STANDARDISATION OF TWO LINE HETEROSIS BREEDING IN RICE (*Oryza sativa* L.) FOR KERALA

By

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(2010-21-107)

THESIS

Submitted in partial fulfilment of the requirement

for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Plant Breeding & Genetics

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR 680656

KERALA, INDIA

2016

DECLARATION

I hereby declare that the thesis entitled **"Standardisation of two line heterosis breeding in rice (*Oryza sativa* L.) for Kerala."** is a bonafide record of the research work done by me during the course of research and this thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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EXTERNAL EXAMINER

Acknowledgement

ACKNOWLEDGEMENT

A great number of people have contributed to this research and for the structure of the thesis and they deserved special mention. It is a pleasure to convey my gratitude to them all in my humble acknowledgment.

I would like to record my gratitude to **Dr. V.V. Radhakrishnan Professor (Rtd)** Chairman of the Advisory committee for his supervision, advice, and guidance for this research. Evenafter retirement Respected Dr.V.V.Radhakrishnan Professor helped me which i particularly remember as very pious and divine.

I extend my heartfelt thanks **Dr. K.T Presanna Kumari, Professor & Head, Department of Plant Breeding & Genetics** and member of my advisory committee, who is person for her heavenly virtues of the teaching profession . I am highly obliged her candid timely help, whole hearted cooperation and student life saving nature.

I gratefully acknowledge **Dr. Rose Mary Francies Assoc Professor & Head** (Seed science & Technology), Member of advisory committee, for providing me unflinching encouragement, support. Her truly scientist intuition has made her as a constant oasis of ideas and passions in science, which exceptionally inspire and enrich my growth as a student, a researcher and a scientist want to be. I am indebted to her.

My heartful thanks are extended to **Dr. E.Sreenivasan Professor & Head (Agronomic Research Station, Chalakudy)** and member of my advisory committee for his sincere help and whole hearted cooperation rendered throughout the Ph.Dprogramme.

I am highly indebted **to Dr. K.K Ibrahim Associate Professor**, Depatment of Plant Breeding &Genetics,His valuable suggestions are worth mentioning.

My earnest thanks to **Dr.A.Latha** Associate Professor (ARS Mannuthy) and the member of Advisory committee for her advice, and crucial contribution and help.

My earnest thanks to **Dr. Jiji Joseph and Dr. Biju** department faculty professors for their timely motivations , perfectual encouragements.

I am obliged to **Dr.S.Krishnan** Associate Professor & Head, Department of Agricultural Statistics, College of Horticulture who helped me in doing the statistical analysis.

I acknowledge **The Director, Centre for Plant Breeding & Genetics, Tamil Nadu Agricultural University, Coimbatore and Professor and Head, Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore** for providing me seven TGMS seed samples for the experiment.

I take this opportunity to extend my gratitude to all the **non teaching staffs** of **Department of Plant Breeding & Genetics** and **AICRP on medicinal plants** for their support in different stages of the study

My heartful thanks to each and every staffs **from CRS Pampadumpara and RARS Pattambi** for smooth conduct of the experiment.

I wish to express my sincere thanks to **Aravind Chetta** for his valuable help to the computer related work

I express my sincere thanks to all **Library staffs of KAU.**

I sincerely thank the fraternity **including Professors , College staffs and students** from the abyss of my heart , having saved me and lent their hands in all the vicissitudes that i confronted with in the student life.

I express to my thanks to my teachers of my **school days, UG** and **PG** classes.

It is my pleasure to mention **my all UG & PG & Ph.D batchmets, junior and senior friends**, whose dedication, love and support.

Words fail me to express my appreciation to **my beloved parents, family members and my village friends.**

(RAJESH T)

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Introduction

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food for about 50 per cent of the world's population. Ninety per cent of the world's rice is grown and consumed in Asia. Rice provides about 29.4 per cent of total calories/capita/day in Asian countries (FAO 2006). However, increase in rice production is not commensurating with population growth. The total global rice production is declining gradually even with the extensive use of the high yielding modern varieties and hybrids. In India rice is grown in an area of 45.54 million ha with a production of 99.18 million tonnes and a productivity of 2178 kg ha^{-1}. In Kerala, rice is cultivated in an area of 0.21 million ha with a production of 0.47 million tonnes and a productivity of 2238 kg ha^{-1}.

Hybrid rice technology was developed in China as early as 1976. Since 1984, the area planted with hybrid rice in China accounted for about 50 per cent of the total rice area of the country. Hybrid rice recorded an yield advantage of about 15 to 20 per cent over best commercial varieties of that area.

Similar to China, rice hybrids could play a greater role in sustaining Indian's food security in 21^{st} century. About 3,400 ha of irrigated rice land was planted to hybrid rice cultivation during 1996 which added nearly 40-50 thousand tonnes of additional paddy to national production. The target being 4.0 m ha under hybrid rice by 2010 AD which would add 3.5-3.6 million tonnes of additional paddy to India's food basket in the next 4 years, *i.e,* one third of additional rice demand could be met by this innovative technology alone (Janaiah, 1998).

Utilization of heterosis through hybrid rice technology can be considered as one of the most attractive achievements that have taken place in the direction of increasing productivity. Heterosis in rice was first reported by Jones (1926) and Ramiah (1933). Since, then several workers reported heterosis for various economically important characters.

One of the most effective ways to make use of crop heterosis in rice is to produce hybrids by taking advantage of three line male sterility system. However, this system is expensive and cumbersome.Compared to the two line system maintaining the CGMS (Cytoplasmic Genic Male Sterile lines) and choosing an appropriate restorer line for developing the fertile hybrids are major limitations. Additionally, the availability of a few male sterile (MS) lines for hybrid development narrows the genetic base and increases the risk of genetic vulnerability.

The two line system of hybrid breeding utilizing Environmental Sensitive Genic Male Sterility (EGMS) is considered as an alternative to overcome the problems associated with three-line breeding and to surpass the yield plateau (Maruyama *et al.,* 1991). In rice, both photoperiod sensitive genic male sterility (PGMS) and temperature sensitive male sterility (TGMS) have been discovered and successfully developed. In tropical condition like India, where day length differences are marginal,TGMS system is considered to be more useful than the PGMS system (Virmani 1996). After the identification of the TGMS mutant, Anong 1S (Tan *et al.,* 1990), several TGMS lines have been developed in China, IRRI and other countries. For successful exploitation of this novel male sterility system in heterosis breeding, more TGMS lines need to be developed and characterized for their sterile and fertile alteration. Studying the inheritance of TGMS would help in breeding new TGMS lines with diverse genetic back grounds.

The TGMS lines become completely sterile under high temperature (> 32°C) and fertile under low temperature (< 24°C) (Maruyama *et al.,* 1990) at panicle initiation stage. This phenomenon has taken advantage off hybrid seed production and seed increase of TGMS lines. The TGMS gene of Norin PL 12 is has been transferred to tropical *indica* varieties at IRR1, Philippines through a Memorandum of Understanding between IRRI and Government of Japan which states that the TGMS lines derived by using Norin PL 12 gene would be made useful to all countries.

The major advantages of TGMS system are simplicity, overcoming the negative effects of male sterile cytoplasm and the ease of multiplication and restoration .These two line hybrids have been reported to exhibit 5-10 per cent yield advantage over the three line hybrids.

Two line breeding is a viable proposition in a state like Kerala where rice is cultivated from below mean sea level to altitudes of 1500 MSL. Exploiting the difference in temperature regimes between the high altitudes and plains, the MS lines can be multiplied and hybrids can be produced on a commercial scale. Preliminary studies at Kerala Agricultural University have shown promising results in this direction . Hence the present study envisaged to identify stable TGMS lines for the development of two line rice hybrids and standardisation of two line heterosis breeding in rice.

Review of Literature

2. REVIEW OF LITERATURE

Rice is the staple food for about half of the world's population. The rapidly increasing demand for rice and the continuous decrease in rice growing areas emphasizes the need to improve rice production. The use of hybrid rice has proved to be an effective and economical way to increase rice production. It is easy to obtain about 10% yield increase just by growing hybrid rice. Thermosensitive genic male sterility (TGMS) is a useful genetic tool for the development of two-line hybrids in rice. At the thermo sensitive stage of panicle development, the TGMS gene(s) cause/s male sterility under high environmental temperatures and result/s in fertility under low temperatures (Li *et al.*, 2005). A TGMS line can therefore be used for hybrid seed production as well as for its seed multiplication under different growing environments. The system provides a much simpler and economic hybrid seed production and broader choice of male parents for enhancing yield potential.

In the tropics, use of TGMS has been effective in developing hybrids and has shown prospects in increasing the efficiency of hybrid rice breeding (Lu *et al.*, 1998; Lopez and Virmani, 2000). TGMS and wide compatible varieties provide a new tool for direct utilisation of rice inter-subspecific heterosis by two line system (Yuan *et al.*, 1994). Developing TGMS lines is one of the basic steps in obtaining superior two-line rice hybrids. A number of elite combinations have been developed which generally out yielded the leading hybrids from three-line system by 5 to 10 per cent and local conventional varieties by 10 to 20 per cent (Wu, 1997).

Literature related to two line hybrids are briefly reviewed under the following heads;

2.1. Evaluation and characterization of TGMS lines

2.2. Evaluation of pollinator

2.3. Evaluation of two line rice hybrids

2.4. Quality analysis in Hybrids

2.5. Molecular analysis

2.1. Morphological characterization of TGMS lines

2.1.1. Floral traits

2.1.1.1. Glume Angle

Ramakrishna *et al.* (2006) characterized thermosensitive genic male sterile lines for thermosensitivity, morphology and floral biology in rice. In a study, Parmar *et al.* (1979) reported that large collection of rice cultivars reported that variation for angle of glume opening was due to both genetic and environmental causes. Eleven male sterile lines and ten restorer lines of rice for floral traits were evaluated and observed that angle of glume opening ranged from 33.16 to 45.00 in CGMS lines were reported by Bassi *et al.* (1992) and 23.43 to 30.20 in CGMS lines by Behla *et al.* (2007).

Singh and Singh (1998) reported moderate GCV and PCV for angle of glume opening. Madhavan and Subramanian (1999) in a study with fifteen male sterile lines and their respective maintainers observed that IR 46828 A, Zhen Shan 97 B and ADT 36 had wider angle of glume opening.

2.1.1.2. Panicle exsertion percentage

Bassi *et al.* (1992) had studied twenty one rice genotypes involving eleven male sterile lines and ten restorer lines of rice and reported that the male sterile lines had higher variability for panicle exsertion, which ranged from 70.12 to 78.35 per cent.

Ten cytosterile lines of rice and their respective maintainers for different floral traits were studied by Singh and Singh (1998) and reported that percentage of panicle exsertion influencing outcrossing was predominant in cytosterile line IR 58025A. Seetharamaiah *et al.* (2001) in a study of 64 rice genotypes for floral traits reported high variability for panicle exsertion which contributed for higher seed set. The panicle exsertion ranged from 68.59 to 82.66 per cent in kharif 2001 and from 69.11 to 84.46 per cent in kharif 2002. IR 58025A had highest panicle exsertion was reported by Sawant *et al.* (2006) and Ali *et al.* (2008) reported the panicle exsertion from 59.18 to 96.86 per cent in kharif 2005.

Out of 35 CGMS lines evaluated, only 14 lines was observed with more than 70 per cent panicle exsertion was reported by Asish *et al.* (2006), Behla *et al.* (2007) and Sidharthan *et al.* (2007). Jayaramaiah *et al.* (2007) reported that out of 28 CGMS lines, only CGMS 7A had complete panicle exsertion. Waghmode *et al.* (2007) studied six CGMS lines and reported that the panicle exsertion per cent ranged from 64.13 to 70.40 per cent. Out of sixty six TGMS lines screened during summer, panicle exsertion percentage ranged from 53.65-83.10 were noticed in a study conducted by Thiyagarajan *et al.* (2010).

2.1.1.3. Stigma exsertion percentage

Ramakrishna *et al.* (2006) reported that the floral characterization of six TGMS lines *viz.,* DRR 1 S, DRR 5 S, IR73827-23 S, IR73834-21 S, UPRI 95-140 S and UPRI 95-167 S, time of anthesis ranged from 9.05 AM to 9.40 AM. For duration of anthesis DRR 5 S took minimum time as 165 min and UPRI 95-140 S took maximum time as 270 min. DRR 5 S showed less exerted stigma (25 per cent) and high exerted stigma was observed in UPRI 95-140 S (70 per cent). Angle of glume opening ranged from 15-25 degree.

Kalaiyarasi *et al.* (2006) reported that high stigma exsertion was observed in the TGMS lines *viz.,* CBTS 0268, CBTS 0272, CBTS 0252, CBTS 0263, CBTS

0261, CBTS 0260 and CBTS 0253 indicated that these TGMS lines could be effectively utilized for exploitation of twoline heterosis breeding in rice.

Bassi *et al.* (1992) reported eleven male sterile lines and ten restorer lines of rice and reported that stigma exsertion ranged from 35.54 to 53.24 per cent. The male sterile line IR 58025A excelled all other male sterile lines in stigma length and stigma exsertion percentage and the range varied from 0.67 to 100 per cent in wild species were noticed in a study conducted by Jayamani and Rangasamy (1995).

In a study, Madhavan and Subramanian (1999) reported with fifteen male sterile lines and their respective maintainers observed that the range of stigma exsertion in A lines was from 12.87 to 48.12 per cent and in another study by Ali *et al.* (2008) noticed that B lines was from 5.25 and 51.50 per cent and the range was from 5 to 35 per cent.

In an investigation, Sidharthan *et al.* (2007) evaluated 35 CGMS lines and their maintainer lines. Out of 35 lines, 16 were observed having above 30 per cent stigma exsertion. Abraham *et al.* (1998), Azzini and Rudger (1982) and Behla *et al.* (2007) reported 48 to 98 per cent stigma exsertion. Jayaramaiah *et al.* (2007) reported that sitgma exsertion of more than 19.87 per cent was recorded in IR 70366A, PMS 10A and IR 66707A.

2.1.2. Critical sterility and fertility temperature (CST/CFT)

2.1.2.1. Critical stages of fertility alteration

Yuan (1990) isolated the first temperature sensitive genic male sterile line Annong-1 S. It was a spontaneous mutant and it showed complete pollen sterility under high temperature and normal fertility at low temperature conditions. Norin PL 12 was developed in Japan by irradiation of a Japanese variety Reimei, using 20 Rds gamma rays . This was completely sterile under 31/24°C and completely fertile under 25/18°C. Subsequently many other temperature sensitive genic male sterile lines *viz.,* Hennong S, R597 S and Norin PL 12 were developed. In these lines high temperature induces sterility and low temperature results fertility (Sun *et al.*, 1989). The critical temperature varies depending on the source of TGMS gene (Lu *et al.*, 1994).

Effect of location and season on TGMS line multiplication and hybrid seed production was reported by Wang *et al.* (1997) and Latha *et al.* (1998). Lopez and Virmani (2000) reported in a study that the TGMS trait was transferred from a temperate japonica TGMS mutant, Norin PL 12 to *indica* and tropical *japonica* rice varieties using the pedigree selection procedure. Six new TGMS rice lines adapted to tropical conditions were developed which showed complete pollen and spikelet sterility when maximum temperature was higher than 30°C 1-2 week after panicle initiation. However, up to 85.5 per cent spikelet fertility was observed when these lines were exposed to 26-29°C during the critical stage.

An investigation was undertaken by Kalaiyarasi and Vaidhyanathan (2000) revealed that both pre and post-meiotic genetic systems operate during anther development for the expression of sterility and sterile anthers were small with empty pollen grains of irregular shape, except for TS 16, which showed pollen-free anthers. This indicates that the sensitive stage of TS 16 at stage IV (stamen and pistil primordia) of panicle development.

Cytological observation of two Environmental Genic Male-Sterile Lines of Rice was reported by Ku *et al.* (2003). Male sterility of the TGMS and PGMS was found to be induced when they were grown at 32°C/26°C (day/night) with 14 hr daylight, while they were fertile at 26°C/20° C (day/night) with 10 hr daylight in a growth chamber. They also examined their anther structures under a light microscope. The light microscopic observation revealed that the EGMS lines showed a complete pollen abortion at the sterile growth condition while they produced normal fertile pollens at the fertile growth condition.

Kalaiyarasi and Vaidyanathan (2002) reported that distinct developmental pattern of pollen production with respect to different classes of pollen fertility in intermated progenies of TGMS lines by following anther clearing technique. The pollen grains of sterile class were small and irregular in shape. Less than 20 per cent sterility in the intermated progenies (IMPs) indicated occurrence of post -meiotic sterility. Kirubakaran *et al.* (2002) reported that an average temperature of 24°C is essential for sterility inducement in the TGMS line *viz.*, TS 29. They also reported that maximum temperature of 30°C to 37°C with minimum temperature of 23 -26°C ensures safe hybrid seed production in the plains.

Cytological screening of TGMS lines in rice and identified that the intermated progenies (IMPs) with less, than 20 per cent sterility *viz.*, TS 15 x TS 16, TS15 x Co 47, TS 18 x TS 16 and TS 18 x CO 47 could be used as a resource base for developing stable TGMS lines were reported by Kalaiyarasi and Vaidyanathan (2003).

The three TGMS lines *viz.*, TM 104 S, TM 105 S and IR 73827-23 S were evaluated in phytotron. Critical sterility point of IR 73827-23 S is 24- 25°C for 12 days. TM 104 S was almost sterile in 24.9°C and partially sterile in 23.9°C. TM 105 S line was completely sterile under 23.9°C and 24.9°C and partially fertile at 22.9°C (Mou *et al.*, 2004). Latha *et al.* (2004) studied genetics, fertility behaviour of a new TGMS line TS 6 in rice and lines had high influence of daily maximum temperature.

One TGMS gene was investigated by a spontaneous rice mutant line (origin- Korean variety), Sokcho-MS. The study revealed that Sokcho-MS is completely sterile at a temperature higher than 27°C and/or lower than 25°C during the development of spikelets, but fertile at the temperature ranging from 25 to 27°C regardless of the levels of day-length (Lee *et al.*, 2005).

Ramakrishna *et al.* (2006) reported that the floral characterization of six TGMS lines *viz.*, DRR 1 S, DRR 5 S, IR 73827-23 S, IR73834-21 S, UPRI 95-140 S and UPRI 95-167 S. All the TGMS lines exhibited critical sterility point at temperature more than 30°C. CST ranged from 30°C (DRR 1 S) to 35.9°C (IR 73827-23 S).

Peng *et al.* (2006) reported cytological obervation in rice TGMS line. Cytological observation showed that pollen sterility was mainly caused by the unusual period of meiosis. The performance of pollen mother cell adhesion and vacuole, meiosis I obstructed the thread in the early period for no abnormal mitosis and cytokinesis.

2.1.2.2. Pollen fertility

Kalaiyarasi and Vaidyanathan (2003) reported cytological differentiation of TGMS genes expression in rice *indica / japonica* derivatives utilizing anther clearing technique. The sterile anthers differed from fertile anthers in their size, filling pattern, shape of pollen grain and anther color in TS 29 x Norin 18 and TS 29 x Hinokikari. Distinct variation was observed between sterile and fertile expression with respect to anther size, shape and color besides content and quantity of the pollen grains in both TGMS lines.

Kalaiyarasi *et al.* (2006) studied pollen fertility status of promising TGMS lines during Kharif 2003. Pollen fertility was high in CBTS 0276, CBTS 0282, CBTS 0268, CBTS 263, CBTS 0254 while spikelet fertility was high in CBTS 0276, CBTS 0280. Lowest spikelet fertility was observed in CBDHTS 023. All the twenty five promising TGMS lines exhibited 100 per cent pollen/ spkelet sterility during Rabi 2004. The result showed that all the promising TGMS lines showed 100 per cent pollen sterility during high temperature (Summer 2003 and Rabi 2004) and reverted to fertility during Kharif 2003 indicated that occurrence of fertility transformation nature of TGMS in these lines.

