PLANT SCIENCE TODAY
Vol 13(sp3): 1-4
https://doi.org/10.14719/pst.13472

eISSN 2348-1900

RESEARCH COMMUNICATION

Red thermo-sensitive genic male sterile rice in Kerala: A step towards climate resilience

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Received: 31 December 2025; Accepted: 03 April 2026; Available online: Version 1.0: 04 May 2026

Cite this article: Neethu CC, Roy S. Red thermo-sensitive genic male sterile rice in Kerala: A step towards climate resilience. Plant Science Today. 2026; 13(sp3): 1-4. https://doi.org/10.14719/pst.13472

Abstract

One of the best options to improve rice production is by exploiting hybrid vigour as proven in China. While considering yield, two-line hybrids have a yield advantage of 30 %. Thermosensitive genic male sterility (TGMS) is a type of environment-sensitive genic male sterility (EGMS) where the plant becomes male sterile above its critical sterility temperature (CST) and male fertile below the CST temperatures. For a tropical region like Kerala, TGMS is ideal and the prerequisite is to develop male sterile lines with stable sterility. With respect to Kerala conditions, TGMS system is more adaptable as the state has significant temperature variation between seasons and between altitudes. Hence this study was conducted as an attempt to develop a TGMS line in red rice background. The study was conducted at the College of Agriculture, Vellayani and the Regional Agricultural Research Station (RARS), Ambalavayal. Crossing was carried out at the College of Agriculture, Vellayani and seed multiplication was done at RARS, Ambalavayal, Wayanad (a high-altitude zone). Seeds of rice varieties Uma, Jyothi and a TGMS line from International Rice Research Institute (IRRI) (EC 720903) were used as parents for crossing. F_1 seeds obtained were collected and self-pollinated to obtain F_2 seeds. The F_2 seeds were bulked, sown and evaluated for male sterility. F_2 plants found to be sterile under Vellayani conditions were transferred to RARS Ambalavayal. Plants that produced seed were observed to have red-coloured F_3 seeds. The F_3 plants were male sterile at Vellayani condition with pollen free anthers. This finding also indicates the suitability of TGMS lines for selection towards crop improvement in rice and climate resilience in the future.

Keywords: critical sterility temperature; pollen free anthers; red thermos-sensitive genic male sterility; two-line system

Introduction

In rice, heterosis was first observed in 1926 (1, 2). In 1966, Yuan Long-ping, father of hybrid rice in China, initiated the attempts for the adoption of hybrid technology (3). Hybrid rice has been reported to produce 15–20 % higher grain yield (3, 4) compared to high-yielding varieties. Hybrid vigour, along with the efficiency of the techniques used for hybrid generation, has been reported to determine the extent of success in hybrid rice (5). As rice is a self-pollinated crop, the main way of hybrid production is to go for male sterility system. Male sterility is basically classified into three types: cytoplasmic genetic male sterility (CMS), environment-sensitive genic male sterility (EGMS) and chemically induced male sterility.

Thermosensitive genic male sterility (TGMS) is a type of EGMS where the plant becomes male sterile above its critical sterility temperature (CST) and it goes male fertile below the CST temperatures. The TGMS is a two-line system whereas CMS is a three-line system (6). The TGMS is a better option over CMS as it can be transferred to the progeny by crossing, since the trait is controlled by nuclear genes. The TGMS lines are those lines which alter their sterility or fertility expression according to temperature (5). A clear understanding of fertility behaviour of TGMS will help to effectively utilise this novel male sterility system, since the nuclear sterile gene reacts differently to temperature based on genetic factors (7). Identification of TGMS lines with stable fertility-sterility transformation behaviour is the first step required in the utilisation of the two-line system of hybrid rice breeding on a large scale (8).

The TGMS system is more adoptable for Kerala as we are having significant temperature variation between seasons and also between altitudes. The lines showing 100 % pollen sterility at high temperature and self-seed set of more than 30 % at low temperature can be taken as TGMS lines for commercial purposes (9). In TGMS, two-line hybrid system, frequency and spread of heterotic hybrids are higher as we are free to use any male fertile line as a male parent. This system is devoid of the negative effects of sterility inducing cytoplasm (10).

Once the critical sterility temperature and the critical stage of thermos-sensitivity of the TGMS line were identified and phenological characterisation was done, this TGMS line can be used as the donor plant for transferring male sterile gene to popular red rice varieties (11). The line EC720903 at Vellayani shows that this line is a suitable female parent for Kerala conditions (12).

For Kerala, TGMS is ideal and developing a male sterile line with stable sterility is the prerequisite. Hence this study was attempted to develop, thermosensitive genic male sterile line in red rice background.

