0187	-0.0346	0.3870
FLL	**P**	0.0018	-0.0071	-0.0009	**-0.0187**	-0.0009	-0.0011	0.0034	0.0009	-0.0012	0.1063
	G	0.0105	-0.0463	-0.0053	**-0.0887**	-0.0059	-0.0084	0.0205	0.0048	-0.0073	0.1407
PL	**P**	-0.0125	0.0202	-0.0047	0.0042	**0.0910**	0.0078	0.0089	-0.0057	0.0038	0.1349
	G	-0.0123	0.0246	-0.0071	0.0057	**0.0860**	0.0098	0.0099	-0.0056	0.0036	0.1564
PE	**P**	-0.0063	0.0003	0.0020	0.0035	0.0050	**0.0590**	-0.0060	0.0036	-0.0104	0.0749
	G	-0.0063	0.0009	0.0032	0.0050	0.0061	**0.0535**	-0.0062	0.0037	-0.0105	0.0874
PF	**P**	0.0040	0.0003	-0.0017	-0.0039	0.0021	-0.0022	**0.0215**	0.0161	0.0011	0.1192
	G	0.0058	0.0003	-0.0027	-0.0070	0.0061	-0.0035	**0.0302**	0.0233	0.0015	0.1251
SF	**P**	0.0199	0.0074	-0.0050	-0.0076	-0.0103	0.0101	0.1235	**0.1648**	0.0021	0.1738
	G	0.0200	0.0086	-0.0058	-0.0087	-0.0105	0.0111	0.1232	**0.1599**	0.0021	0.1777
NGP	**P**	0.0033	0.0115	-0.0062	0.0071	0.0042	-0.0190	0.0054	0.0014	**0.1408**	0.1060
	G	0.0037	0.0129	-0.0077	0.0094	0.0049	-0.0225	0.0058	0.0016	**0.1151**	0.1077

Residual effect = 0.8673

DFF : Days to 50% flowering
PH : Plant height (cm)
NPT : Number of productive tillers
FLL : Flag leaf length (cm)
PL : Panicle length(cm)
PE : Panicle exertion (%)
PF : Pollen fertility (%)
SF : Spikelet fertility (%)
NGP : Number of grains per panicle
SPY : Single plant yield (g)

Table 8. Genotypic and phenotypic path coefficients of floral traits for pollen sterility at sterility favouring environment in rice TGMS lines

Traits		Anther length	Anther breadth	Stigma length	Stigma breadth	Glume opening angle	Stigma exertion	Sterile Lemma length	Pollen sterility
Anther length	**G**	**-0.0961**	0.0072	-0.0055	-0.0031	0.0017	0.0056	-0.0177	-0.0752
	P	**-0.0773**	0.0054	-0.0045	-0.0045	0.0013	0.0045	-0.0088	-0.0724
Anther breadth	**G**	0.0246	**-0.3287**	0.0050	-0.0384	-0.0103	0.0208	0.0057	-0.3064
	P	0.0230	**-0.3272**	0.0051	0.0050	-0.0098	0.0204	0.0043	-0.3044
Stigma length	**G**	-0.0042	0.0011	**-0.0729**	-0.0083	0.0018	0.0026	0.0068	-0.0632
	P	-0.0035	0.0009	**-0.0600**	-0.0601	0.0015	0.0021	0.0031	-0.0621
Stigma breadth	**G**	0.0021	0.0076	0.0074	**0.0649**	0.0128	-0.0003	-0.0119	0.0320
	P	0.0000	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000	0.0000
Glume opening angle	**G**	-0.0011	0.0020	-0.0015	0.0124	**0.0630**	-0.0102	-0.0090	0.0829
	P	-0.0015	0.0025	-0.0020	-0.0020	**0.0842**	-0.0137	-0.0073	0.0818
Stigma exertion	**G**	0.0038	0.0041	0.0023	0.0003	0.0106	**-0.0654**	-0.0010	-0.0473
	P	0.0037	0.0040	0.0023	0.0023	0.0105	**-0.0646**	-0.0007	-0.0469
Sterile Lemma length	**G**	-0.0042	0.0004	0.0021	0.0042	0.0033	-0.0004	**-0.0228**	-0.0500
	P	-0.0039	0.0004	0.0018	0.0018	0.0029	-0.0004	**-0.0338**	-0.0302

Residual effect = 0.8359