Ranges of critical temperature for fertility alteration in different TGMS / PGMS lines given in Table 1. Different stages of panicle development showed fertility alteration behaviour in different TGMS lines (Table 2).

Table 1. Critical temperature for fertility alteration in different PGMS/TGMS Lines

TGMS Lines	CST	CFT	References
5460 S	29.5°C	28.0-29.5°C	Sun *et al.* (1989); Cheng *et al.* (1990) and Yang (1990)
SM 3	33.9°C	20.0-24.0°C	Ali *et al.* (1995)
SM 5	32.3°C	20.0-24.0°C	Ali *et al.* (1995)
SA 2	32.3°C	20.0°C	Ali *et al.* (1995)
JP8-1A-12	30.9°C	20.0°C	Ali *et al.* (1995)
F 61	20.0°C	20.0°C	Ali *et al.* (1995)
UPRI 95-140 TGMS	28.7°C	26.2 °C	Pandey *et al.* (1998)
JP 24A (RTGMS)	26.0°C	28.0 °C	Reddy *et al.* (1998)
IR 68945-4-33-4-14, IR 68949-11-5-31	30.0°C	24-28°C	Viraktamath *et al.* (1998)
TS 12	33.2 °C	30.3°C	Cherian (1998)
TS 14	33.2 °C	31.8°C	Cherian (1998)
TS 18	30.6°C	30.36°C	Sampoornam (1998)
GD 98013	25.9°C	25.0°C	Sundar (2003)
GD 98179	27.3°C	27.0°C	Kavimani (2004)
GD 99049	26.9°C	25.1°C	
GD 99051	25.9°C	25.5°C	
TS 6	26.7°C	25.5°C	Latha *et al.* (2004)
TS 18	24.2°C	24.0°C	
TS 29	25.6°C	25.3°C	
TS 46	25.4°C	25.3°C	

Table 1. (Contd…)

GD 98014	26.0°C	25.8°C	Chandirakala (2005)
GD 99017	27.1°C	26.9°C	
GD 98029	26.5°C	25.8°C	
GD 98049	27.2°C	26.9°C	
DRR 1S	36.6	25.1	
DRR 18S	34.7	24.4	Salgotra *et al.* (2012)
DRR 19S	35.5	22.3	
DRR 20S	35.7	24.3	

TGMS Lines	Critical temperature	References
5460 S	28.5°C	Sun *et al.* (1993)
Annong 1 S, W 6154 S	24.0°C	Wu and Yin (1992)
Hennong 1 S	27.0°C	Wu and Yin (1992)
W 8013 S	24.4°C	Zhang and Lu (1991)
R 59 TS	24.0°C	Yang (1990)
W 6154 S, W 8013 S	24.0°C- 27.0°C	Zhang *et al.* (1994)
Pei ai 64 S	21.0°C -24.0°C	Zhang *et al.* (1994)
KS-14	21.0°C -24.0°C	Zhang *et al.* (1994)
24 Zhaizao (RTGMS)	23.0°C	Shen *et al.* (1994)
T 436 S	26.1°C	Dong *et al.* (1995)
Hennong 3 S	27.0°C	Gao *et al.* (1996)
Norin PL 12	27.0°C	Viraktamath *et al.* (1998)

Table 1. (Contd...)

TS 6, TS 7, TS 16, TS 32, TS 33, TS 36	25.2°C	Rangaswamy *et al.* (1998)
2-2 S, K 1405, 2136 S	23.7°C-24.5°C	Mou *et al.* (1998)
F 131 S	24.3-24.7°C	Mou *et al.* (1998)
Pei ai 34 S	24.6-25.1°C	Mou *et al.* (1998)
1290 S	25.5-26.2°C	Mou *et al.* (1998)
N 17 S	25.4-26.1°C	Mou *et al.* (1998)
W 6154 S, W 6184 S, W 6111 S, W 6417 S, W 8013 S	26.5°C	Mou *et al.* (1998)
W 9046 S	25.5°C	Mou *et al.* (1998)
W 91607 S	24.0°C	Mou *et al.* (1998)
IR 68945-4-33-4-14 IR 68949-11-5-31	32.0°C	Viraktamath and Virmani (2001)
TS 29	24°C	Kirubakaran *et al.* (2002)
TS 15 TS 16 TS 18 and TS 29	27.5–32°C	Kalaiyarasi and Vaidyanathan (2003)

CST-Critical Sterility Temperature CFT-Critical Fertility Temperature

Table 2. Critical stages of panicle development for fertility alteration

TGMS Lines	Critical Stages	References
Nongken 58S	Secondary rachis and spikelet primordial differentiation of PMC formation	Yuan (1998) Wan and Deng (1990)
Nongken 58S	Stamen and pistil primordium differentiation	Wang *et al.* (1990)
5460 S	Stamen and pistil primordium differentiation Meiosis of PMC PMC formation to meiosis of PMC PMC formation to late uninucleate stage	Zhang *et al.* (1992) Cheng *et al.* (1990) Zhang and Lu (1991) Sun *et al.* (1993)
SA 2, JP 2, F 61, SM 5, SM 3	Stamen and pistil primordium differentiation	Ali *et al.* (1995)
GD 2 S	Secondary rachis differentiation and spikelet primordium differentiation	Wang *et al.* (2003)
Norin PL 2	Stamen and pistil primordium differentiation	Borkakati and Virmani (1997)
IR 32364 TGMS	Stamen and pistil formation to meiosis of PMC	Borkakati and Virmani (1997)
Annong 1 S	Stamen and pistil formation	Liu *et al.* (1997)
Annong 810 S	Secondary branch primordia differentiation to filling stage of pollen	Liu *et al.* (1997)
W 9457 S, W 9461 S W 91607 S	PMC formation to pollen ripening stage	Mou *et al.* (1998)
2-2 S, K 1405, 2136 S	PMC formation to meiosis of PMC	Mou *et al.* (1998)

Table 2. (Contd...)

TGMS Lines	Critical Stages	References
GD-1S	Stamen and pistil primordium differentiation to formation of PMC	Mou *et al.* (1998)
TS 16, TS 29	Meiosis of PMC to pollen ripening stage	Latha (2001)
TS 18	Stamen and pistil primordium differentiation to pollen ripening	Latha (2001)
TS 29	Stamen and pistil primordia development	Kalaiyarasi and Vaidyanathan (2003)
GD 98013	PMC formation to pollen ripening stage	Sundar (2003)
GD 98179	Pollen filling to pollen ripening	Kavimani (2004)
GD99049	Secondary branch primordia differentiation to pollen ripening stage	Kavimani (2004)
GD 99051	First bract primordia differentiation to pollen ripening	Kavimani (2004)
TS 6	First bract primordia differentiation to pollen ripening	Latha *et al.* (2004)
TS 46, TS 47	First bract primordia differentiation to pollen ripening	Latha *et al.* (2005)
GD 98014 GD 99017 GD 98049	Differentiation of first bract primordium to pollen ripening stage	Chandirakala (2005)
GD 98029	First branch primordia differentiation to pollen ripening	Chandirakala (2005)

2 .2 Evaluation of pollinators

Latest studies conducted in rice by various authors that are relevant to variability, heritability and genetic advance, correlation and path coefficient analysis are reviewed hereunder.

2.2.1 Variability studies

Variability is required for successful crop improvement programme. Variation present in the population is of three types *viz*., phenotypic, genotypic and environmental. Phenotypic variation is the visually observable variation present for a character in a population. It includes both genotypic and environmental components of variation and as a result, its magnitude differs under different environmental conditions. To apportion this observed variability into genetic and environmental factors, parameters such as genotypic coefficient of variability (GCV) and phenotypic coefficient of variability (PCV) are assessed. The progress through selection depends upon the magnitude of genetic variability available in the breeding population. Thus insight into the magnitude of genetic variability is of prime importance. The studies conducted.on variability by different research workers in rice are reviewed herunder.

Table 3. Genotypic and phenotypic coefficient of variation for grain yield and its component characters in rice

Characters	PCV	GCV	References
Days to flowering	Low	Low	Bastia *et al* .(2008)
	Low	Low	Bisne *et al.* (2009)
	Medium	Medium	Yadav *et al.* (2010)
	Low	Low	Akinwale *et al.* (2011)
	Low	Low	Singh *et al.* (2011)

Table 3. (Contd...)

	Low	Low	Seyoum *et al.* (2012)
	Medium	Low	Vanisree *et al.* (2013)
Plant height	Medium	Medium	Kole and Hasib. (2008)
	Medium	Medium	Bisne *et al.* (2009)
	High	High	Yadav *et al.* (2010)
	Medium	Medium	Singh *et al.* (2011)
	Low	Low	Akinwale *et al.* (2011)
	Medium	Medium	Parikh *et al.* (2012)
	High	High	Tuwar *et al.* (2013)
Number of productive tillers plant^{-1}	Medium	High	Parikh *et al.* (2012)
	High	High	Tuwar *et al.* (2013)
	High	High	Hossain *et al.* (2015)
	High	Low	Idris *et al.* (2012)
	Low	Low	Vanisree *et al.* (2013)
Panicle length	Low	Low	Bastia *et al.* (2008)
	Medium	Medium	Kole and Hasib (2003)
	Low	Low	Bisne *et al.* (2009)
	Low	Low	Singh *et al.* (2011)
	Medium	Medium	Fukeri *et al.* (2011)
	Low	Low	Akinwale *et al.* (2011)
	Low	Low	Idris and Mohamed (2013)

Table 3. (Contd...)

	Low	Low	Vanisree *et al.* (2013)
Total number of spikelets panicle^{-1}	Medium High High Low High	Medium High High Low High	Bisne *et al.* (2009) Yadav *et al.* (2010) Singh *et al.* (2011) Seyoum *et al.* (2012) Tuwar *et al.* (2013)
Number of filled grains panicle^{-1}	High Medium High	High High High	Bisne *et al.* (2009) Idris *et al.* (2012) Vanisree *et al.* (2013)
1000 grain weight	High Medium Low Low Medium Medium	High Low Low Low Medium Medium	Karim *et al.* (2007) Yadav *et al.* (2010) Akinwale *et al.* (2011) Seyoum *et al.* (2012) Vanisree *et al.* (2013) Idris *et al.* (2012)
Grain length	Low Medium Low	Low Medium Low	Vanaja and Babu (2006) Kole and Hasib (2008) Bisne *et al.* (2009)
Grain breadth	Medium Low	Medium Low	Vanaja and Babu (2006) Bisne *et al.* (2009)
L/B ratio of grain	Medium Medium	Medium Medium	Vanaja and Babu (2006) Kole and Hasib (2008)

Table 3. (Contd...)

Single plant grain yield	Medium	Medium	Kole and Hasib (2008)
	High	High	Bisne *et al.* (2009)
	High	High	Hossain *et al.* (2015)
	High	High	Yadav *et al.* (2010)
	High	High	Singh *et al.* (2011)
	High	High	Tuwar *et al.* (2013)
	Medium	High	Vanisree *et al.* (2013)
Harvest index	Medium	Medium	Karim *et al.* (2007)
	Medium	Low	Bastia *et al.* (2008)
	Medium	Medium	Kole and Hasib (2008)
	High	High	Bisne *et al.* (2009)
	Medium	Medium	Singh *et al.* (2011)
	High	High	Parikh *et al.* (2012)

2.2.2 Heritability and genetic advance

Heritability estimates indicate the heritable portion of the phenotypic variation. Information on heritability is important in crop improvement, as it gives an indication of the effectiveness with which selection of genotypes can be done based on phenotypic expression.

Table 4. Heritability, Genetic advance and genetic gain for grain yield and its component characters in rice

Characters	Hertability	Genetic advance	Genetic gain	References
Days to flowering	High	-	Medium	Bisne *et al.* (2009)
	High	High	High	Yadav *et al.* (2010)
	High	Low	-	Akinwale *et al.* (2011)
	High	-	Medium	Singh *et al.* (2011)
	High	-	Low	Seyoum *et al.* (2012)
	High	Low	Low	Vanisree *et al.* (2013)
Plant height	High	-	High	Bisne *et al.* (2009)
	High	High	High	Yadav *et al.* (2010)
	High	-	High	Singh *et al.* (2011)
	High	Medium	-	Akinwale *et al.* (2011)
	High	High	-	Parikh *et al.* (2012)
	High	High	High	Fukeri *et al.*(2012)
	High	-	High	Tuwar *et al.* (2013)
Number of productive tillers plant^{-1}	High	High	-	Seetharam *et al.* (2009)
	Low	-	Medium	Parikh *et al.* (2012)
	High	-	High	Tuwar *et al.* (2013)
	Low	-	Medium	Idris *et al.* (2013)
	Low	-	High	Vanisree *et al.* (2013)

Table 4. (Contd…)

Panicle length	High	-	High	Bisne *et al.* (2009)
	High	-	Low	Singh *et al.* (2011)
	High	-	Medium	Fukeri *et al.* (2011)
	Medium	High	-	Akinwale *et al.* (2011)
	Medium	Low	-	Idris *et al.* (2013)
	High	Low	Low	Vanisree *et al.* (2013)
Total number of spikelets panicle^{-1}	High	-	High	Bisne *et al.* (2009)
	High	High	High	Yadav *et al.* (2010)
	High	-	High	Singh *et al.* (2011)
	High	-	Low	Seyoum *et al.* (2012)
	High	-	High	Tuwar *et al.* (2013)
Number of filled grain s panicle^{-1}	High	-	High	Bisne *et al.* (2009)
	High	-	High	Idris *et al.* (2013)
	High	High	High	Vanisree *et al.* (2013)
1000 grain weight	High	Medium	High	Karim *et al.* (2007)
	Medium	Low	Medium	Yadav *et al.* (2010)
	Low	Low	-	Akinwale *et al.* (2011)
	High	-	Medium	Seyoum *et al.* (2012)
	Medium	Low	Low	Vanisree *et al.* (2013)
	High	Low	-	Idris *et al.* (2013)
Grain length	High	Low	Medium	Vanaja and Babu (2006)
	High	-	Medium	Bisne *et al.*(2009)
Grain breadth	High	High	High	Vanaja and Babu (2006)
	High	-	Medium	Bisne *et al.* (2009)
L/B ratio of grain	High	High	High	Vanaja and Babu (2006)

Table 4. (Contd...)

Single plant grain yield	High	-	High	Bisne *et al.* (2009)
	High	Medium	High	Yadav *et al.* (2010)
	High	-	Medium	Singh *et al.* (2011)
	Medium	-	High	Tuwar *et al.* (2013)
	High	Low	High	Vanisree *et al.* (2013)
Harvest index	High	Low	Medium	Karim *et al.* (2007)
	High	-	High	Bisne *et al.* (2009)
	High	-	High	Singh *et al.* (2011)
	High	-	High	Parikh *et al.* (2012)

2.2.3 Correlation and Path analysis in Varieties (Pollinators)

Bala *et al.* (1999) indicated that grain yield and panicle length had positive and significant correlation with plot yield . grain yield /m^2 and panicle length had positive direct effect with plot yield

Chen *et al.* (2001) conducetd path analysis and based on their effect on yield, the traits were ranked in the order , total number of grains $panicle^{-1}$,effective number of panicles /m^2 ,fertility and 1000 grain weight on the descending order.

Janardhanam *et al.* (2001) found out grains per panicle as the only character that was directly and positively associated with single plant yield. Significant positive associations were observed between plant height and productive tillers, panicle length and spikelets per panicle.

Mishra and Verma (2002) reported that grain yield per plant was significantly and positively correlated with number of ear bearing tillers $plant^{-1}$,biological yield, harvest index, and number of filled grains per panicle. Path coefficient analysis revealed that biological yield and harvest index had the highest positive direct effects on grain yield. The characters namely number of filled grains per panicle, number of productive tillers /m^2 and 1000 grain weight also recorded positive direct effect on grain yield.

Surek and Beser (2003) recorded that grain yield was significantly correlated with its componenet vharacters like the number of productive tillers /m^2, biological yield, harvest index and number of filled grains per panicle. Path coefficient analysis revealed that biological yield and harvest index had the highest positive direct effects on grain yield. The characters namely number of filled grains per panicle, number of productive tillers /m^2 and 1000 grain weight also recorded positive direct effect on grain yield.

Correlation analysis by Khedikar *et al.* (2003) with twenty scented rice genotypes revealed that grain yield had phenotypic and genetic correlation with effective tillers per plant. Geotypic correlation was slightly higher than respective values of phenotypic correlation for most of the characters. The path coefficient analysis revealed that test weight had the highest direct effect on grain yield per plant. It was followed by effective tillers per plant, panicle length and days to 50 per cent flowering and hence direct selection through these characters is more effective.

Correlation and path analysis for yield and yield componenets in rice by Sathis *et al.* (2009) reported that number of productive tillers plant^{-1} , 1000 grain weight, panicle length and number of grains panicle^{-1} showed a positive association with grain yield plant^{-1} .the study also revealed that path analysis the number of grains per panicle, days to 50 % flowering, 1000 grain weight, number of productive tillers plant^{-1} shown high positive direct effects on grain yield

Bagheri *et al.* (2011) reported that panicle length, total number of spikelets panicle^{-1} , number of filled grain panicle^{-1} and the panicle number plant^{-1} correlated significantly with grain yield. Path coefficient analysis revealed that panicle length had the highest positive direct effect on grain yield. Grain yield linearly correlated with panicle length,the number of panicles plant^{-1}, number of filled grain panicle^{-1} .Therefore these traits may be used in the selection for grain yield in rice.

Akinwale *et al.* (2011) reported that grain yield exhibit positive correlation with the number of tillers plant^{-1}, panicle weight, and the number of grains per panicle.

Studies based on correlation and path analysis of traditional rice accession by Ekka *et al.* (2011) indicated that grain yield plant^{-1} had significant positive correlation with leaf width, days to 50% flowering, plant height, panicle length, number of filled grains panicle^{-1}, 100 seed weight, and paddy length. Path coefficient analysis revealed that direct selection for days to 50% flowering, 100 seed weight, panicle length, leaf length and milling per centage would likely be effective for increasing grain yield. Abarshahr *et al.* (2011) reported that path analysis for paddy yield indicated that the number of spiklelets panicle^{-1} and flag leaf length had positive direct effects and days to complete maturity and plant height had negative direct effect on paddy yield under optimum irrigation conmdition while flag leaf width and number of filled grains panicle^{-1} had positive direct effects and days to 50% flowering had negative direct on paddy yield under drought stress conditions.

Satheeshkumar and Saravanan (2012) reported that grain yield plant^{-1} exhibited high significant and positive genotypic correlation with number of productive tillers plant^{-1} , filled grain panicle^{-1} , total number of grains. Path analysis showed maximum positive direct effect for kernel L/B ratio, kernel length, number of filled grains panicle^{-1}, total number of grains and number of productive tillers plant^{-1} hence selection based on these traits could be more effective in rice.

Angustina *et al.* (2013) reported that number of grains panicle^{-1} had the highest and significant correlation with grain yield, days to booting, days to 50% heading had negative but high correlation.

Studies based on correlation and path analysis of traditional aman rice accession by Hossain *et al.* (2015) indicated that grain yield plant^{-1} had significant positive correlation with both genotypic and phenotypic level by days to flowering and plant height.

2.3 Evaluation of two line rice hybrids

2.3.1 Variability, combining ability and heterosis of segregating populations of rice

Table 5. Genotypic and phenotypic coefficient of variation for grain yield and its component characters in segregating populations of rice

Characters	PCV	GCV	References
	Low	Low	Hasan *et al.* (2011)
	Low	Low	Subbaiah *et al.* (2011)
	Low	Low	Tai (1979)
Days to flowering	Medium	Medium	Das *et al.* (2013)
Plant height	High	High	Jaiswal *et al.* (2007)
	High	Low	Karad and Pol (2008)
	Moderate	Moderate	Kishore *et al.* (2008)
	High	High	Nayak (2008)
	Low	Medium	Hasan *et al.* (2011)
	Low	Low	Subbaiah *et al.* (2011)
	Medium	Low	Babu *et al.* (2012)
	Medium	Medium	Das *et al.* (2013)
Number of productive tillers plant^{-1}	High	High	Subbaiah *et al.* (2011)
	Medium	Medium	Babu *et al.* (2012)
Panicle length	High	High	Jaiswal *et al.* (2007)
	Low	Low	Singh *et al.* (2011)

Table 5. (Contd...)