Materials and Methods

The experiment was undertaken with the objective of developing TGMS rice in red rice background. To achieve this objective, plants were raised in pots at Department of Plant Physiology, College of Agriculture, Vellayani (2014–2016) situated at 8°5' N latitude and 76°9' E longitude and an altitude of 29 m above mean sea level. Seed multiplication was done at Regional Agricultural Research Station (RARS), Ambalavayal, Wayanad which is at 11°6' N latitude and 76°2' E longitude and 974 m above mean sea level.

Parents used for crossing were seeds of rice varieties Uma, Jyothi and a TGMS line (EC 720903) from International Rice Research Institute (IRRI). The F_1 and F_2 generations from the parental crosses were also used so as to evaluate for male sterility. The available TGMS line (EC 720903) and suitable red rice varieties (Uma, Jyothi) were grown in pots and crossed using proximal method (The proximal method of hybridisation refers to a technique used in rice breeding to facilitate controlled cross-pollination by positioning (or "proximating") the panicles of female and male parent plants close together, often bending or tying them to ensure pollen transfer without emasculation.) to obtain F_1 progeny. The F_1 was self-pollinated to get F_2 which was sown monthly and then evaluated for male sterility. Pollen sterility was analysed using 1 % iodine-potassium iodide (IKI) solution. Anthers were collected from flowers on or just before anthesis, on to which 2–3 drops of 1 % IKI was added after keeping on a glass slide and observed under compound microscope. Pollen sterility was expressed in percent.

The F_2 seeds were bulked and sown separately and evaluated for male sterility. As and when a plant was found to be male sterile, it was taken to RARS Ambalavayal (high altitude location) to confirm TGMS character and also to obtain seeds from ratoon. Collected seeds were observed for red colour also.

Results

The TGMS parent was found to be male sterile with 100 % spikelet sterility and pollen free anthers (Fig. 1). The number of sterile and fertile plants varied in different months as the seeds were from a bulk lot.

The sterile F_2 plants showed 100 % spikelet sterility and with pollen free anthers. The minimum pollen sterility exhibited by fertile F_2 plants was in those sown in the month of March, i.e., 2.9 % and spikelet sterility in those sown in November, i.e., 22 %. The maximum pollen sterility was recorded in January-sown plants with 5.3 % pollen sterility and spikelet sterility of 30 % in May-sown plants (Table 1).

The F_2 plants under Jyothi background, which were found to be sterile at Vellayani condition were taken to high altitude zone at RARS Ambalavayal and found to be fertile there (Fig. 2). The seeds were observed to be red in colour and a total of 291 such F_3 seeds were obtained (Fig. 3). On planting these seeds, F_3 plants were also found to be male sterile at Vellayani condition with pollen free anthers (Fig. 4) which is the character of the female parent EC720903 for selection.

Discussion

Even though many rice hybrids are available in India with white kernels, which are developed by three-line system, utilising CMS, for a state like Kerala with a preference for red rice, TGMS system will be ideal. Kerala having clear temperature variation with altitude as well as seasons is suitable for utilising TGMS system. As TGMS trait is controlled by nuclear genes, it can be transferred to suitable red rice of our choice.



Fig. 1. Male sterile anthers of thermo-sensitive genic male sterile (TGMS) rice.

Table 1. Pollen and spikelet sterility characters of F_2 plants

Month of sowing	Pollen sterility		Spikelet sterility	
	Fertile plants	Sterile plants	Fertile plants	Sterile plants
November	F (3.9 %)	0	22.00	0
December	F (4.6 %)	0	28.00	0
January	F (5.3 %)	0	27.58	0
February	F (4.5 %)	100 %	28.28	100 %
March	F (2.9 %)	100 %	16.32	100 %
April	F (4.0 %)	100 %	23.00	100 %
May	F (4.0 %)	100 %	30.00	100 %
June	F (3.2 %)	100 %	31.81	100 %
July	F (3.7 %)	100 %	25.5	100 %
December	F (4.0 %)	100 %	27.58	100 %
January	F (4.4 %)	100 %	27.83	100 %
February	F (5.0 %)	0	28.00	0