	High	Low	Karad and Pol (2008)
	High	Moderate	Kishore *et al.* (2008)
	High	High	Kole and Hisab (2008)
	High	High	Nayak (2008)
	High	High	Kumar *et al.* (2014)
	Low	Low	Hasan *et al.* (2011)
	Low	Low	Subbaiah *et al.* (2011)
	Low	Low	Babu *et al.* (2012)
	Medium	Medium	Das *et al.* (2013)
Number of filled grains panicle^{-1}	High	High	Babu *et al.* (2012)
1000 grain weight	Low	Low	Babu *et al.* (2012)
	Medium	Medium	Das *et al.* (2013)
Single plant grain yield	High	High	Jaiswal *et al.* (2007)
	High	High	Nayak (2008)
	High	High	Kumar *et al.* (2014)
	Medium	Medium	Subbaiah *et al.* (2011)

Table 6. Heritability, genetic advance and genetic gain for grain yield and its component characters in segregating populations of rice

Characters	**Hertability**	**Genetic advance**	**Genetic gain**	**References**
	High	Low	Low	Hasan *et al.* (2011)
	High	Medium	Medium	Subbaiah *et al.* (2011)
	High	Medium	Medium	Babu *et al.* (2012)
Days to flowering	High	High	-	Das *et al.* (2013)
Plant height	High	-	Medium	Hasan *et al.* (2011)
	High	Medium	Medium	Subbaiah *et al.* (2011)
	High	Medium	Medium	Babu *et al.* (2012)
	High	High	-	Das *et al.* (2013)
Number of productive tillers plant^{-1}	High	Low	High	Subbaiah *et al.* (2011)
	High	Low	Low	Babu *et al.* (2012)
Panicle length	High	High	-	Kumar *et al.* (2014)
	High	High	-	Nayak (2008)
	High	-	Medium	Hasan *et al.* (2011)
	High	Low	Medium	Subbaiah *et al.* (2011)
	Medium	Low	Low	Babu *et al.* (2012)
	High	High	-	Das *et al.* (2013)

Table 6. (contd…)

Number of filled grains panicle^{-1}	High	High	High	Babu *et al.* (2012)

1000 grain weight	High High	Low High	Medium -	Babu *et al.* (2012) Das *et al.* (2013)
Single plant grain yield	High	Low	High	Subbaiah *et al.* (2011)

2.3.2 Correlation and Path analysis in rice hybrids

Ganesan (2000) conducted a study to assess the nature and magnitude of association between grain yield and its componenets characters of hybrids . most of the characters studied *viz.*, days to flowering, plant height, number of tillers,productive tillers plant^{-1}, panicle exsertion,spikelets panicle^{-1} and filled grains panicle^{-1} exhibited positive correlation with grain yield at both genotypic as well as phenotypic level.

Durai (2001) studied the genotypic and phenotypic correlation among hybrid rice yield componenets viz., productive tillers plant^{-1}, filled grains ear^{-1}, 100 grain weight and grain yield plant^{-1}. At the genotypic level , plant yield was positively and significantly correlated with productive tillers plant^{-1}, however at genotypic abnd phenotypic levels, it was significantly and positively correlated with harvest index. The yield components were interrelated 100 grain weight with total dry matter accumulation and harvest index.100 grain weight exhibited a high indirect effect on yield through total dry matter accumulation

Correlation analysis by Jin *et al.* (2001) in two line hybrid revealed that extremely and significantly positive correlations existed among the character viz.panicle length, total grain number per panicle and grain weight per panicle with correlation coefficients ranging from 0.652 to 0.994.

Tang *et al.* (2004) reported that yield of crosses was positively related to the number of effective panicles, filled grain number , seed setting rate and 100 grain weight, whereas the number of effective panicles were negatively related to plant height.

Verma and Srivastava (2004) found that grain yield /plant was associated positively and significantly at both henotypic levels with biological yield, number of total and productive tillers per plant, 100 grain weight and panicle length in F_1. Inter correlation was noted among biological yied with number of total and productive tillers per plant; L/B ratio with 100 grain weight and kernel length.

Correlation and Path analysis of popular rice hybrids of India by Babu *et al.* (2012) revealed that character association of the yield attributing traits revealed significantly positive association of grain yield plant^{-1} with number of productive tillers plant^{-1} ·Hence selection for these traits can improve the yield. Path coefficient analysis revealed that panicle length and number of productive tillers plant^{-1} exhibited positive direct effect on yield.among these charaters number of productive tillers plant $^{-1}$ possessed both positive association and high direct effects. Hence selection for this characters could bring improvement in yield and yield componenets.

Correlation and path analysis of yield and yield components in rice by Bhadru *et al.* (2012) revealed that the characters plant height, panicle length, number of productive tillers plant^{-1}· filled grains panicle^{-1} exhibited significant positive association with grain yield plant^{-1} . Direct positive effect and indirect association among the traits were observed at both genotypic and phenotypic levels. Thus simultaneous selection for these characters helps in selection of superior cross combinations in hybrid rice.

2.3.3. Combining ability

Assessing the combining ability of parental lines is extremely useful in a hybrid breeding program, especially when many prospective parental lines are available and the most promising ones are to be identified on the basis of their ability to give superior hybrids. Combining ability refers to the ability of a genotype to transfer its desirable traits its progenies (Spargue and Tatum, 1942). The average performance of a line or population in several hybrid combinations is known as "general combining ability" (GCA) and the deviation in performance of the specific hybrid expected from *gca* of parents is referred to as "specific combining ability" (SCA).

China was the first country to release two line hybrids for commercial cultivation. Hybrids developed by two line system generally had given better heterosis than three line hybrids because there are lesser restrictions in the choice of parents in comparison to three line system involving cytoplasmic male sterility.

In China, during 1989, a series of two line intervarietal hybrids had been successfully developed and satisfactory results were obtained in trials and demonstrations (Yuan, 1990). The hybrid combination 5047S/R 91 recorded 20 per cent higher yield than that of conventional rice variety E-yi 105 and E-Wan 5. In 1991, the two line hybrids were planted to 20,000 ha throughout China.

Mou *et al.* (1998) found that the SCA variance was greater than GCA variance for grain yield per plant and highlighted the importance of non additive gene action as well as additive gene action as well as additive gene action for all other agronomic traits studied.

The lines W 6154 S and W 6184 S were identified as good general combiners for grain yield (Mou *et al.*, 1998). Gong *et al.* (1993) observed that the TGMS lines *viz.,* Hennong and 3130 S were the best combiners. Sun *et al.* (1993) found that days to heading in the hybrids were significantly affected by *gca* of the parents.

The *indica* two line combinations like W6154 S/ Teqing, W6154 S/ 312, W6154 S/ Tesanai, K9 S/ 03, Pei ai 64 S / Xiangzaoxian and 5460 S / Minghui 63 were having a coverage of 30,000 ha in the Yangtze River valley and South China (Lu. *et al.,* 1994). Yields were generally 8.3 – 9.8t/ha, the highest being more than 11 t/ha, 5-10 per cent higher than that of three line hybrids.

He *et al.* (1995) studied combining ability of two line hybrids and reported that heterosis was influenced by SCA of both male sterile and restorer lines. The total combining ability and total GCA were closely related characteristics. The best hybrids produced 27.5, 16.6, 12.8 and 7.4 per cent greater grain yields than the control 76-27B / T 806, respectively.

Bai and Luo (1996) evolved new two line hybrid rice in China. The hybrid rice Liangyou Piete (Pei ai 64S / Teqing) yielded more than 7.5 t/ha with a maximum yield 10.4t/ha, in late season crop. It yielded a record of 17.1 t/ha in Yong Sheny county, Yuhan. This two line hybrid had about 10 per cent yield advantage over its three line hybrid counter parts.

Kalaiyarsai (2000) identified TS 18 as a good general combiner. The hybrids TS 29 X TNAU 9424, TS 18 X Yamadanishiki and TS 29 X P -R-R-16 had high *sca* for yield and yield traits.

Chen *et al.* (1997) reported that the grain yield per plant appeared to be under the control of non additive genes while plant height and heading date were mainly controlled by additive gene effects.

Predominance of non additive gene action was reported for the yield and yield related traits by several workers (Sampoornam and Thiyagarajan, 1998; Patil, 2000).

Du *et al.* (1997) identified the line VN1 with good general combining ability for growth duration, plant height, panicle length, grains per panicle and 1000 grain weight.

The TGMS line TS 18 was reported as good general combiner for various traits (Sampoornam and Thiyagarajan, 1998; Patil, 2000).

Cherian (1998) identified TS 16 as a good general combiner with significant *gca* effects for all the traits studied.

The lines TS 15 and TS 18 were good general combiners for filled grains per panicle and spikelet fertility and TS 16 for productive tillers per plant. (Rangaswamy *et al.*, 1998).

Chen *et al.* (2000) reported that the lines viz., Pei ai 64 S, N 422 S and 108 S were good general combiners for grain yield per plant. Yang *et al.* (1990) identified the good general combiners *viz.*, 3204 S for number of panicles per plant and 1103 S for panicle length, seed set per cent and grain yield per plant.

Radhidevi (2000) observed predominance of additive gene action for days to 50 per cent flowering and panicle length and non-additive gene action for other traits. Yang *et al.* (1990) reported that the variance due to GCA was higher than SCA variance in their studies.

Latha (2001) reported the predominance of non additive gene action governing the characters *viz.*, plant height, number of productive tillers per plant, panicle length, Spikelet fertility and grain field per plant, while additive and non-additive gene action for days to 50 per cent flowering, number of filled grains per panicle and 100 grain weight.

Kalaiyarasi *et al.* (2002) studied the panicle exsertion of TGMS lines TS 15, TS 16, TS 18, and TS 29 and reported that the line TS 15 has the high *gca* effect for panicle exsertion. She also reported on the role of non additive gene action for yield and yield contributing characters.

The lines TS 18 and TS 46 were identified as good general combiners for number of productive tillers per plant, spikelet fertility and grain yield per plant and the hybrids TS 18 x CB 96073, TS 29 x CB 96073, TS 29 X TNAU 841434 had high *sca* effect for yield per plant (Latha, 2001).

Radhidevi *et al.* (2002) found that TS 29 had been a good general combiner and the hybrids TS 18 x IR 65515 and TS 29 x IR 65515 had *sca* effects for grain yield. The line GD 98049 and the tester IR 69726-54-3-1R were identified as the best general combiners for days to 50 per cent flowering, plant length, number of filled grains per panicle, spikelet fertility and the grain yield per plant. The hybrid GD 98014 x IR 69726-54-3-1R was the best with 42.84 and 52.72 per cent yield increase over the standard check hybrids, CORH 2 and ADTRH 1 respectively (Sundar, 2003).

Sadhasivam (2004) identified that the line GD 99007 and the tester IET 17886 were identified as the best general combiners for the panicle, length, 100 grain weight number of grains per panicle, panicle exsertion and grain yield per plant. He also identified that the GD 99007 X IET H886 was the best with 66.72 per cent yield increase over standard check variety CO(R) 47.

Panwar (2005) recorded the hybrids *viz.,* IET13846 x Pusa Basmati-1, IET 13846 x IR 64, IET 13846 x Kasturi and IET 13846 x Taraori Basmati had high *per se* performance with significant *sca* effects for grain yield, high to moderate heterosis and both the parents of these crosses were good general combiners.

Aananthi and Jebaraj (2006) recorded the hybrid TS 29 x Ponni recorded the maximum standard heterosis (51.65%) followed by TS 6 x Ponni (37.7%) TS 29 x CO 45 (32.00%) and TS 16 x CO 43 (23.06%) for single plant yield and it recorded more than 10 per cent heterosis over the three line hybrid CORH 2.

Gnanasekaran *et al.* (2006) identified the TGMS lines *viz.,* GD 98049 and GD 98014, and the testers CB 97033 and IR 72 were the best based on the mean and *gca* effects.

Rashid *et al.* (2007) identified that the crosses between Basmati-370/DM-25 and Super Basmati/DM-107-4 were good specific combiners for yield/plant.

Satheesh *et al.* (2010) reported that the parents JAYA and CRAC 2221-67 were good general combiners for grain yield per plant and most of the yield traits. The cross combinations CRAC2221-67 x JAYA and IR6331-1-B-3R-B-24-3 X JAYA were the best specific combiners for grain yield per plant.

Yussouf *et al.* (2010) identified the hybrids *viz.*, Basmati 2000, Super Basmati and Kashmir Basmati and one tester Basmati-385 were good general combiners based on their mean performance and *gca* effects for yield and its various traits.

Among the 20 two line crosses Chandirakala (2005) reported that GD 99017 x CO 47 and GD 98014 x TKM 12 showed high specific combining ability effects. GD 98049 x IR72and GD98049 x CO43 were good specific combine for different characters. These crosses can be used for development of rice hybrids in future.

2.3.4. Heterosis for two line hybrids

Hybrid vigour in rice was reported by Jones in 1926 and Ramiah in 1933. The discovery of Cytoplasmic Male Sterility (CMS) in rice (Athwal and Virmani (1972), Erickson (1969) and Shinjyo (1969) suggested that breeders could develop a commercially viable F_1 hybrid, but little serious interest was paid until China released successful F_1 hybrids for cultivation in 1976.

Virmani *et al.* (1981) presented data on the large variation in heterosis and hetero beltiosis for yield and yield components. Heterobeltiosis ranged from 69 to -91 per cent for yield, 55 to - 70 per cent for grains per panicle, 14 to -31 per cent for grain weight and 05 to -45 per cent for panicles per plant

The Intervarietal *japonica* two line combinations developed in China *viz.*, N 5047S X R 9 - 1, 5088S X R187, 5088S x R 9-1, 31301S X1514 and 7001S X Lunhui 422 recorded 6.8 - 7.5 t/ha was 10-15 per cent higher than the leading *japonica* varieties Ewan 5 and Eyi 105. However, the yield increase was not significant compared with the leading three line hybrid Shanyou 63. The intervarietal *indica* two line combinations viz., W 6154S x Teqing, W 6154S X 312, W6154S X Tesanai, K9 S X 03, Pei ai 64S X Xiangzaoxian 1 and 5460S X Minhui 63 yielded 8.3 - 9.8 t/ha, which was 5-10 per cent higher than that of shanyou 63 and Shanyogui 33, the promising three line hybrids. The yield potential of inter sub specific two line hybrids was 30 per cent higher than that of inter-varietal hybrids. The TGMS lines with wide compatible (WC) gene *viz.*, Pei ai 64S, W 9001S and 3105 S were utilized for evolving intersubspecific hybrids. W 6111S x Varylava 1312 (Yayou 1) and W 6154S x Varylava 1312 were the successful inter sub specific hybrids with an yield of 9.8-11.3 t/ha with 15 per cent increased yield over Shanyou 63 (Luo *et al.*, 1994).

Feng *et al.* (1985) recorded significant heterosis for the characters total grains per panicle, number of filled grains per panicle and grain weight per plant in two line hybrid while the heterosis was weak for growth period, per cent seed set and 1000 grain weight. Heterosis was also reported by Zhu *et al.* (1995) for grains per panicle and number of panicles per plant.

Reddy *et al.* (1996) observed standard heterosis to an extent of 58 per cent for seed yield which ranged from 2.3 to 31.3g per plant. The spikelet fertility of inter and intra subspecific combinations was 2.7 to 88.4 and 3.6 to 9.6 per cent respectively. The hybrid TGMS 1 x IR 64 developed from Directorate of Rice. Research (DRR), Hyderabad produced yield of 10 t/ha (DRR, 1996).

Hussain (1996) attempted a comparative study on the performance of two line and three line hybrids for yield contributing character. He reported the highest percentage of heterosis for number of panicles per plant, number of spikelets per panicle, filled grains per panicle, spikelet fertility and grain yield per plant in two line hybrids while three line hybrids recorded more heterosis for panicle exsertion, panicle length and thousand grain weight. The two line hybrid, TGMS 18 x IR 10198-66-2R exhibited a standard heterosis of 35.52 per cent over the standard variety CO 45 and 31.34 per cent over the three line hybrid IR 62829 A x C 20 R.

Huang *et al.* (1997) identified the *cross* combinations 2136 S x Doxi No.l, 2136 S x Minghui 63 and 2136 S x 6078 with a yield advantage of 10.4, 13.6 and 15.2 per cent respectively over the check Shanyou 63.

Hoang *et al.* (1997) developed two line hybrids with 73.2 to 162.0 per cent standard heterosis for panicle length, plant height and grain yield utilizing the TGMS lines VN 01S, VN 02S and TG 162S. Du *et al.* (1997) have also reported significant heterosis for growth duration, plant height, panicle length, grains per panicle and 1000 grain weight in the hybrids VN 01S x D 212 and VN 01 x D 18. The two line hybrid Peiza 67 (Pei ai 64S x Peiza Shanqing) developed by Liu *et al.* (1997) showed significant positive heterosis for grains per panicle and grain yield while negative heterosis was recorded for plant height and duration.

Chen *et al.* (1997a) evaluated the direct and reciprocal crosses between TGMS lines and wide compatible varieties and reported 13.9 and 20.4 per cent heterosis for grain yield and 26.8 and 29.9 per cent heterosis for spikelet fertility, respectively.

Cherian (1998) identified TS16 x AS 781/3 as a superior hybrid based on mean performance, *sca* and standard heterosis for yield and yield contributing traits. TS 18 x Norin PL 9 and TS 16 x C 22 were the other two best performing hybrids with standard heterosis of 45.64 and 34.68 per cent, respectively.

Sampoornam and Thiyagarajan (1998) reported six promising two line hybrids *viz.,* TS 18 x ADT 42, TS 15 x ASD 18, TS 18 x IR 55722-13-6-3-2R, TS 18 x Norin PL 9, TS 18 x BPI 76 and TS 18 x CO(R) 37 in which the magnitude of standard heterosis ranged froM 20.7 to 81.56 per cent. Thiyagarajan *et al.* (1998) recorded high standard heterosis for grain yield in the hybrids TS 18 x IR 68902B (41.36%), TS IS x ADT 36 (26.63%), TS 18 x IR59601-301-3-6R (12.18%) and TS 15 x IR 37399-101-3-3-2R (11.61%).

Hoang *et al.* (2000) evaluated new two line hybrids *viz.,*11S x MH 86, US x QC 1, 7S x QC l, 7S x MH86 and 6S x RC 1 and found that the cross combination US x MH 86 (TM 4) was the promising one with 6.76 tonnes per hectare.

Zeng *et al.* (2000) reported that more than ten two line hybrid combinations have been approved for cultivation in China and the dual purpose genic male sterile line Pei ai 64S has been used extensively. Several putative super hybrid rice have been developed and some of them produced daily rice production of 100 kg /ha.

Sun *et al.* (2000) studied the heterosis of two line hybrids between PGMS / TGMS lines and improved cultivars. They reported strong heterosis for number of panicles per plant, number of filled grains per panicle, 1000 grain weight and grain yield per plant.

Patil (2000) identified TS 18 x C 20 and Pei ai 64S xC 20 as promising two line hybrids with 49.66 and 46.55 per cent standard heterosis, respectively over the check hybrid CORH 2. The two line hybrid *viz.* TS 18 x CB 96026 recorded 26.11 per cent increased yield over CORH 2 (Latha, 2001). She also reported that the hybrids viz., TS 46 x BPI 76, TS 18 x MRST 9, TS 18 x BPI 76 had registered an increased yield of more than 10 per cent over CORH 2.

Kalaiyarasi *et al.* (2002) reported two line hybrids *viz.,* TS 29 x TNAU 94241 (36.59 %), TS 18 x CO(R) 47 (7.42 %) and TS 29 x Duiar (5.37 %) with increased yield over the standard check CORH 2. Sundar (2003) reported that the hybrids GD 98014 x CB 97042, GD 99017 x IR 66758 -42-3-1 and GD 98029 x IR 63908-46-2-2-2R had significant standard heterosis for the yield.

Sadhasivam (2004) recorded that the hybrids GD 98168 x AD 98208, GD 98159 x CB 99170, GD 99007 x IET 16527, GD 98168 x IET 17886 and GD 99036 x IET 17886 had superior significant standard heterosis for yield.

Kalaiyarasi *et al.* (2006) reported that inter-subspecies two line hybrids *viz.,* TS 29 x TNAU 94241, TS 29 x CB 96073 (*indica/indica*), TS 18 x Yamadanishiki, TS 18 x Gohyakumangohu (*indica/japonica*), TS 29 x Dular (*indica/javanica*) were identified as best hybrids which could be used for exploitation of heterosis in rice.

Chandrakala and Thiyagarajan (2010) reported the hybrids GD 98029 x IR61608-213, GD9804 x IR61608-213 and GD98014 x RR 166-645 could be exploited for earliness as they exhibited negative and significant standard heterosis for days to 50 per cent flowering over the checks. Top yielding hybrids *viz.*, GD 98049 x IR 63875-196-2-2-1-3, GD 98014 x TKM11, GD 98049 x TKM 11, GD 99017 x TKM 12 exhibited significant standard heterosis over CORH 2 and ADTRH 1.

Yussouf *et al.* (2010) recorded hybrids like Basmati Pak x Basmati-385, Super Basmati x Basmati-385, DM-107-4 x Basmati 385, Basmati 2000 x EL-30- 2-1, Basmati 2000 x DM-25, DM-16-5-1 x Basmati-385 and Kashmir Basmati x DM-25 showed high mean performance, *sca* effects and heterobeltiosis for grain yield.

2.4. Quality analysis in Hybrids

In countries where rice is consumed, traits of grain quality dictate market value and have a pivotal role in the adoption of new varieties (Juliano, 2003 and Fitzgerald *et al.*, 2008). Quality traits encompass physical appearance, cooking and sensory properties and, more recently, nutritional value. The value of each trait, for example the length of the grain, varies according to local cuisine and culture. Physical properties include yield of edible and marketable polished grain, uniform shape, whiteness and, in most countries, translucence. These traits are immediately obvious to consumers and so are major factors defining market value. Cooking and sensory qualities typically include: cooking time (Juliano *et al.*, 1964) textural properties of cooked rice aroma and its retention after cooking and the ability to remain soft for several hours after cooking (Philpot *et al.*, 2006).

Yield of rice hybrids by itself would not make hybrid rice technology acceptable. They must also have acceptable grain quality. Only limited efforts have been made to improve the grain quality of hybrid rice (Khush *et al.*, 1986).

In a study, Yi *et al.* (2009) reported that to improve fragrance and intermediate amylase content in Manawthukha, Basmati 370 was used as a donor parent to introgress the Basmati alleles of genes conferring fragrance and intermediate amylase content into Manawthukha by Marker Assisted Backcrossing .

Asish *et al.* (2007) reported that the high GCV and PCV values were observed for head rice recovery, volume expansion, alkali spreading value, gel consistency and medium values for milling out turn, kernel length, kernel breadth, L/B ratio, kernel length after cooking, kernel breadth after cooking, breadth-wise elongation ratio and amylose content.

2.4.1. Milling quality traits

Concern of farmers and millers is to get higher price of produce (both paddy and rice) which is determined by market quality standards comprised by shape, size, colour, hulling percentage, milling percentage, head rice recovery, whereas consumer's concern is to get rice of good cooking and eating quality which is determined by physio-chemical properties.

The milling percentage of the fifteen test varieties ranged from 55.00 to 73.15 per cent. The head rice recovery had a maximum value 59.67 per cent in K-332 was reported by Dipti *et al.* (2002). A quality rice variety should have high head rice recovery of atleast 70 per cent if calculated as per cent of milled rice which comes about to be minimum of 47 per cent if worked out as a per cent of rough rice.

Asish *et al.* (2007) reported that physicochemical characteristics of rice grains are important indicators of grain quality and high GCV and PCV values were observed for head rice recovery, volume expansion, alkali spreading value, gel consistency and medium values for milling out turn, kernel length, kernel breadth, L/B ratio, kernel length after cooking, kernel breadth after cooking, breadth wise elongation ratio and amylose content. Correlation studies revealed that kernel length had highly significant positive correlation with length / breadth ratio, gelatinization temperature and significant positive association with kernel length after cooking and amylose content. Milling out turn had highly significant positive association with head rice recovery.

2.4.2. Physical grain quality traits

Kernel length (L), Breadth (B), Kernel length/breadth ratio (L/B ratio)

In quality rice, kernel length, kernel breadth and Kernel length/breadth ratio are important traits. The rice is classified according to the kernel length as short-grain, medium-grain, and long-grain and long slender grain.

Bai *et al.* (1991) in their study for grain quality attributes of 11 rice genotypes showed that kernel length ranged from 5.11 to 7.05 mm, kernel breadth from 2.22 to 2.72 mm and L/B ratio from 1.95 to 2.82. Khanna *et al.* (1992) in their study with ten genotypes reported that the kernel length ranged from 5.66 to 6.98 mm, the grain width from 1.99 to 2.71 mm and the kernel length/breadth ratio from 2.09 to 3.51.

Arumugachamy *et al.* (1995) in a study with ten quality rice varieties showed that Kasthuri and Pusa basmati-1 have brown rice length of more than 7 mm and kernel length/breadth ratio of about four. They also reported that kernel length ranged from 5.1 to 8.3 mm, kernel breadth from 1.9 to 2.7 mm and Kernel length/breadth ratio from 1.9 to 4.3.

Hussain *et al.* (1987) studied grain quality traits in 100 indigenous germplasm lines of upland rice reported low and moderate GCV and PCV for kernel length and breadth respectively. Ganesan (1995) in a study with 28 F_1 hybrids reported low GCV and PCV for kernel length and breadth. Verma *et al.* (2000) in a study involving seven diverse parents, F_1's and F_2's reported low variability for kernel length / breadth ratio.

Quality analysis of kerala rice varieties by Suganthi and Nacchair (2015) reported that the level of damaged kernel and discolored kernals were relatively low and showed no significant difference.

2.4.3. Cooking quality traits

Kernel elongation

Lengthwise elongation after cooking without increase in girth is considered most desirable in high quality rices. During cooking, rice grains absorb water and increase in length, breadth and volume was noticed in experiment conducted by Sood (1983). Both lengthwise and breadth-wise splitting of grains may accompany the increase. The mechanism of grain elongation is not well understood, but it is thought to be both physical and chemical phenomena. Anatomical features such as endosperm cells, affect kernel elongation upon cooking.

Bai *et al.* (1991) in their study with eleven red rice genotypes reported elongation ratio ranging from 1.53 in Karthika to 2.23 in Aruna. Khanna *et al.* (1992) in their study with ten genotypes reported elongation ratio ranging from 1.4 in RHR 6 to 1.7 in RHR1, RHR 4 and Jaya.

In a study with ten early mutants and the parent variety Samba Mahsuri, Kulkarni *et al.* (2000) reported that elongation ratio varied from 1.34 to 1.60. Mutants M-7 and M-20 had higher elongation ratio than the parent variety. Mishra and Verma (2002) evaluated 72 F_1s and 16 parents and they reported high GCV for kernel elongation ratio while kernel length after cooking recorded low GCV. Kernel elongation ratio varied from 1.53 to 1.89 and short bold rices recorded 1.64 kernel elongation ratio, though it had intermediate kernel length after cooking was observed by Shikari *et al.* (2008). Dipti *et al.* (2003) noticed linear elongation ratio less than 1.32 is undesirable.

Gel consistency

Gel consistency (GC) is a good index of cooked rice texture. Varieties having the same amylose content may differ in tenderness and therefore, cooked rices may be differentiated by GC test (Cagampang *et al.*, 1973). Within the same amylose group, most rice consumers generally prefer varieties with softer gel consistency. Karim *et al.* (1992) comparing the physico-chemical characteristics of some promising medium-grain rice breeding lines with standard varieties IR 6 and KS 282 reported that gel consistency values range from 32 to 64 mm.

Out of fifteen entries evaluated, 11 exhibited soft gel consistency, two had medium to hard gels and two showed hard gel consistency (Singh *et al.*, 2008). High flacky rices have gels in the range of 41 to 60 mm and soft gel types have 61-100 mm in length were noticed in a study conducted by Bansal *et al.* (2006).

Amylose content

Tan *et al.* (1999) conducted genetic analysis of three traits, amylose content (AC), gel consistency (GC) and gelatinization temperature (GT). The materials used in the analysis included F_2 seeds, an $F_{2:3}$ population, and an F_9 recombinant inbred-line. Segregation analyses of these three generations showed that each of the three traits was controlled by a single Mendelian locus and a single locus that controls the expression of all three traits.

Amylose content is considered as one of the important criteria which determine the cooking and eating characteristics of rice. Amylose content ranged from 16 per cent in Pavizham to 21.9 per cent in Remya in a study on the quality attributes of 11 red rice genotypes (Bai *et al.*, 1991). Khanna *et al.* (1992) in their study with ten genotypes showed that the amylose content ranged from 16 per cent to 29.6 per cent.

Arumugachamy *et al.* (1995) reported that the amylose content ranged from 16 per cent to 32.4 per cent in a study with 16 rice cultivars. He also reported that CR 1009, CO 43, ADT 36, ADT 42, TKM 9, ADT 37 and ASD 16 had high amylose content (more than 24 per cent) and ADT 41 had very low amylose content (16 per cent).

Shobha Rani *et al.* (2008) studied 78 rice genotypes for grain quality variation for physicochemical, milling and cooking properties in Indian rices and the amylose content ranged from low (15.57 per cent) to high (27.9 per cent). Twenty six genotypes possess intermediate amylose content which is a desirable combination governing the cooking and eating quality features.

The maximum value of amylose content was recorded for Pusa suganth-3 (28 per cent) among the fifteen genotypes observed by Shikari *et al.* (2008).

2.5. Molecular analysis

Numerous genes of economic importance having quantitative nature are repeatedly transferred from one varietal background to another by plant breeders through conventional breeding. Phenotypic observations of many traits are time consuming and expensive, if such genes can be tagged with DNA markers, time and money can be saved when transferring them from one varietal background to another. The recent development of DNA markers and linkage maps of rice provided new opportunities for genetic improvement of rice grain quality (Shobha Rani *et al.*, 2008).

2.5.1. Microsatellites or Simple Sequence Repeats (SSR) marker

Genetic studies have shown that a recessive nuclear gene controlled the TGMS trait in rice. At present, five single recessive TGMS genes located on different chromosomes have been reported (Sun *et al.*, 1989; Maruyama *et al.*, 1991; Wang *et al.*, 1995; Subudhi *et al.*, 1997; Dong *et al.*, 2000; Reddy *et al.*, 2000 and Lopez *et al.*, 2003).

Microsatellites or SSRs are tandemely arranged repeats of 1-6 nucleotide long DNA motifs that frequently exhibit variations in the number of repeats at a locus as reported by Parida *et al.* (2006). They are ubiquitous in eukaryotic genomes and can be analysed through PCR technology. The sequences flanking specific microsatellite loci in a genome are believed to be conserved within a particular species, across species within a genus and rarely even across related genera (Varshney *et al.*, 2002). The conserved sequences, which flank the SSR, have been used for designing suitable primers for amplification of the SSR loci using PCR. Micro-satellites differ from mini-satellites, which are repeated sequences having repeat units ranging from 11-60 bp in length. These loci contain tandem repeats that vary in the number of repeat units between genotypes and are referred to as Variable Number of Tandem Repeats (VNTR) or Hyper Variable Regions (HVR).

SSRs are currently considered as the molecular markers of choice and are rapidly being adapted by plant researchers because of their simplicity, high levels of polymorphism have been reported (Huang *et al.,* 2002; Fufa *et al.,* 2005), high reproducibility and codominant inheritance patterns (Roder *et al.,*1998). These markers are chromosome specific (often amplifying a single locus with multiple alleles), and can be evenly distributed along different chromosomes. SSR markers are excellent markers for genetic diversity analysis and genotype identification in self-pollinated species such as rice and wheat (Domini *et al.,* 2000). The first attempt to use SSR markers in rice was made by Zhao and Kochert (1993).

SSRs are currently considered to be the most informative molecular genetic marker for DNA finger printing and varietal identification (Udupa *et al.,* 1999), genome mapping (Chen *et al.,* 1997b and McCouch *et al.,* 1997), gene tagging (Blair and McCouch, 1997) and studies of population dynamics (Yang *et al.,* 1990). Furthermore, a saturated map of SSR markers is available (McCouch *et al.,* 2002 and Zhang *et al.,* 2007). Compared with RFLPs, microsatellite markers detect a significantly higher degree of polymorphism in rice and are especially suitable for evaluating genetic diversity among closely related rice cultivars (Akagi *et al.,* 1997).

In a study, Sunita *et al.* (2004) assessed the genetic relationships among Indian aromatic and quality rice germplasm using 30 fluorescently labeled rice microsatellite markers. The 69 rice genotypes used in this study included 52 Basmati and other scented/quality rice varieties. A total of 235 alleles were detected at the 30 simple sequence repeat (SSR) loci, 62 (26.4 per cent) of which were present only in Basmati and other scented/quality rice germplasm accessions.

Simple sequence repeats markers (microsatellites) are co-dominant, hypervariable, abundant and well distributed throughout the rice genome (Temnykh *et al.*, 2001). About 2240 microsatellite markers are now available through the published high-density linkage map (McCouch *et al.*, 2002) or public database. The application of microsatellites markers in rice include characterization of the genetic structure of the cultivated rice *O. sativa* at both the inter and intra-varietal level (Garris *et al.*, 2005), genetic diversity and/or evolutionary analyses of landraces, weedy and wild rice germplasm (Gao, 2005 and Gao *et al.*, 2005), determination of the purity of breeding material or seed stocks (Olufowote *et al.*, 1997), prediction of hybrid performance and heterosis (Xiao *et al.*, 1996) and the analyses and tagging of valuable quantitative trait loci (QTL) and genes. Microsatellites are also considered ideal markers in gene mapping studies (Zou *et al.*, 2000).

Microsatellites have been developed in a large number of plants including major cereal species like barley, maize (Yu *et al.*, 2000) and wheat (Varshney *et al.*, 2002), due to production of genomic libraries enriched for microsatellites (Edwards *et al.*, 1996 and Fisher *et al.*, 1996). The frequency of microsatellites varies significantly among different organisms (Weising *et al.*, 1998). In a survey of published DNA sequences in 54 plant species, Wang *et al.* (1994) observed that (AT) sequences are the most abundant in plants while (GT) are frequent in animals. Micro-satellites are abundant and occur frequently and randomly in all eukaryotic nuclear DNAs and advantages of SSR, over other molecular markers have been reported by Gupta and Varshney (2000).

2.5.2. SSR analysis in rice TGMS genes

Yang *et al.* (2007a) reported that AnnongS-1 and Y58S, two derivative TGMS lines of Annong S, were both controlled by a single recessive gene named *tms5*, which was genetically mapped on chromosome 2. Populations (Annong S-1 x Nanjing11, Y58S x Q611, and Y58S x Guanghui122) were developed to investigate the *tms5* gene molecular map and suggested that the *tms5* gene was physically mapped to a 19 kb DNA fragment between two markers, 4039-1 and 4039-2, located on the BAC clone AP004039.

In an investigation, Wang *et al.* (2004) reported an *indica* rice TGMS mutant, 0A15-1, was crossed with a fertile *indica* line "Guisi-8" to map the gene responsible to the TGMS. A RAPD maker S187-770 linked to the TGMS gene at a distance of 1.3 cM in coupling phase was identified. The S187-770 was then cloned and sequenced to develop a dominant SCAR (Sequence Characterized Amplified Region) marker. Homology search against rice genome DNA sequence database indicated that S187-770 located on the short arm of chromosome 3 and close to centromere as a single copy sequence.

Lopez *et al.* (2003) aimed to develop TGMS lines with aromatic Thai rice back ground by molecular marker-aided breeding. Four microsatellite markers (RM2, RM10, RM11, and RM214) on chromosome 7 in the vicinity of the TGMS gene *tms2* and showing polymorphism between two parents were used in genotyping the mapping population consisting of 157 F_2 plants derived from a cross between Norin PL12 and KDML 105. The RM11 marker was approximately 5 cM from it while RM2 was approximately 16 cM from it.

A newly discovered reverse thermo-sensitive genic male-sterile line, J 207 S, has an opposite phenotype compared to the normal TGMS lines. J207S is completely sterile when the temperature is lower than 3° C. Genetic analysis indicated that the sterility of J 207 S was controlled by a single recessive gene which was first named as *rtms1*. An F_2 population from J 207 S x E 921 was developed and used for molecular mapping of the *rtms1* gene by Jia *et al.* (2001).

Reddy *et al.* (2000) attempted to identify suitable molecular markers closely linked to the TGMS and microsatellite RM257, located earlier on chromosome 9, was linked with the TGMS trait in SA2 at a distance of 6.2 cM. RM257 produced a codominant polymorphism with 145-bp (sterile) and 132-bp (fertile) products. Both individually and collectively, the markers TS200 and RM257 located on either side of the TGMS locus are very useful for marker-assisted selection.

Subudhi *et al.* (1997) was aimed to molecular markers linked TGMS gene of IR 32364 TGMS were different from TGMS gene which Wang *et al.* (1995) reported moreover Borkakati and Virmani (1997) showed TGMS gene of IR32364 TGMS was different from *tms-2*. from the results of the study reported here, *tms-2* is also different from the TGMS gene located on chromosome 8 .

Yamaguchi *et al.* (1997) reported that parental line Norin –PL12 has TGMS gene *tms-2* of RFLP markers in F_2 population derived from a cross between Norin-PL 12 and Aus variety, Dular. QTL analysis using RFLP revealed that the gene *tms-2* located between R 643A and R 1440 on chromosome 7.

In an investigation F_2 population developed from TGMS–VN1 x CH1 (fertile *indica* line) was used to identify molecular markers linked to the TGMS gene and chromosomal location on the linkage map by Dong *et al.* (2000). Bulk segregant analysis was performed using the AFLP technique. From the survey of 200 AFLP primer combinations, four AFLP markers (E2/M5–600, E3/M16–400, E5/M12–600, and E5/M12–200) linked to the TGMS gene were identified. Linkage of microsatellite marker RM 27 with TGMS gene confirmed its location on chromosome 2 and new gene is tentatively designated as *tms4*(t).

Lee *et al.* (2005) reported that the genetic analysis and molecular mapping based on SSR, STS and EST markers revealed that a single recessive gene locus involved the control of genic male sterility in Sokcho-MS. By using an F_2 (Sokcho-MS x fertile indica variety Neda) mapping population and new TGMS gene designated as *tms6*, was mapped primarily to the long arm of chromosome 5 of *Oryza sativa* and *tms6* was fine mapped to the interval between markers RM3351 (0.1 cM) and E60663 (1.9 cM).

Molecular analysis indicated that the sterility of AnnongS-1 was controlled by a single resessive gene named *tms5*. A RIL population from AnnongS-1 x Nanjing11was developed and used for the fine mapping of the *tms5* gene. Two AFLP markers (AF10, AF8), one RAPD marker (RA4), one STS marker (C365- 1), one CAPs marker (G227-1) and four SSR markers (RM279, RM492, RM327, RM324) were found to be closely linked to *tms5* gene was noticed by Wang *et al.* (2004).

Wang *et al.* (1995) reported the bulked segregant analysis of an F2 population from 5460s x 'Hong Wan 52' was used to identify RAPD markers linked to the rice TGMS gene. Four primers out of 400 RAPD were produced polymorphic products. Only one single copy sequence fragment was found, a 1.2-kb fragment amplified by primer OPB-19 and subsequently named TGMS1.2 and mapped on chromosome 8 .