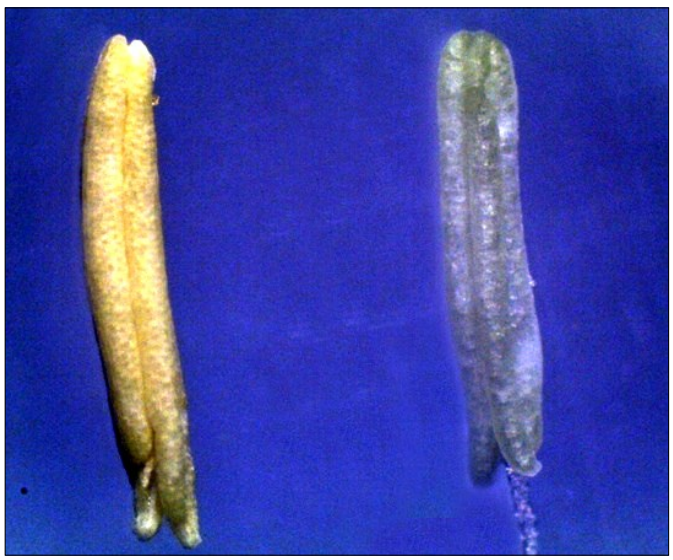


Fig. 2. Male fertile and male sterile anthers of F_2 plant (03 × Jyothi).

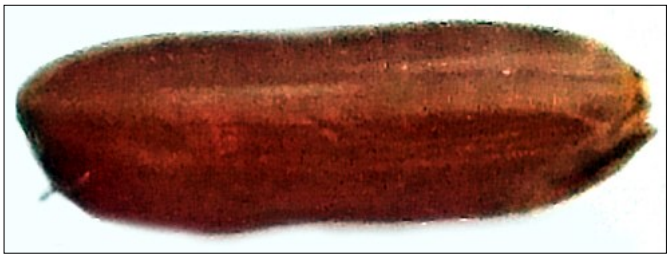


Fig. 3. Red male sterile F_3 seed on Jyothi background.



Fig. 4. Sterile/pollen free anthers of thermo-sensitive genic male sterile (TGMS) F_3.

The F_2 plants showed a similar flowering behaviour as that of the TGMS parent (12). According to Peng and coworkers, environment-sensitive male sterility-fertility system is a recessive trait (13). The tracking technique which was used in the present study to understand the CSP of TGMS line which was found to be 26.1 °C (12). According to previous researchers, cytoplasmic sterility parent (CSP) and cytoplasmic fertility parent (CFP) are the factors which decides the usefulness of a commercial TGMS line (14). If CSP is very low, it affects seed multiplication and if it is high, it affects hybrid seed production. As the TGMS is found to be male sterile with pollen free anthers, which is more stable male sterility than non-pollen abortion, it is suitable in two-line system of breeding. It is the most desirable character to be selected as the female parent (15, 16) which is in line with the present work.

The pollen and spikelet sterility characters observed in this study is in line with the earlier reports, according to which high temperature lead to spikelet sterility due to poor anther dehiscence and low pollen production (17, 18). According to another study there is need for identification of fertile and sterile sensitive phase of TGMS for different ecological areas. It will be helpful to determine the suitable location for hybridisation and seed multiplication (8).

The present study shows that the TGMS line EC 720903 was male sterile at high temperature and was male fertile at lower temperature. The TGMS F_2 and F_3 plants (from red seeded F_2) obtained by crossing TGMS line with Jyothi parent also showed a similar nature with pollen free anthers as that of the female parent which is in line with the findings of previous researchers (11). According to another report, gene was successfully interrogated into Thai cultivar and had given sterile pollen at high temperature and fertile at lower temperature (19).

Conclusion

The prevailing situation in Kerala demands higher production of rice which can be achieved by exploiting hybrid vigour. For a state like Kerala with a preference for red rice, thermo-sensitive genic male sterile system will be ideal. Kerala exhibits clear temperature variation across altitude and seasons, making it suitable for utilising TGMS system. As TGMS trait is controlled by nuclear genes, it is transferable and can be transferred to suitable red rice. This finding also indicates the suitability of TGMS lines for selection towards crop improvement and climate resilience in the future.

Acknowledgements

The authors sincerely acknowledge Dr. P. Rajendran (Ret. Associate Director of Research, RARS Ambalavayal), Dr. Seeja G. (Professor, Department of Genetics and Plant Breeding, College of Agriculture, Vellayani), Dr. T. Sajitha Rani (Professor, Department of Agronomy, College of Agriculture, Padanakkad), Dr. Soni K. B. (Ret. Professor and Head, Department of Molecular Biology and Biotechnology, College of Agriculture, Vellayani) and Mrs. Shaban R., Mr. Vipin, Mrs. Anila Abhilash, Mr. Shreekanth and Mrs. Niya Celine for their invaluable assistance throughout this study. The authors also express their gratitude to Kerala Agricultural University for providing timely financial support.

Authors' contributions

RS designed and coordinated the study, managed the writing and ensured the availability of seeds and all other resources. NCC raised the plants, performed crosses and selfing, transported plants to RARS and evaluated them for sterility. Both authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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