In an investigation, Prathyusha *et al.* (2009) reported that the molecular characterization and diversity analysis of thirty-two rice genotypes using 11 SSR primers were undertaken in order to further utilize these lines in the breeding programmes. The results revealed that 7 primers showed distinct polymorphism among the genotypes consistently. A total of 33 amplification products were obtained with all the selected seven primers. The number of alleles varied from 3 to 7 with a mean of 4.71.

Lee *et al.* (2005) reported the genetic characterization and fine mapping of a novel thermo-sensitive genic male-sterile gene *tms6* in rice. Genetic analysis and molecular mapping based on SSR, STS and EST markers revealed that a single recessive gene locus involved the control of genic male sterility in TGMS line Sokcho-MS.

Three pairs of independent recessive (*tms*) genes with additive effects were involved in TGMS expression in UPRI 95-140 TGMS was noticed by Rongbai *et al.* (2005). Expression of the trait in F_2 generation involving 44 different genetic backgrounds indicated monogenic (3F: 1S), digenic (15F: 1S) and trigenic (63F: 1S) inheritance with frequencies of 18.2, 52.3 and 29.5 per cent respectively. No single pair of gene was capable of causing complete male sterility. Two pairs of major *tms* genes in UPRI 95-140 TGMS, non-allelic to any of the known *tms* genes were located on chromosomes 3 and 7, and tentatively designated as *tms6*(*t*) and *tms7*(*t*) respectively.

Xul *et al.* (2000) reported thirty maintainer lines from IRRI and 47 restorer lines from the Philippines Rice Research Institute were surveyed for molecular diversity using thirty seven SSR markers distributed over 12 rice chromosomes. The mean number of alleles per SSR locus was 4.24 ranging from 2 to 9.

Ni *et al.* (2002) evaluated 38 rice cultivars and two wild species by means of 111 SSR markers distributed over the whole rice genome. A total 753 alleles were detected and the number of alleles per marker ranged from 1 to 17, with an average of 6.8. The genetic diversity and pattern of relationships among 18 rice genotypes representative of the traditional Basmati, cross bred Basmati and non-basmati rice varieties were evaluated using AFLP, ISSR and SSR markers and found that SSR are more efficient for discriminating between the rice groups compared to AFLPs and ISSRs (Saini *et al.*, 2004).

Forty two quantitative and qualitative traits and 39 SSR markers were assessed among accessions with ten different names. Discriminant function analysis showed that only 36 per cent of accessions could be clustered according to name by morphological traits. Only one SSR locus was polymorphic, distinguishing only one accession by Bajracharya *et al.* (2005). Chakravarthi and Naravaneni (2006) studied 15 rice genotypes using 30 SSR primers on chromosome number 7-12. All the primers showed distinct polymorphism among the cultivars.

Thirty four coloured rice lines showed 20 polymorphic bands using seven SSR primer pairs were evaluated and reported that average three alleles per SSR marker. The average of genetic distance based on SSR marker was 0.56 and ranged from 0.22 to 0.81 was noticed by Ji *et al.* (2007).

Materials and Methods

3. MATERIALS AND METHOD

The present investigation was carried at the Department of Plant Breeding & Genetics, College of Horticulture Vellanikkara, Kerala Agricultural University, Thrissur during 2011-2013. The materials used and the methods followed for this whole investigation are presented below.

The study was grouped in to five experiments.

3.1 EXPERIMENT I

Evaluation and characterization of TGMS lines

3.1.1 Materials

The materials used in the study comprised seven TGMS lines collected from Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore. The details of the genotypes are given in Table 7. Evaluation was carried out at two locations namely College Of Horticulture Vellanikkara, Cardamom Research Station, Pampadumpara.

3.1.2 Methodology

Sequential sowing of TGMS lines was done from second week of March 2011 to second week of March 2012. Twenty five days old seedlings were transplanted in single seedlings per pots. Five plant per entry were maintained. Manures and plant protection chemicals were applied as recommended in the Package of Practices Recommendations: Crops, Kerala Agricultural University (2010). Observations on morphological characters were recorded on each of five plants per entry. Pollen sterility/fertility behavior was studied in relation to weather parameters collected from the Department of Meteorology, College of Horticulture Vellanikkara.

Table 7. List of TGMS lines taken for evaluation

Sl.No	TGMS lines	Source
1	TGMS 74S	TNAU, Coimbatore
2	TGMS 81S	TNAU, Coimbatore
3	TGMS 82S	TNAU, Coimbatore
4	TGMS 91S	TNAU, Coimbatore
5	TGMS 92S	TNAU, Coimbatore
6	TGMS 93S	TNAU, Coimbatore
7	TGMS 94S	TNAU, Coimbatore

3.1.3 Observations recorded

A) Morphological Characters

1. Days to 50% flowering

The number of days taken from the date of sowing to the date of primary panicle emergence in 50 per cent of the population in each treatment was recorded.

2. Plant height (cm)

The height of the plant was measured from the ground level to the tip of the primary panicle in centimeter at the time of maturity.

3. Number of productive tillers plant^{-1}

The total number of panicle bearing tillers per plant was counted at the time of maturity.

4. Panicle length (cm)

The length of the primary panicle in each of the randomly selected single plant was measured from the tip of the panicle to the ciliate ring and expressed in centimeter

5. Total number of spikelets panicle^{-1}

Total number of spikelets in the main panicle of each plant was recorded.

6. Number of filled grains panicle^{-1}

The number of well filled and fully matured grains in the panicle of the main tiller in each of the selected plant was counted and recorded.

7. Grain length (mm)

The mean length of ten grains in millimeters was taken from the base of the lowermost sterile lemma to the tip

8. Grain breadth (mm)

The distance across the fertile lemma and palea at the widest point was measured in millimeters for ten grains and the mean was worked out.

9. L/B ratio of grain

It is the ratio of length to breadth of the grains. Grain shape can be easily estimated by this method.

L/B ratio	Shape
>3	Slender
2.1 - 3.0	Medium
1.1 - 2.0	Bold
<1.1	Round

10. 1000 grain Weight (g)

The weight of one thousand well filled grains in each plant was recorded and expressed in grams.

11. Single plant grain yield (g)

Well dried and cleaned grains obtained from the single plant were weighed and expressed in grams.

12. Single plant Straw yield (g)

Straw obtained from the single plant were weighed and expressed in grams.

13. Harvest index

The proportion of economic yield was represented over biological yield, using the formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

B) Spikelet characters

1. Duration of anthesis in a panicle

Time interval between opening of first flower and closing of last flower in a panicle was calculated and expressed as mean number of days.

2. Duration of spikelet opening

Time interval between spikelet opening and closing was noted in individual spikelets and expressed in minutes.

3. Angle of glume opening

The observations was taken one hour after glume opening, in individual spikelets. Three points namely, the tips of lemma, palea and the point of attachment of pedicel were plotted on a thick paper from the field. The angle was later measured using protractor and expressed in degrees.

4. Stigma exsertion percentage

The stigma exsertion was calculated by the ratio of spikelets with exserted stigma to the total number of spikelets and expressed in percentage.

C) Pollen sterility/fertility in relation to weather parameters

The pollen sterility/fertility was observed in three randomly selected plants at the time of heading. The spikelets were collected before anthesis ,the anthers were dissected out from the spikelet, squeezed to release the pollen grain and stained using I-KI (1%) solution. Darkly stained and round pollen grains were considered as fertile, whereas irregular shaped non stained pollen grains were grouped as sterile pollen. Pollen fertility/sterility per centage was worked out.

$$\text{Pollen fertility (\%)} = \frac{\text{Number of stained round pollen}}{\text{Total number of pollen counted}} \times 100$$

The sterility status was fixed as under following the IRRI Standard Evaluation System (1996)

Pollen sterility(%)	Group
100.00	Completely sterile
99.00 – 99.99	Highly sterile
95.00 – 98.90	Sterile
70.00 – 94.90	Partially Sterile
< 70	Partially fertile to Fertile

From the one year data on pollen sterility/fertility, the fertile and sterile phases of TGMS lines, the duration of each phase and the fertility transition phase were identified. The flowering period in which the line with full sterility (100 per cent pollen sterility) was taken as sterile phase. The period in which the plants recorded more than 50 per cent pollen fertility was considered as fertile phase. The period of partial sterility was considered as the phase of fertility transition.

D) Spikelet fertility

Spikelet fertility per centage was carried out in CRS Pampadumpara. Total number of filled grains and ill filled grains on main panicle of each plant was counted separately. The proportion of number of fully developed grains to the total number of spikelets was calculated as spikelet fertility. (IRRI-Standard Evaluation System 1996).

$$\text{Spikelet fertility (\%)} = \frac{\text{Number of filled grains per panicle}}{\text{Total number of spikelets per panicle}} \times 100$$

Based on spikelet fertility percentage, parents and hybrids were classified as follows.

Scale	Spikelet fertility (%)	Fertility status
1	>90	Highly fertile
3	75-89	Fertile
5	50-74	Partially fertile
7	1-49	Partially sterile
9	0	Full Sterile

3.1.4 Identification of critical stages of fertility alteration in TGMS lines

3.1.4.1 Critical Sterility Temperature (CST)

The lowest temperature at which the TGMS line becomes sterile from fertile condition is called as the critical sterility temperature of a particular line. The period of complete pollen sterility was taken into account for determining the CST of the line. For the panicles that emerged in complete pollen sterility phase, the mean maximum temperatures during the panicle development stages were worked out and lowest among these mean maximum temperatures was taken as the CST of that particular line. Critical sterility temperature was worked out for seven TGMS lines.

3.1.4.2 Critical Fertility Temperature (CFT)

The highest temperature at which the line becomes fertile from sterile condition is called as the critical fertility temperature of a particular line. Similarly for determining CFT, the period of high pollen fertility was taken into consideration. For the panicles that headed in high pollen fertility phase the mean maximum temperatures during developmental stages were worked out and the highest mean maximum temperature was taken as the CFT of that particular line. Critical fertility temperature was worked out for seven TGMS lines.

3.1.5 Statistical analysis

The data were subjected to the following statistical analysis.

3.1.5.1 Estimation of variability

Variability existing among the seven lines in different seasons and environments for the various characters under observation was estimated as per the procedure.

3.1.5.2 Estimation of correlation

Simple correlation coefficients among the pollen sterility and weather parameters was worked out. Correlation was also worked out using the time series data on maximum and minimum temperature during the period of 26 days before heading with that of pollen sterility.

3.2 EXPERIMENT II

Evaluation of pollinators

3.2.1 Materials

The experimental material consisted of twenty two high yielding rice varieties collected from different research stations of Kerala (Table 8)

3.2.2 Methodology

The varieties were sown in raised nursery bed and 25 days old seedlings were transplanted to the main field in a Randomized Block Design (RBD) replicated thrice. Each variety was transplanted in three rows of 3m length adopting a spacing of

Table 8. List of pollinator parents used in the study

Sl.No	Pollinators	Source
1	Ahalya	COH –Vellanikkara
2	Aiswarya	COH –Vellanikkara
3	Annapoorna	RARS-Pattambi
4	Bhadra	RRS-Moncompu
5	Gouri	RRS-Moncompu
6	Harsha	COH –Vellanikkara
7	Jyothi	COH –Vellanikkara
8	Kunjukunju Varna	RARS-Pattambi
9	Kairali	RARS-Pattambi
10	Kanakom	RRS-Moncompu
11	Kanchana	COH –Vellanikkara
12	Makom	RRS-Moncompu
13	Manupriya	COH –Vellanikkara
14	Matta Triveni	COH –Vellanikkara
15	Pavizham	RRS-Moncompu
16	Prathyasa	RRS-Moncompu
17	Remanika	RRS-Moncompu
18	Samyuktha	RARS-Pattambi
19	Swarnaprabha	COH –Vellanikkara
20	Uma	COH –Vellanikkara
21	Vaishak	COH –Vellanikkara
22	Varsha	COH –Vellanikkara

15cm between rows and 20 cm between plants. All the recommended agronomic package of practices were adopted during the entire crop growth period.

Observations on morphological and spikelet characters were recorded on five randomly selected plants in each replication after leaving the border rows. The mean values were utilized for statistical analysis

3.2.3 Observations recorded

A. Morphological Characters

1. Days to 50% flowering

The number of days taken from the date of sowing to the date of primary panicle emergence in 50 per cent of the population in each treatment was recorded.

2. Plant height (cm)

The height of the plant was measured from the ground level to the tip of the primary panicle in centimeter at the time of maturity.

3. Number of productive tillers plant^{-1}

The total number of panicle bearing tillers per plant was counted at the time of maturity

4. Panicle length (cm)

The length of the primary panicle in each of the randomly selected single plant was measured from the tip of the panicle to the ciliate ring and expressed in centimeter

5. Total number of spikelets panicle^{-1}

Total number of spikelets in the main panicle of each plant was recorded.

6. Number of filled grains panicle^{-1}

The number of well filled and fully matured grains in the panicle of the main tiller in each of the selected plant was counted and recorded.

7. 1000 grain Weight (g)

The weight of thousand well filled grains in each plant was recorded and expressed in grams.

8. Grain length (mm)

The mean length of ten grains in millimeters was taken from the base of the lowermost sterile lemma to the tip

9. Grain breadth (mm)

The distance across the fertile lemma and palea at the widest point was measured in millimeters for ten grains and the mean was worked out.

10. L/B ratio of grain

It is the ratio of length to breadth of the grains. Grain shape can be easily estimated by this method.

L/B ratio	Shape
>3	Slender
2.1-3.0	Medium
1.1-2.0	Bold
<1.1	Round

11. Single plant grain yield (g)

Well dried and cleaned grains obtained from the single plants were weighed and expressed in grams.

12. Single plant straw yield (g)

Straw obtained from the single plants was weighed and expressed in grams.

13. Harvest index

The proportion of economic yield was represented over biological yield, using the formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.2.4 Statistical analysis

The data were subjected to the following statiatical analysis

3.2.4.1 Estimation of selection parameters

a) Variability

Coefficient of variation (C.V)

Co efficient of variation was estimated using the formula

$$C.V. (\%) = \frac{\text{Standard deviation}}{\bar{x}} \times 100$$

The range of coefficient of variation was categorized as below

Range	Category
Below 10 per cent	Low
11-19 per cent	Moderate
20 per cent and above	High

The total variability observed for each of the treatment was taken as a measure of phenotypic variance (V_p) whereas the variability existing in the parents was considered as environmental variance (V_e). Genotypic variance was calculated by subtracting the environmental variance from phenotypic variance.

Genotypic and phenotypic coefficient of variation (%)

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated using the formula by Johnson *et al.* (1955).

$$\sqrt{\text{Genotypic variance}}$$

GCV = ------------------------ x 100

Mean

$$PCV = \frac{\sqrt{\text{Phenotypic variance}}}{\text{Mean}} \times 100$$

Categorization of the range of variation was effected as proposed by Sivasubramanian and Madhava menon (1973) as follows

Percentage of variability	Category
0 - 10	Low
11-20	Moderate
> 20	High

b) Heritability

Heritability in broad sense was calculated following the method advocated by Lush (1940) and expressed in percentage.

$$\text{Heritability (broad sense)} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

As suggested by Johnson *et al.* (1955) heritability values were categorized as follows:

Low – 0 to 31 per cent

Medium – 31 to 61 per cent

High – 61 per cent and above

c) Genetic advance

Genetic advance was estimated by the method given by Johnson *et al.* (1955).

$$\text{Genetic advance} = \frac{\text{Genotypic variance}}{\text{Phenotypic standard deviation}} \times K$$

Where K = Selection differential 2.06 at 5 per cent selection intensity.

d) Genetic advance as per centage of mean

$$\text{Genetic advance as per cent of mean} = \frac{\text{Genetic advance}}{\text{Grand mean}} \times 100$$

The range of Genetic advance was classified as suggested by Johnson *et al.* (1955):

Low – less than 10 per cent

Moderate – 10 to 20 per cent

High – more than 20 per cent

e) Direct and indirect effects of yield attributes on yield through path analysis

Path coefficient analysis suggested by Wright (1923) was applied to study the cause and effect relationship of yield and yield attributes. The direct and indirect effects were classified based on the scale given by Lenka and Mishra (1973).

>1.0 – Very high

0.30 - 0.99 - High

0.20 - 0.29 - Moderate

0.10 - 0.19 - Low

0.00 - 0.09 – Negligible

3.3 EXPERIMENT III

Production of rice hybrids

3.3.1 Materials

Seven TGMS lines and selected rice varieties constituted the materials for the study (Table 3). Study period was February 2012 – May 2012. Manures, fertilizers and plant protection chemicals were applied as per POP Recommendations, KAU.

Table 9. Hybridization block

Sl.No	Lines	Testers
1.	TGMS 74S(TNAU 74S) TGMS 81S(TNAU 81S) X TGMS 82S(TNAU 82S) TGMS 91S(TNAU 91S)	Aiswarya Jyothi Kairali Kanchana Makom Matta Triveni Prathyasa Samyuktha Vaishak Varsha
2.	TGMS 92S(TNAU 92S) TGMS 93S(TNAU 93S) X TGMS 94S(TNAU 94S)	Bhadra Remanika Uma

3.3.2 Methodology

The seven TGMS lines and ten testers were raised in a crossing block during 2012-2013.Crossing was done in the field in line x tester mating design. Hybridization was carried out during the month of April 2012. During the hybridization period, the TGMS lines were sterile under high temperature regime. Based on the microscopic studies of the anthers, 100 per cent sterile plants were identified and labeled. TGMS lines being male sterile, are not emasculated. They were bagged with butter paper cover to avoid contamination. This process was done at the beginning of anthesis time (7.00 A.M. to 9.00 A.M). During the time of anthesis (10.00 A.M. to 11.30 A.M.), partially opened panicles were selected from the testers (pollinators) and were churned over the panicles of the lines that were bagged earlier so that the pollen grains were dusted on it. The crossed panicles were covered and labeled. Twenty five days after pollination, the crossed seeds were collected and adequately dried.

3.4 EXPERIMENT IV

Evaluation of Two line hybrids:

3.4.1 Materials

F_1 seeds of hybrid cross combinations and parental seeds constituted materials for this experiment (Table 10). The experiment was carried out at two locations namely College of Horticulture, Vellanikkara, and RARS, Pattambi

3.4.2 Methodology

The seeds were sown in nursery raised in the field. 25 days old seedlings of the two line hybrids and their parents were planted in plots of 3 rows at a spacing of 20 x 15 cm. The experiment was laid out in RBD with two replications. Manures and plant protection chemicals were applied as recommended by package of practice of recommendations, Kerala Agricultural University.

At flowering, in each replication five plants in the middle of rows were selected in each treatment at random and tag labeled. Observations were recorded on morphological and quality parameters.

3.4.3 Observations recorded

A) Morphological characters

1. Days to 50% flowering

The number of days taken from the date of sowing to the date of primary panicle emergence in 50 per cent of the population in each treatment was recorded.

2. Plant height (cm)

The height of the plant was measured from the ground level to the tip of the primary panicle in cm at the time of maturity.

3. Number of productive tillers plant^{-1}

The total number of panicle bearing tillers were counted in each plant at the time of harvesting and recorded.

4. Panicle length (cm)

The length of the primary panicle in each of the randomly selected single plant was measured from the tip of the panicle to the ciliate ring and expressed in centimeter.

5. Total number of spikelets panicle^{-1}

Total number of spikelets in the main panicle of each plant was recorded.

6. Number of filled grains panicle^{-1}

Number of well filled grains per panicle from randomly selected panicles was counted at the maturity.

7. 1000 grain Weight (g)

The weight of thousand well filled grains in each plant was recorded and expressed in grams.

8. Grain length (mm)

The mean length of ten grains in millimeters was taken from the base of the lowermost sterile lemma to the tip.

9. Grain breadth (mm)

The distance across the fertile lemma and palea at the widest point was measured in millimeters for ten grains and the mean was worked out.

10. L/B ratio of grain

It is the ratio of length to breadth of the grains. Grain shape can be easily estimated by this method.

Table 10. List of two line hybrids used for the evaluation of hybrids

Sl.No	Two line rice hybrids
1	TGMS 74S x Aiswarya
2	TGMS 74S x Kanchana
3	TGMS 74S x Kairali
4	TGMS 74S x Makom
5	TGMS 74S x Samyuktha
6	TGMS 81S x Aiswarya
7	TGMS 81S x Kanchana
8	TGMS 81S x Kairali
9	TGMS 81S x Makom
10	TGMS 81S x Samyuktha
11	TGMS 82S x Aiswarya
12	TGMS 82S x Kanchana
13	TGMS 82S x Kairali
14	TGMS 82S x Makom
15	TGMS 82S x Samyuktha
16	TGMS 91S x Aiswarya
17	TGMS 91S x Kanchana
18	TGMS 91S x Kairali
19	TGMS 91S x Makom
20	TGMS 91S x Samyuktha
21	TGMS 81S x Matta Triveni
22	TGMS 81S x Prathyasa
23	TGMS 82S x Prathyasa
24	TGMS 91S x Matta Triveni
25	TGMS 91S x Varsha

L/B ratio	Shape
>3	Slender
2.1-3.0	Medium
1.1-2.0	Bold
<1.1	Round

11. Single plant grain yield (g)

Well dried and cleaned grains obtained from the single plant were weighed and expressed in grams.

12. Single plant straw yield (g)

Straw yield per plant was recorded and expressed in grams.

13.Harvest index

The proportion of economic yield was represented over biological yield using the formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

B.Grain and milling quality characters

1. Kernel colour

Kernel colour was identified as red or white.

2. Kernel length (mm)

Length of 10 unbroken brown rice, in three sets was measured and the mean was expressed in mm and the grains were categorized as follows.

Size category	Length (mm)
Extra long	>7.50
Long	6.61-7.50
Medium	5.51-6.60
Short	< 5.50

3. Kernel width (SES-IRRI, 1996)

Breadth of 10 unbroken brown rice was measured using vernier caliper in three sets and the mean was expressed in mm

4. Milling traits

Milling recovery of rough rice is an estimation of the quantity of head rice and total milled rice that can be produced from a unit of rough rice. It is generally expressed as percentage (Khush *et al.*, 1979)

$$\text{Hulling percentage} = \frac{\text{Total hulled rice}}{\text{Total rough rice}} \times 100$$

$$\text{Milling percentage} = \frac{\text{Total milled rice}}{\text{Total rough rice}} \times 100$$

$$\text{Head rice recovery} = \frac{\text{Total head rice}}{\text{Total rough rice}} \times 100$$

5. Amylose content

Test Samples were weighed about 100 mg ± 0.5 mg three times for each sample and these samples were placed into 100 ml volumetric flasks. To this, 1 ml of ethanol was added by using pipette to wash down any of the flour adhering to the side of the flask. These contents were shaked well in order to wet the entire sample. To this, 9.0 ml of NaOH solution (1M) was added and mixed it well until the starch was

Table 11. List of hybrids selected for analysis of quality parameters

S.No.	Hybrids
1	TGMS 91S x Samyuktha
2	TGMS 81S x Matta Triveni
3	TGMS 91S x Kanchana
4	TGMS 74S x Kairali
5	TGMS 91S x Makom
6	TGMS 82S x Prathyasa
7	TGMS 81S x Makom
8	TGMS 81S x Kanchana
9	TGMS 81S x Aiswarya
10	TGMS 74S x Aiswarya

completely dissolved by standing overnight. The test solutions were allowed to cool at room temperature and made up the volume with the distilled water. The blank solution was prepared without the sample in the 1000 ml volumetric flask, from the prepared test solutions, 0.5 ml aliquot was pipetted out into two test tubes. To this, 5.0ml of water, 0.1 ml of acetic acid and 0.20 ml of iodine were added, to make up the volume to 10.0 ml. These contents were mixed well by using vortex mixer. The test chemicals were measured the absorbance at 720 nm against the blank solution using the spectrophotometer. Based on the amylose content the rice was categorized as waxy (< 2%), very low (2 – 8%), low (8- 19%), intermediate (20 - 25%), and high (>25%) suggested (IRRI, 1972)

6. Alkali spreading value

Ten milled rice kernels were placed in 10.0 ml of 1.7 per cent KOH in shallow container (petriplate) .The kernels were so arranged that they did not touch each other. They were allowed to stand for 23 hours at 30^0 C. The appearance and disintegration of the kernels were usually after incubation based on the following numerical scale

A rating of 1 to 2 was classified as high final gelatinization temperature, 3 as high intermediate, 4 to 5 as intermediate(70-74^0C) and 6 to 7 as low final gelatinization temperature(<70^0C)

Numerical scale for rating kernels for alkali spreading value.

Description	Score
Grain not affected	1
Grain swollen	2
Grain swollen, collar incomplete or narrow	3

Grain swollen, collar complete and wide	4
Grain split or segmented, collar complete and wide	5
Grain dispersed, merging with collar	6
Grain completely dispersed and intermingled	7

ɔ) Cooking quality characters

1. ... ... expansion ratio

The volume of raw rice as well as cooked rice was determined by water displacement using a measuring cylinder (Onate and Del Mundo,1966)

$$\text{Volume expansion ratio} = \frac{\text{Volume of cooked rice}}{\text{Volume of raw rice}}$$

2. Kernel elongation ratio

Kernel elongation was determined as described by Azeez and Shafi (1966). Ten raw and ten cooked kernels were taken at random and their length was measured.

$$\text{Kernel elongation ratio} = \frac{\text{Mean length of cooked kernel}}{\text{Mean length of raw kernel}}$$

D) Sensory characters

1. Appearance after cooking

5g rice samples were taken in a test tube.15 ml of water added and soaked for 10 min. Rice samples were cooked in a water bath for 15 min and transferred in to a petridish and scored as per panel test performance like white, creamish white, red streaks, white with brown streaks and white with black streaks

2. Cohesiveness

5g rice samples were taken in a test tube.15 ml of water added and soaked for 10 min. Rice samples were cooked in a water bath for 15 min and transferred in to a petridish and scored as per panel test performance like well separated, partially separated, slightly separated, moderately separated and very sticky.

3. Tenderness to touch

5g rice samples were taken in a test tube.15 ml of water added and soaked for 10 min. Rice samples were cooked in a water bath for 15 min and transferred in to a petridish and scored as per panel test performance like soft, moderately soft, moderately hard, hard and very soft.

4. Tenderness on chewing

5g rice samples were taken in a test tube.15 ml of water was added and soaked for 10 min. Rice samples were cooked in a water bath for 15 minutes and transferred in to a petridish and scored as per panel test performance like soft, moderately soft, moderately hard, hard and very soft.

5. Taste

5g rice samples were taken in a test tube.15 ml of water added and soaked for 10 min. Rice samples were cooked in a water bath for 15 min and transferred in to a petridish and scored as per panel test performance like good,desirable, tasteless and undesirable.

3.4.4 Statistical analysis

The data were subjected to the following statiatical analysis

3.4.4.1 Analysis of variance

Analysis of variance were carried out for the quantitative characters following the procedure outlined by Panse and Sukhatme (1964).

3.4.4.2 Combining ability analysis

Combining ability analysis was carried out according to the methodology of Kempthorne (1957). The general combining ability of the parents and specific combining ability of the hybrids were assessed. The expected mean squares due to the different sources of variation and their genetic expectation were estimated as indicated in the following ANOVA table.

Source	Degrees of Freedom	Mean squares	Expected mean square
Replication	(r - 1)	-	
Hybrids	(lt – 1)	-	
Lines	(l – 1)	M_1	EMS +r [Cov (F.S.) – 2 Cov (H.S.)] + rt [Cov (H.S.)]
Testers	(t – 1)	M_2	EMS +r [(Cov (F.S.) – 2 Cov (H.S.)] + rl [Cov (H.S.)]
Lines x Testers	(l – 1)(t -1)	M_3	EMS +r [Cov (F.S.) – 2 Cov (H.S.)]

Error	(r – t) (lt – 1)	M_4	EMS
Total	rtl – 1		

Where,

r = number of replications

l= number of lines

t = number of testers

Estimates of covariance of full sibs and half sibs were calculated from the genetic expectations of mean squares as:

$$\text{Cov (F.S.)} = \frac{(M_1 - M_4)+(M_2-M_4)+(M_3-M_4) + 6r\ \text{Cov (H.S.)} - r\ (l + t)\ \text{Cov (H.S.)}}{3r}$$

$$\text{Cov (H.S.)} = \frac{(M_1-M_3) + (M_2-M_4)}{r\ (l + t)}$$

Where,

Cov (F.S.) = Covariance between full sibs

Cov (H.S.) = Covariance between half sibs.

Table 12. List of two line hybrids used in line x tester analysis

Sl.No	Two line hybrids
1	TGMS 74S x Aiswarya
2	TGMS 74S x Kanchana
3	TGMS 74S x Kairali
4	TGMS 74S x Makom
5	TGMS 74S x Samyuktha
6	TGMS 81S x Aiswarya
7	TGMS 81S x Kanchana
8	TGMS 81S x Kairali
9	TGMS 81S x Makom
10	TGMS 81S x Samyuktha
11	TGMS 82S x Aiswarya
12	TGMS 82S x Kanchana
13	TGMS 82S x Kairali
14	TGMS 82S x Makom
15	TGMS 82S x Samyuktha
16	TGMS 91S x Aiswarya
17	TGMS 91S x Kanchana
18	TGMS 91S x Kairali
19	TGMS 91S x Makom
20	TGMS 91S x Samyuktha

From the covariance of full sibs and covariance of half sibs, variance due to general combining ability, (GCA) and specific combining ability (SCA) were estimated as follows:

σ^2 GCA = Cov. H.S.

σ^2 SCA = Cov. F.S. - 2 Cov. H.S.

3.4.4.3 Estimation of *gca* and *sca* effects

The *gca* and *sca* effects of parents and hybrids respectively were estimated based on the following model.

$$X_{ijk} = \mu + g_{i.} + g_{.j} + s_{ij} + e_{ijk}$$

Where,

X_{ijk} = value of the ijk[th] observation

μ = population mean

$g_{i.}$ = *gca* effect of i[th] line

$g_{.j}$ = *gca* effect of the j[th] tester

S_{ij} = *sca* effect of the ij[th] hybrid

e_{ijk} = error effect associated with ijk[th] observation

i = number of lines

j = number of testers

k = number of replications

The individual effects of *gca* and *sca* effects were obtained from the two way table of lines vs testers, in which each figure was a total over replications

And was calculated as follows:

$$\mu = \frac{X...}{rlt}$$

gca effects of lines, $g_i = \frac{X_{i..}}{rt} - \frac{X_{...}}{rlt}$

gca effects of testers, $g_j = \frac{X_{.j.}}{rl} - \frac{X_{...}}{rlt}$

sca effects of hybrids, $S_{ij} = \frac{X_{ij.}}{r} - \frac{X_{i..}}{rt} - \frac{X_{.j.}}{rl} + \frac{X_{...}}{rlt}$

Where

$X...$ = total of all hybrid combinations

$X_{i..}$ = total of i^{th} line over 'l' testers and 'r' replications.

$X_{ij.}$ = total hybrids between i^{th} line and j^{th} tester over replications.

$X_{.j.}$ = total of j^{th} tester over 'l' lines and 'r' replications

The standard errors pertaining to *gca* and *sca* effects were calculated as given below.

(i) Standard error for testing the *gca* effects of lines

$SE(g_i) = [EMS/rt]^{1/2}$

(ii) Standard error for testing the *gca* effects of testers

$SE(g_j) = [EMS/rl]^{1/2}$

(iii) Standard error or testing the *sca* effects of hybrids

$SE(s_{ij}) = [EMS/r]^{1/2}$

Test of significance

For lines, $$t_{gi} = \frac{gi}{SE\ (gi)}$$

For testers, $$t_{gj} = \frac{gj}{SE\ (gj)}$$

For hybrids, $$t_{sij} = \frac{sij}{SE\ (sij)}$$

3.4.4.4 Estimation of heterosis

Heterosis was estimated form the overall mean of each hybrid for each trait. Relative heterosis (d_i) was estimated as per cent deviation of the F_1 from the mid parental value (MP). Heterobeltiosis (d_{ii}) was estimated as per cent increase or decrease of F_1 over better parent (BP). Standard heterosis (d_{iii}) for each character was expressed as per cent increase or decrease of F_1 value over the standard variety (SV). The above types of heterosis were calculated for the quantitative traits.

(i) Relative heterosis (over the mid parent)

$$di = \frac{\overline{F1} - \overline{MP}}{\overline{MP}} \times 100$$

(ii) Heterobeltosis (over the better parent)

$$dii = \frac{\overline{F1} - \overline{BP}}{\overline{BP}} \times 100$$

(iii) Standard heterosis (over the standard variety)

$$diii = \frac{\overline{F1} - \overline{SV}}{\overline{SV}} \times 100$$

Where,

$\bar{F}_1$= Average performance of the hybrid

$\overline{MP}$ = Arithmetic mean of two parents involved in each cross.

$\overline{BP}$ = Average performance of better parent

$\overline{SV}$ = Average performance of standard variety

Significance of heterosis was tested using the formula given by Snedecor and Cochran (1967).

$SE_{(di)} = \sqrt{3EMS/2r}$

$SE_{(dii)} = \sqrt{2EMS/r}$

$SE_{(diii)} = \sqrt{2EMS/r}$

Where,

EMS = error mean square, obtained from analysis of variance.

r = number of replications

t (cal) = d_i/SEd_i or d_{ii}/SEd_{ii} or d_{iii}/SEd_{iii}

The calculated‘t’ value was tested against table‘t’ value at error degrees of freedom for five and one per cent probability levels.

3.5 EXPERIMENT V

Molecular characterization of hybrids and parents

3.5.1 Materials

DNA profiling of hybrids and parental lines was done through PCR analysis using gene specific microsatellite (SSR) markers chosen randomly to cover all the 12 linkage groups (Table 13)

3.5.2 Methodology

3.5.2.1 DNA isolation

Two grams of leaves were ground with liquid nitrogen to a very fine powder in a mortar and pestle. The CTAB buffer (15 ml) was added into the 50 ml centrifuge tube containing leaf powder and 10 µl of 2-β mercatoethanol was also added into the buffer just before the use under a fume hood. The mixture was incubated at 65°C for 30 min with occasional vigorous shaking. After incubation 15 ml of chloroform:isoamylalcohol was added, shaken before centrifuging the contents at 4,000 rpm for 20 minutes to resolve phases. The aqueous phase was carefully pipetted out and transferred into a fresh tube, and added 15 ml of pre-chilled Isopropanol, mixed well and incubated at 4°C for overnight. On completion of the incubation period, tubes were centrifuged at 4000 rpm for 20 min to collect the precipitate. The supernatant was discarded and the pellet was washed with 70 per cent ethanol and air dried. The precipitate was dissolved using 500 µl of TE buffer by gentle inversion. To this aliquot 15 µl of RNAse A(10 mg/ml) was added and incubated at 37°C for 30 minutes. The tubes were centrifuged at 10000 rpm for 20 minutes to resolve phases and the aqueous phase was carefully pipetted out and transferred into a fresh tube. Fifty ml of 3M sodium acetate and an equal quantity of absolute ethanol was added to the above and incubate at - 4°C overnight. The tubes were centrifuged at 10000 rpm for 20 minutes. After incubation the pellets were rinsed with 70 per cent ethanol and air dried. The pellets were then dissolved in 500 µl TE buffer and transferred into 1.5ml microfuge tube. The extracted genomic DNA were store at -20°C for further analysis.

Table 13. List of SSR primer used for molecular analysis

Sl.No	Primer	Chromosome location	Sequential information (5' to 3')		Repeat motif	Anneal temperature	Expected PCR product size
			Forward	Reverse			
1	RM128	1	AGCTTGGGTGATTTCTTGGAAGCG	ACGACGAGGAGTCGCCGTGCAG	(GAA)9	55	157
2	RM492	2	CCA AAA ATA GCG CGA GAG AG	AAG ACG TAC ATG GGT CAG GC	(GA)11	55	224
3	RM168	3	TGCTGCTTGCCTGCTTCCTTT	GAAACGAATCAATCCACGGC	T5(GT)14	55	116
4	RM119	4	CATCCCCCTGCTGCTGCTGCTG	CGCCGGATGTGTGGGACTAGCG	(GTC)6	67	166
5	RM440	5	CAT GCA ACA ACG TCA CCT TC	ATG GTT GGT AGG CAC CAA AG	(CTT)22	55	169
6	RM3351	5	ATG GAA GGA ATG GAG GTG AG	TAC CCC TAC GTC GAT CGA TC	(CT)15	55	174
7	RM50	6	ACT GTA CCG GTC GAA GAC G	AAA TTC CAC GTC AGC CTC C	(CTAT)4(CT)15	55	201
8	RM2	7	ACG TGT CAC CGC TTC CTC	ATG TCC GGG ATC TCA TCG	(GA)13	55	150
9	RM11	7	ACA CCA ACT CTT GCC TGC AT	TGA AGC AAA AAC ATG GCT GG	(GA) 17	55	140
10	RM149	8	GCTGACCAACGAACCTAGGCCG	GTTGGAAGCCTTTCCTCGTAACACG	(AT)10	55	253
11	RM257	9	CAG TTC CGA GCA AGA GTA CTC	GGA TCG GAC GTG GCA TAT G	(CT)24	55	147
12	RM216	10	GCA TGG CCG ATG GTA AAG	TGT ATA AAA CCA CAC GGC CAT	(CT)18	55	146
13	RM206	11	CCC ATG CGT TTA ACT ATT CT	CGT TCC ATC GAT CCG TAT GG	(CT)21	55	147
14	RM260	12	ACT CCA CTA TGA CCC AGA G	GAA CAA TCC CTT CTA CGA T	(CT)34	55	111
15	RM174	2	AGC GAC GCC AAG ACA AGT CGG G	TCC ACG TCG ATC GAC ACG ACG G	(AGG)7 (GA)10	67	208

Table 13. (Contd…)

16	RM21	11	ACA GTA TTC CGT AGG CAC GG	GCT CCA TGA GGG TGG TAG AG	(GA)18	55	157
17	RM224	11	ATC GAT CGA TCT TCA CGA GG	TGC TAT AAA AGG CAT TCG GG	(AAG)8(AG)13	55	157
18	RM71	2	CTA GAG GCG AAA ACG AGA TG	GGG TGG GCG AGG TAA TAA TG	(ATT)10T(ATT)4	55	149
19	RM104	1	GGA AGA GGA GAG AAA GAT GTG TGT CG	TCA ACA GAC ACA CCG CCA CCG GC	(GA)9	61	222
20	RM5897	2	GGC ATC TTC CCC TCT CTC TC	CCA ACC CAA ACC AGT CTA CC	(ATT)15	55	141

3.5.2.2 DNA quality and quantity check

The nucleic acids were quantification by the methods of Spectrophotometric determination and gel (0.8 per cent agarose gel). DNA concentration for PCR amplification was estimated by comparing the band intensity of a sample with the

band intensities of known dilutions that gave good amplifications. The dilutions were carried out by dissolving the genomic DNA in appropriate volume of TE buffer.

3.5.2.3 PCR amplification

The cocktail for PCR amplification of respective SSR fragments was prepared as shown in the annexure III. Amplifications were performed in Bio-Rad (MyCycler thermal cycler) and Corbett PCR machine. The thermal cycler was programmed as follows.

Step 1	Initial denaturing step	94°C for 5 minutes
Step 2	Denaturing	94°C for 1 minute
Step 3	Annealing	55°C for 1 minute
Step 4	Extension	72°C for 2 minutes
Step 5	Repeat steps 2 through 4 for a total of 35 cycles (34 times)	
Step 6	Final extension	72°C for 5 minutes
Step 7	4°C hold until sample retrieval.	
Step 8	End	

PCR products were kept at 4°C until further use. PCR amplified products (15.0 µl) were subjected to electrophoresis in a 3.0 per cent agarose gel in 1X TBE buffer at 100 volts for 3.0 hours using submarine electrophoresis unit. The ethidium bromide stained gels were documented using – Ge Nei ™ 1200 Germany. Sizes of the identified bands were determined relative to 100 bp ladder (Fermentas, Germany).

3.5.2.4 Gel electrophoresis

Agarose gel electrophoresis was performed to separate amplification products.

3.5.2.4.1 Materials

a. Loading dye:

Glycerol	50% (v/v)
Bromophenol blue	0.55 (w/v)

b. 10X TBE (Tris Borate EDTA) buffer:

Tris base	107.8 g
Boric acid	55.03 g
EDTA ($Na_2.2H_2O$)	8.19 g

(Dissolved in 800 ml of sterile distilled water and made up to 1000 ml)

3.5.2.4.2 Protocol

1. Gel casting plate and comb were washed with distilled water, and wiped with alcohol; the two open ends of the Pyrex gel casting plate were sealed with cello tape and placed on a perfectly horizontal levelled platform.

2. Three per cent agarose was added to 1X TBE, boiled till the agarose dissolved completely and then cooled to 50-60°C. Ethidium bromide was used as the staining agent at the final concentration of 1 µg/ml.

3. The solution was then poured into the gel-casting tray and the comb was placed properly and the gel was allowed to solidify for 30 minutes.

4. After solidification of the agarose, the comb and the cello tape were removed.

5. The casting gel was placed in the electrophoresis unit with wells towards the cathode and submerged with 1X TBE to a depth of about 1cm.

6. DNA samples (10 µl) were mixed well with 3.0 µl of loading dye and were loaded into the gel wells.

7. The gel was run at 120 volts for 3 hours and bands were visualized and documented in the gel documentation system (GeNei ™ 1200.Germany).

Results

4. RESULTS

4.1 Evaluation of TGMS lines

4.1.1 COH Vellanikkara

The experiment was conducted using the seven TGMS lines *viz* TGMS 74S, TGMS 81S, TGMS 82S, TGMS 91S, TGMS 92S, TGMS 93S, and TGMS 94S. The lines were evaluated for various morphological characters, spikelet characters and sterility/fertility behaviour during the year 2011 March to 2012 March. The data were subjected to statistical analysis and the results are presented below.

4.1.1.1 Genetic variability

In the present study the extent of genetic variability with respect to various characters was estimated.

Results from analysis of variance revealed highly significant differences between the genotypes for all the characters studied.

4.1.1.2 Mean performance

Mean performance of seven TGMS lines during the entire study period is presented in **Table 14** and mean , SEM and range of characters studied are given in **Table 15.**

4.1.1.3 Sterility/fertility behavior

Weekly sterility/fertility pattern of TGMS lines are presented in **Table 16.**

Table 14. Comparison of mean performance of TGMS lines at COH Vellanikkara.

Sl. No	Characters	TGMS 74S	TGMS 81S	TGMS 82S	TGMS 91S	TGMS 92S	TGMS 93S	TGMS 94S
1	Days to 50% flowering	92.33	87.67	97.33	87.00	129.67	122.67	126.67
2	Plant height (cm)	85.33	83.67	96.33	100.00	116.00	109.67	95.33
3	Number of productive tillers plant^{-1}	16.00	12.67	13.67	14.33	12.33	13.00	12.00
4	Panicle length (cm)	18.70	20.37	19.80	19.10	22.77	21.83	22.13
5	Grain length (mm)	07.88	08.08	08.23	08.15	08.23	08.22	08.41
6	Grain breadth (mm)	01.44	00.96	00.81	00.99	00.80	00.80	00.89
7	L/B ratio of grain	05.47	08.42	10.20	09.95	10.24	10.36	09.42
8	1000 grain weight (g)	27.20	22.90	23.43	21.83	22.90	23.15	23.50
9	Duration of anthesis in a panicle (days)	03.33	03.67	04.00	04.00	04.67	05.00	04.33
10	Duration of spikelet opening (hrs)	03.13	03.27	03.25	03.27	03.29	03.31	03.23
11	Angle of glume opening	21.67	30.00	24.33	38.33	30.00	20.00	30.00
12	Stigma exertion percentage	74.62	68.43	70.29	21.88	71.36	76.94	80.84
13	Total number of spikelets panicle $^{-1}$	97.67	108.33	102.33	100.67	141.33	127.33	135.33
14	Single plant grain yield (g)	13.03	11.32	11.99	11.59	11.37	12.82	13.78
15	Single plant straw yield (g)	17.06	16.34	15.52	14.73	15.29	15.62	20.91
16	Harvest index	00.43	00.41	00.44	00.44	00.43	00.45	00.39

Table 15. Mean, SEM and range of characters studied in TGMS lines at COH Vellanikkara

Sl.No	Characters (unit)	Mean ± SEM	Range
1	Days to 50% flowering	106.19 ± 0.72	87.00 – 129.67
2	Plant height (cm)	98.04 ± 2.34	83.67 - 116.00
3	Number of productive tillers plant^{-1}	13.42 ± 1.37	12.00 - 16.00
4	Panicle length (cm)	20.67 ± 0.88	18.70 - 22.77
5	Total number of spikelets panicle $^{-1}$	116.14 ±6.02	97.67 - 141.33
6	1000 grain weight (g)	23.56 ± 0.16	21.83 - 27.20
7	Grain length (mm)	8.17 ± 0.01	7.88 - 8.41
8	Grain breadth (mm)	0.95 ± 0.01	0.80 - 1.44
9	L/B ratio of grain	9.15 ± 0.16	5.47 - 10.36
10	Single plant grain yield (g)	09.32 ± 0.31	0.00 - 13.78
11	Single plant straw yield (g)	16.49 ± 0.47	14.73 -20.91
12	Harvest index	0.48 ± 0.00	0.47 - 0.49
13	Angle of glume opening	27.76 ±0.95	21.67 - 38.33
14	Duration of anthesis (days)	4.14 ± 0.33	3.33 - 5.00
15	Duration of spikelet opening (hrs)	3.25 ± 0.08	3.13 - 3.31
16	Stigma exertion percentage	66.33 ±2.99	21.88 -80.84

Table 16. Sterility behaviour of TGMS lines at COH Vellanikkara 2011-2012

Month (week)	TGMS 74S	TGMS 81S	TGMS 82S	TGMS 91S	TGMS 92S	TGMS 93S	TGMS 94S	Remarks (7TGMS LINES)
March								
1	79.17	83.33	88.88	83.72	62.79	61.54	82.61	**PF-PS**
2	83.33	89.47	92.68	86.05	67.44	64.10	86.96	**PF –S**
3	94.44	98.20	95.12	90.69	69.56	69.23	91.30	**PF-S**
4	99.50	100	100	93.02	73.91	84.21	95.65	**PS-CS**
Average	**89.11**	**92.75**	**94.17**	**88.37**	**68.43**	**69.77**	**89.13**	
Remarks	**PS**	**S**	**S**	**PS**	**PF**	**PF**	**PS**	
April								
1	100	100	100	93.48	86.96	91.30	100	**PS to CS**
2	100	100	100	100	100	100	100	**CS**
3	100	100	100	100	100	100	100	**CS**
4	100	100	100	100	100	100	100	**CS**
Average	**100**	**100**	**100**	**98.37**	**96.74**	**97.83**	**100**	
Remarks	**CS**	**CS**	**CS**	**S**	**S**	**S**	**CS**	
May								
1	100	100	100	100	100	100	100	**CS**
2	100	100	100	100	100	100	100	**CS**
3	100	100	100	100	100	100	100	**CS**
4	100	100	100	100	100	100	100	**CS**
Average	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**CS**

Table 16. (Cont...)

Remarks	**CS**	**CS**	**CS**	**CS**	**CS**	**CS**	**CS**	
June								
1	100	100	100	100	100	100	100	**CS**
2	100	100	100	100	100	100	100	**CS**
3	83.72	65.12	78.72	65.21	25.53	28.26	29.27	**F to PS**
4	48.78	37.04	68.75	30.00	15.63	13.95	11.11	**F to PF**
Average	**83.13**	**75.54**	**86.88**	**73.80**	**60.29**	**60.55**	**60.09**	
Remarks	**PS**	**PS**	**PS**	**PS**	**PF**	**PF**	**PF**	
July								
1	10.71	14.29	38.46	14.29	09.76	10.64	09.30	**FF-PF**
2	0	0	0	0	0	0	0	**FF**
3	0	0	0	0	0	0	0	**FF**
4	0	0	0	0	0	0	0	**FF**
Average	**2.68**	**3.57**	**9.62**	**3.57**	**2.44**	**2.66**	**2.33**	
Remarks	**FF**	**FF**	**FF**	**FF**	**FF**	**FF**	**FF**	
August								
1	0	0	0	0	0	0	0	**FF**
2	0	0	0	0	0	0	0	**FF**
3	0	0	0	0	0	0	0	**FF**
4	0	0	18.42	26.32	0	0	0	**F**
Average	**0**	**0**	**4.61**	**6.58**	**0**	**0**	**0**	
Remarks	**FF**	**FF**	**FF**	**FF**	**FF**	**FF**	**FF**	
September								

Table 16. (Cont...)

1	39.95	34.75	31.71	41.30	42.85	47.62	30.00	F –PF
2	42.31	37.04	34.04	43.38	48.72	58.97	28.70	F-PF
3	46.88	39.29	36.17	47.83	53.85	61.54	30.10	F-PF
4	57.69	46.34	41.30	63.04	65.79	61.54	63.16	PF
Average	**46.71**	**39.36**	**35.79**	**48.89**	**52.80**	**57.42**	**37.99**	
Remarks	**PF**	**PF**	**PF**	**PF**	**PF**	**PF**	**PF**	
October								
1	65.12	43.48	42.86	66.66	68.00	65.21	65.79	PF
2	71.40	45.65	46.15	68.29	69.56	67.39	67.39	PF
3	80.00	46.43	47.22	74.42	73.91	73.91	68.00	PF -PS
4	85.00	47.05	48.15	76.74	76.08	78.95	72.34	PF - PS
Average	**75.38**	**45.65**	**46.09**	**71.53**	**71.89**	**71.37**	**68.38**	
Remarks	**PS**	**PF**	**PF**	**PS**	**PS**	**PS**	**PF**	
November								
1	86.05	45.83	51.22	82.98	76.08	82.05	76.47	PF – PS
2	88.00	46.15	53.66	84.78	78.95	83.72	77.77	PF – PS
3	90.69	46.43	56.09	86.96	86.84	85.19	81.25	PF – S
4	91.18	46.51	57.45	89.13	89.74	87.50	83.33	PF – S
Average	**88.98**	**46.23**	**54.61**	**85.96**	**82.90**	**84.62**	**79.71**	
Remarks	**PS**	**PF**	**PF**	**PS**	**PS**	**PS**	**PS**	

Table 16. (Cont…)

December								
1	92.31	46.81	58.97	90.00	93.02	88.00	84.21	**PF – S**
2	93.02	48.94	60.87	90.90	95.35	91.49	86.84	**PF – S**
3	95.35	61.70	55.32	84.37	97.67	93.62	87.18	**PF –S**
4	97.67	63.83	48.84	90.24	97.83	95.74	89.74	**PF - S**
Average	**94.59**	**55.32**	**56.00**	**88.88**	**88.47**	**92.22**	**86.99**	
Remarks	**CS**	**PF**	**PF**	**PS**	**PS**	**S**	**PS**	
January 12								
1	94.87	48.15	83.72	84.78	95.55	95.83	82.93	**PF-S**
2	97.43	54.17	65.00	86.96	95.74	96.15	85.37	**PF – S**
3	88.00	66.66	60.00	87.23	96.15	97.37	87.80	**PF – S**
4	88.88	90.00	65.12	89.36	95.83	97.56	48.84	**PF - S**
Average	**92.30**	**64.75**	**68.46**	**87.08**	**95.82**	**96.73**	**76.24**	
Remarks	**S**	**PF**	**PF**	**PS**	**S**	**S**	**PS**	
February								
1	41.46	38.46	42.55	11.63	12.50	35.71	16.66	**FF-PF**
2	43.90	36.84	55.32	12.50	17.86	42.31	36.11	**FF-PF**
3	48.84	53.85	59.57	43.75	21.43	53.13	61.11	**F-PF**
4	55.81	76.08	81.39	62.50	53.85	59.26	72.22	**PF-PS**
Average	**47.50**	**51.28**	**59.71**	**32.59**	**26.41**	**47.60**	**46.53**	
Remarks	**PF**	**PF**	**PF**	**PF**	**F**	**PF**	**PF**	

CS:Complete sterile, S:Sterile, PS:Partially sterile, PF:Partially fertile, F:Fertile

4.1.1.4 Influence of weather parameters on sterility/fertility

The sterility/fertility behaviour of TGMS lines were studied in relation to weather parameters namely, maximum temperature, minimum temperature, sunshine hours, relative humidity and rainfall. Abstract of monthly weather data is given in **Table 17.**

Table 17. Monthly weather data of COH Vellanikkra (2011-2012)

Month	Maximun Temperature (^{0}C)	Minimum temperature (^{0}C)	Relative humidity (%)	Sunshine hours	Rainfall (mm)
March -11	34.8	23.9	43	8.7	010.0
April	34.3	24.5	58	6.6	207.1
May	33.0	24.9	63	6.8	198.5
June	29.3	23.6	82	2.5	799.6
July	29.1	22.5	81	1.6	500.2
August	29.4	22.9	78	2.2	713.0
September	30.0	23.1	75	5.4	435.2
October	31.1	23.5	65	6.1	193.0
November	31.4	22.9	57	6.3	240.0
December	31.9	21.9	49	7.3	002.4
January -12	32.8	21.3	58	9.5	000.0
February	35.1	22.1	54	9.2	000.0
March-12	35.2	24.2	67	7.6	003.5

Among the seven TGMS lines, TGMS 74S, TGMS 81S, TGMS 82S and TGMS 94S showed completely male sterile (100 per cent) during April first week to June second week. TGMS 91S, TGMS 92S and TGMS 93S showed completely male sterile (100 per cent) from April second week to June second week. On visual inspections, white coloured non dehiscent anthers were noted and no seed was set in the bagged panicles.

June third week onwards slowly changed to fertile condition to partial fertile and all TGMS lines showed 100 % fertile from July second week to August third week. During this period the anthers were yellow and dehiscent. Seeds were produced in the bagged panicles. Fertile pollen grains which were spherical and stained were noted mixed with lightly stained and spherical unstained pollen grains.

Sterility/fertility pattern of TGMS lines was studied for the tweleve months during March 2011 to March 2012 and the results are shown in **Table 18.**

Table 18. Monthwise sterility status

TGMS LINES	TGMS 74S	TGMS 81S	TGMS 82S	TGMS 91S	TGMS 92S	TGMS 93S	TGMS 94S
March-11	PS	S	S	PS	PF	PF	PS
April	CS	CS	CS	S	S	S	CS
May	CS	CS	CS	CS	CS	CS	CS
June	PS	PS	PS	PS	PF	PF	PF
July	FF	FF	FF	FF	FF	FF	FF
August	FF	FF	FF	FF	FF	FF	FF
September	PF	PF	PF	PF	PF	PF	PF
October	PS	PF	PF	PS	PS	PS	PF
November	PS	PF	PF	PS	PS	PS	PS
December	CS	PF	PF	PS	PS	S	PS
January-12	S	PF	PF	PS	S	S	PS
February-12	PF	PF	PF	PF	F	PF	PF
March-12	PS	S	S	PS	PF	PF	PS

Table 19. Correlation coefficient of pollen sterility with mean of different weather parameters over the period of 26 days before heading

Weather parameters	TGMS 74S	TGMS 81S	TGMS 82S	TGMS 91S	TGMS 92S	TGMS 93S	TGMS 94S
Maximum temperature	0.507**	0.415*	0.397*	0.338*	0.305	0.540**	0.585**
Minimum temperature	0.306	0.430*	0.584**	0.392*	0.423*	0.335*	0.397*
Mean temperature	0.566**	0.391*	0.415*	0.385*	0.368*	0.586**	0.675**
Relative humidity	-0.092	-0.063	0.078	-0.097	0.123	-0.086	-0.109
Rain fall	-0.002	0.215	0.237	-0.057	-0.098	0.015	0.161
Sun shine hours	0.294	-0.187	-0.273	0.286	0.418*	0.168	0.365*

** Significant at 1% level   * Significant at 5% level

Table 20. Correlation coefficient of pollen sterility with daily temperature in TGMS 74S, TGMS 81S, TGMS 82S and TGMS91S

Days before heading	TGMS 74S			TGMS 81S			TGMS 82S			TGMS 91S		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
26	0.801**	0.035	0.435*	0.508**	0.213	0.453**	0.243	0.342*	0.123	0.963**	0.806**	0.168
25	0.433*	0.045	0.821**	0.458**	0.346*	0.495**	0.195	0.475**	0.145	0.964**	0.965**	0.962**
24	0.321	0.423*	0.423*	0.546**	0.312	0.345*	0.259	0.585**	0.476**	0.997**	0.996**	0.999**
23	0.851**	0.341*	0.752**	0.465**	0.561**	0.365*	0.467**	0.880**	0.785**	0.990**	0.815**	0.960**
22	0.213	0.023	0.235	0.648**	0.354*	0.004	0.878**	0.795**	0.523**	0.970**	0.725**	0.957**
21	0.823**	0.055	0.750**	0.649**	0.093	-0.234	0.881**	0.439*	0.019	0.966**	0.735**	0.958**
20	0.873**	0.094	0.820**	0.544**	0.078	-0.197	0.748**	0.357*	-0.001	0.915**	0.703**	0.959**
19	0.904**	0.266	0.864**	0.597**	0.310	0.060	0.769**	0.510**	0.202	0.871**	0.706**	0.957**
18	0.900**	0.409*	0.887**	0.675**	0.350*	0.006	0.802**	0.531**	0.140	0.258	0.402*	0.397*
17	0.904**	0.465**	0.899**	0.717**	0.410*	0.051	0.815**	0.573**	0.126	0.032	0.256	0.167
16	0.880**	0.527**	0.907**	0.596**	0.317	-0.030	0.692**	0.473**	0.091	-0.011	0.201	0.107
15	0.859**	0.561**	0.909**	0.630**	0.296	-0.110	0.714**	0.448*	0.004	-0.161	0.303	0.070
14	0.497**	0.432*	0.586**	0.096	0.322	0.243	0.243	0.457**	0.268	-0.283	0.261	-0.054
13	0.348*	0.341	0.433*	0.116	0.351*	0.396*	0.036	0.474**	0.395*	-0.343*	0.220	-0.124
12	0.324	0.309	0.398*	0.279	0.429*	0.524**	0.133	0.531**	0.504**	-0.090	0.197	0.023
11	0.212	0.387*	0.379*	0.333	0.505**	0.594**	0.193	0.585**	0.567**	0.142	0.120	0.178
10	0.101	0.363*	0.287	0.383*	0.546**	0.637**	0.248	0.616**	0.608**	0.290	0.099	0.301
9	0.045**	0.338*	0.232	0.387*	0.589**	0.669**	0.258	0.648**	0.639**	0.285	0.092	0.292
8	0.203	0.326	0.329	0.387*	0.617**	0.688**	0.263	0.670**	0.658**	0.242	0.184	0.299
7	0.366*	0.270	0.432*	0.380*	0.618**	0.681**	0.281	0.686**	0.677**	0.167	0.271	0.285
6	0.473**	0.256	0.515**	0.323	0.591**	0.630**	0.258	0.679**	0.660**	0.085	0.266	0.203
5	0.468**	0.253	0.509**	0.321	0.581**	0.619**	0.265	0.677**	0.662**	0.100	0.256	0.212
4	0.435*	0.319	0.516**	0.245	0.613**	0.614**	0.215	0.698**	0.664**	0.146	0.283	0.261
3	0.369*	0.384*	0.507**	0.159	0.606**	0.564**	0.154	0.695**	0.631**	0.129	0.099	0.161
2	0.292	0.382*	0.441*	0.114	0.598**	0.533**	0.120	0.691**	0.610**	0.108	0.129	0.187
1	0.307	0.376*	0.450*	0.240	0.595**	0.579**	0.213	0.690**	0.632**	0.078	0.124	0.133

Table 21. Correlation coefficient of pollen sterility with daily temperature in TGMS 92S , TGMS 93S and TGMS 94S

Days before heading	TGMS 92S			TGMS 93S			TGMS 94S		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
26	0.269	0.625**	0.235	0.435*	0.453**	0.523**	0.564**	0.485**	0.523**
25	0.235	0.521**	0.365*	0.786**	0.431*	0.465**	0.421*	0.452**	0.621**
24	0.453**	0.532**	0.325	0.435*	0.465**	0.432*	0.356*	0.465**	0.635**
23	0.365*	0.465*	0.545**	0.524**	0.245	0.523**	0.465**	0.453**	0.652**
22	0.356*	0.435*	0.562**	0.165	0.268	0.461**	0.325	0.056	0.635**
21	0.244	0.222	0.543**	0.823**	0.055	0.750**	0.823**	0.055	0.750**
20	0.512**	0.572**	0.766**	0.873**	0.094	0.820**	0.873**	0.094	0.820**
19	0.536**	0.669**	0.813**	0.904**	0.266	0.864**	0.904**	0.266	0.864**
18	0.631**	0.428*	0.838**	0.900**	0.409*	0.887**	0.900**	0.409*	0.887**
17	0.677**	0.502**	0.807**	0.904**	0.465**	0.899**	0.904**	0.465**	0.899**
16	0.709**	0.554**	0.819**	0.880**	0.527**	0.907**	0.880**	0.527**	0.907**
15	0.286	0.586**	0.496**	0.859**	0.561**	0.909**	0.859**	0.561**	0.909**
14	0.241	0.659**	0.005	0.583**	0.478**	0.670**	0.725**	0.547**	0.807**
13	0.456**	0.652**	0.268	0.431*	0.388*	0.516**	0.597**	0.477**	0.680**
12	0.411*	0.638**	0.223	0.399*	0.354*	0.475**	0.561**	0.446*	0.637**
11	0.330	0.361*	0.218	0.284	0.424*	0.451**	0.448*	0.500**	0.609**
10	0.210	0.118	0.180	0.169	0.399*	0.356*	0.332*	0.476**	0.515**
9	0.090	0.135	0.044	0.111	0.373*	0.299	0.271	0.451**	0.457**
8	0.108	0.159	0.053	0.252	0.360*	0.384*	0.366*	0.437*	0.512**
7	0.263	0.038	0.293	0.524**	0.168	0.509**	0.513**	0.356*	0.594**
6	0.159	0.442*	0.083	0.650**	0.141	0.612**	0.605**	0.330*	0.660**
5	0.084	0.388*	0.124	0.596**	0.140	0.565**	0.587**	0.320	0.640**
4	0.002	0.298	0.154	0.522**	0.247	0.555**	0.543**	0.386*	0.637**
3	0.054	0.400*	0.261	0.418*	0.347*	0.529**	0.464**	0.449*	0.620**

Table 22. Correlation coefficient of pollen sterility with relative humidity, rainfall and sunshine hours in TGMS 74S, TGMS 81S, TGMS 82S and TGMS 91S.

Days before heading	TGMS 74S			TGMS 81S			TGMS 82S			TGMS 91S		
	RH	Rf	SS	RH	Rf	SS	RH	Rf	SS	RH	Rf	SS
26	-0.054	-0.125	0.211	-0.096	0.074	-0.143	0.036	0.278	-0.005	-0.005	-0.236	0.158
25	-0.275	-0.124	0.242	-0.086	0.056	-0.356*	0.231	0.296	-0.425*	-0.265	-0.236	0.625**
24	-0.052	-0.123	0.064	0.213	0.045	-0.112	0.944**	0.287	-0.720**	-0.205	-0.165	0.981**
23	-0.003	-0.112	0.324	0.265	0.408*	-0.123	0.883**	0.321	-0.946**	-0.385*	0.333*	0.940**
22	-0.073	-0.121	0.251	-0.045	0.423*	-0.421*	0.491**	0.269	-0.197	-0.432*	0.251	0.943**
21	0.422*	-0.141	0.405*	0.074	0.351*	0.094	0.221	0.268	-0.004	-0.255	0.242	0.744**
20	-0.027	-0.004	0.441*	0.206	0.256	0.052	0.359*	0.254	-0.021	-0.172	0.166	0.638**
19	-0.388*	0.487**	0.553**	0.088	0.234	-0.167	0.229	0.328	-0.215	-0.126	0.142	0.619**
18	-0.470**	0.395*	0.584**	0.266	0.195	-0.354*	0.371*	0.342*	-0.381*	0.134	-0.066	0.531**
17	-0.274	0.333*	0.482**	0.070	0.168	-0.464**	0.166	0.301	-0.479**	-0.143	-0.122	0.175
16	-0.162	0.288	0.409*	-0.056	0.421*	-0.346*	0.032	0.256	-0.364*	-0.063	-0.155	0.184
15	-0.094	0.254	0.461**	-0.041	0.321	-0.404*	0.043	0.254	-0.417*	-0.023	-0.178	0.122
14	0.103	0.051	0.472**	0.122	0.265	-0.279	0.165	0.125	-0.324	0.010	-0.195	0.080
13	-0.145	-0.008	0.249	-0.096	0.045	-0.248	-0.030	0.123	-0.298	0.033	-0.209	0.138
12	-0.073	-0.043	0.260	-0.347*	0.404*	-0.151	-0.270	0.356*	-0.210	-0.122	-0.220	0.230
11	-0.033	-0.067	0.222	-0.431*	0.353*	-0.119	-0.354*	0.316	-0.179	-0.194	-0.228	0.299
10	-0.003	-0.085	0.195	-0.303	0.315	-0.179	-0.245	0.284	-0.230	-0.141	-0.235	0.207
9	0.018	-0.100	0.241	-0.220	0.284	-0.226	-0.173	0.259	-0.270	-0.112	-0.241	0.247
8	-0.137	-0.112	0.313	-0.165	0.260	-0.164	-0.125	0.238	-0.211	-0.060	-0.246	0.083
7	-0.207	-0.123	0.365*	-0.069	0.190	-0.047	-0.073	0.205	-0.140	-0.039	-0.136	-0.067
6	-0.158	-0.133	0.299	-0.218	0.146	-0.133	-0.173	0.180	-0.192	0.019	-0.148	-0.088
5	-0.130	-0.141	0.330	-0.174	0.114	-0.117	-0.148	0.159	-0.181	-0.022	-0.158	-0.163
4	-0.080	-0.148	0.200	-0.147	0.091	-0.137	-0.132	0.141	-0.195	-0.005	0.155	-0.138
3	-0.059	-0.040	0.061	-0.125	0.072	-0.154	-0.118	0.126	-0.207	-0.017	0.139	-0.062
2	-0.000	-0.053	0.043	-0.108	0.056	-0.119	-0.105	0.114	-0.180	0.007	0.126	-0.007
1	-0.043	-0.064	-0.032	-0.226	0.043	-0.053	-0.195	0.102	-0.126	0.037	0.114	0.018

Table 23. Correlation coefficient of pollen sterility with relative humidity, rainfall, and sunshine hours in TGMS 92S TGMS 93S and TGMS 94S.

Days before heading	TGMS 92S			TGMS 93S			TGMS 94S		
	RH	Rf	SS	RH	Rf	SS	RH	Rf	SS
26	0.286	-0.362*	0.241	-0.086	-0.345	0.234	-0.231	0.365*	0.365*
25	0.352*	-0.354*	0.245	-0.069	-0.035	0.325	-0.325	0.286	0.425*
24	0.321	-0.256	0.234	-0.265	-0.032	0.241	-0.063	0.256	0.365*
23	0.265	-0.321	0.428*	-0.035	-0.012	0.142	-0.035	0.325	0.461**
22	0.235	-0.235	0.328	-0.076	-0.124	0.134	-0.086	0.365*	0.435*
21	0.231	-0.245	0.428*	0.422*	-0.013	0.012	0.422*	0.423*	0.405*
20	-0.076	-0.258	0.299	-0.027	-0.036	0.023	-0.027	0.453**	0.441*
19	0.009	-0.292	0.330	-0.388*	0.487**	0.152	-0.388*	0.487**	0.553**
18	0.054	-0.316	0.511**	-0.470**	0.395**	0.432*	-0.470**	0.395*	0.584**
17	0.085	-0.333*	0.441*	-0.274	0.333**	0.262	-0.274	0.333*	0.482**
16	0.108	-0.346*	0.421*	-0.162	0.288	0.272	-0.162	0.288	0.409*
15	-0.051	-0.356*	0.521**	-0.094	0.254	0.234	-0.094	0.254	0.461**
14	-0.173	-0.311	0.553**	0.082	0.084	0.128	0.034	0.146	0.528**
13	-0.074	-0.302	0.584**	-0.148	0.021	0.018	-0.148	0.088	0.360*
12	-0.026	-0.301	0.436	-0.079	-0.015	0.232	-0.090	0.049	0.364*
11	0.045	-0.303	0.482**	-0.040	-0.041	0.212	-0.055	0.021	0.327
10	0.071	-0.159	0.313	-0.011	-0.061	0.201	-0.029	0.002	0.300
9	0.142	-0.175	0.216	0.011	-0.077	0.201	-0.007	-0.017	0.335*
8	0.083	-0.188	0.226	-0.140	-0.089	0.256	-0.143	-0.031	0.391*
7	0.120	0.721**	0.432*	-0.245	-0.095	0.205	-0.220	-0.052	0.435*
6	0.063	0.532**	0.702**	-0.140	-0.106	0.088	-0.162	-0.068	0.352*
5	0.126	0.428*	0.553**	-0.092	-0.115	0.128	-0.130	-0.080	0.381*
4	0.190	0.358*	0.518**	-0.021	-0.124	0.018	-0.075	-0.091	0.234
3	0.243	0.308	0.508**	0.003	0.020	0.248	-0.053	0.019	0.081
2	0.285	0.269	0.406*	0.077	-0.132	0.067	0.010	0.003	0.060

Table 24. Correlation coefficient of pollen sterility with different weather parameters in different stages of panicle development

Weather parameters	Panicle development stages	TGMS 74S	TGMS 81S	TGMS 82S	TGMS 91S	TGMS 92S	TGMS 93S	TGMS 94S
Maximum temperature	S_1	0.617**	0.483**	0.219	0.963**	0.252	0.610**	0.492**
	S_2	0.462**	0.553**	0.534**	0.985**	0.391*	0.374**	0.382*
	S_3	0.866**	0.596**	0.799**	0.917**	0.430*	0.866**	0.866**
	S_4	0.885**	0.654**	0.718**	0.029	0.575**	0.885**	0.885**
	S_5	0.389*	0.163	0.137	-0.238	0.369*	0.471**	0.627**
	S_6	0.119	0.367*	0.233	0.239	0.210	0.188	0.350*
	S_7	0.385*	0.302	0.239	0.144	0.111	0.493**	0.513**
	S_8	0.299	0.177	0.166	0.093	0.132	0.315	0.350*
Minimum temperature	S_1	0.040	0.279	0.408*	0.885**	0.573**	0.442*	0.468**
	S_2	0.262	0.409*	0.753**	0.845**	0.477**	0.326	0.324
	S_3	0.138	0.160	0.435*	0.714**	0.487**	0.138	0.138
	S_4	0.490**	0.343*	0.506**	0.290	0.517**	0.490**	0.490**
	S_5	0.360*	0.367*	0.487**	0.260	0.649**	0.406*	0.490**
	S_6	0.362*	0.546**	0.616**	0.103	0.204	0.398*	0.435**
	S_7	0.292	0.604**	0.684**	0.226	0.287	0.233	0.379*
	S_8	0.379*	0.595**	0.325	0.126	0.306	0.335*	0.438*
Mean temperature	S_1	0.628**	0.474**	0.134	0.565**	0.300	0.494**	0.572**
	S_2	0.470**	0.264	0.594**	0.972**	0.477**	0.472**	0.640**
	S_3	0.811**	-0.123	0.073	0.958**	0.707**	0.811**	0.811**
	S_4	0.900**	-0.020	0.090	0.185	0.739**	0.900**	0.900**
	S_5	0.482**	0.387*	0.389*	-0.051	0.165	0.553**	0.708**
	S_6	0.299	0.633**	0.604**	0.257	0.147	0.373*	0.527**
	S_7	0.468**	0.632**	0.658**	0.236	0.161	0.525**	0.610**
	S_8	0.445*	0.556**	0.621**	0.160	0.285	0.439**	0.544**
Relative humidity	S_1	-0.164	-0.091	0.133	-0.135	0.319	-0.077	-0.278
	S_2	-0.042	0.144	0.772**	-0.340*	0.273	-0.125	-0.061
	S_3	0.002	0.122	0.269	-0.184	0.054	0.002	0.002
	S_4	-0.250	0.059	0.153	-0.023	0.049	-0.250	-0.250
	S_5	-0.038	-0.107	-0.045	-0.026	0.091	-0.048	-0.068
	S_6	-0.006	-0.318	-0.257	-0.149	0.086	-0.013	-0.030
	S_7	-0.128	-0.149	-0.128	-0.020	0.137	-0.105	-0.130
	S_8	-0.021	-0.167	-0.150	0.022	0.288	0.046	-0.013

Table 24. (Contd...)

Weather parameters	Panicle development stages	TGMS 74S	TGMS 81S	TGMS 82S	TGMS 91S	TGMS 92S	TGMS 93S	TGMS 94S
Rain fall	S_1	-0.124	0.065	0.287	-0.236	-0.358*	-0.190	0.325
	S_2	-0.118	0.292	0.292	0.139	-0.270	-0.050	0.315
	S_3	0.114	0.280	0.283	0.183	-0.265	0.146	0.454**
	S_4	0.313	0.276	0.288	-0.130	-0.337*	0.317	0.317
	S_5	0.001	0.238	0.201	-0.208	-0.304	0.030	0.094
	S_6	-0.084	0.317	0.286	-0.234	-0.212	-0.059	0.002
	S_7	-0.116	0.145	0.174	-0.065	0.359*	-0.084	-0.050
	S_8	-0.058	0.049	0.108	0.120	0.253	-0.074	-0.003
Sun shine hours	S_1	0.226	-0.249	-0.215	0.391*	0.243	0.279	0.395*
	S_2	0.213	-0.218	-0.621**	0.954**	0.330*	0.172	0.420**
	S_3	0.466**	-0.007	-0.080	0.667**	0.352*	0.062	0.467**
	S_4	0.484**	0.392*	-0.409**	0.830**	0.461**	0.300	0.483**
	S_5	0.327	-0.226	-0.277	0.149	0.524**	0.123	0.417*
	S_6	0.219	-0.174	-0.276	0.251	0.337	0.204	0.320
	S_7	0.261	-0.125	-0.187	-0.072	0.489**	0.157	0.312
	S_8	0.005	-0.086	-0.153	0.005	0.354*	0.087	0.019

** Significant at 1% level * Significant at 5% level

Table 25. CST, CFT of all TGMS lines

Sl.No	Entries	Heading date with sterility	Duration	Pollen sterility (%)	CST (^{0}C)	Heading date with maximum fertility	Duration	Pollen fertility (%)	CFT (^{0}C)
1	TGMS 74S	Apr 01-June 18	79	100	34.2	July 06 –Aug 31	57	100	23.0
2	TGMS 81S	Mar 25 –June 14	83	100	32.9	July 10 –Aug 31	53	100	24.2
3	TGMS 82S	Mar 25 –June 18	87	100	32.9	June 28 –Aug 28	52	100	24.2
4	TGMS 91S	Apr 05- June 15	72	100	34.2	July 10 –Aug 30	52	100	22.7
5	TGMS 92S	Apr 08-June 15	69	100	34.2	July 10 –Aug 31	53	100	24.2
6	TGMS 93S	Apr 01- June 17	78	100	34.2	July 10 – Sep 01	54	100	24.2
7	TGMS 94S	Apr 01- June 18	79	100	34.2	July 11 –Sep 01	53	100	24.2

4.1.1.5 Influence of weather parameters on fertility of TGMS lines

The relative influence of environmental factors *viz.*, maximum temperature, minimum temperature, sunshine hours, relative humidity and photoperiod on fertility of TGMS lines was studied by simple correlation analysis between these and male sterility.

The association of the weather parameters prevailed each day from one to 26 days before heading, average of each factor at different stages of panicle development (from S1 to S8) and overall mean of each factor throughout the panicle development stage with pollen sterility of each line are presented in **Table 19 to 25.**

4.1.2 CRS Pampadumpara

The TGMS lines flowered normally and set seeds at CRS, Pampadumpara. Data on yield and yield components were recorded from CRS Pampadumpara and were subjected to statistical analysis and the results are given below.

4.1.2.1 Genetic variability

Present investigation analyzed the genetic variability existing among the genotypes. The seven TGMS lines differed significantly with respect to the characters.

4.1.2.2 Mean performace

Mean performance of seven TGMS lines during the entire study period is presented in **Table 26.** The range, mean and standard error of mean for different characters are shown in **Table 27.**

Table 26. Comparison of mean performance of seven TGMS lines at CRS Pampadumpara

Sl.No	Characters	TGMS 74S	TGMS 81S	TGMS 82S	TGMS 91S	TGMS 92S	TGMS 93S	TGMS 94S
1	Days to 50 % flowering	101.67	101.67	104.33	101.67	130.33	134.00	136.00
2	Plant height (cm)	57.83	57.00	60.00	59.17	60.17	43.67	61.83
3	No. productive tillers/plant	5.66	5.33	5.00	5.33	6.33	6.67	5.33
4	Panicle length (cm)	17.60	17.53	20.30	18.23	22.43	21.00	22.33
5	Grain length (mm)	7.81	8.04	8.20	8.17	8.21	8.21	8.39
6	Grain breadth (mm)	1.40	0.92	0.78	0.84	0.81	0.79	0.89
7	L/B ratio of grain	5.59	8.71	10.56	9.77	10.18	10.36	9.40
8	1000 grain weight (g)	26.86	23.03	21.70	20.63	23.07	22.70	24.23
9	Duration of anthesis in a panicle	5.00	5.67	5.00	5.00	5.67	5.33	4.67
10	Duration of spikelet opening (hrs)	3.27	3.29	3.36	3.25	3.28	3.18	3.30
11	Angle of glume opening	21.67	30.00	26.00	34.33	27.67	20.00	29.33
12	Stigma exertion percentage	72.14	71.29	65.86	29.67	65.06	68.12	66.75
13	Total number of spikelets panicle^{-1}	82.33	69.00	104.33	85.00	139.00	123.66	126.67
14	Number of filled grains panicle^{-1}	73.67	60.67	93.33	76.00	129.00	111.00	105.33
15	Single plant grain yield (g)	16.12	14.65	15.58	14.94	15.58	15.13	16.99
16	Single plant straw yield (g)	18.07	15.73	16.83	16.10	16.51	16.07	18.25
17	Harvest index	0.47	0.48	0.48	0.48	0.48	0.48	0.49

Table 27. Mean, SEM and range of characters studied in TGMS lines at CRS Pampadumpara

Sl.No	Characters (unit)	Mean ± SEM	Range
1	Days to 50% flowering	115.67 ± 0.60	101.67 - 136.00
2	Plant height (cm)	57.06 ± 3.63	43.67 - 61.83
3	Number of productive tillers plant^{-1}	05.67 ± 0.38	05.33 - 06.68
4	Panicle length(cm)	19.92 ± 0.32	17.60 - 22.43
5	Total number of spikelets panicle $^{-1}$	104.29 ±3.64	69.00 - 139.00
6	Number of filled grains panicle^{-1}	92.71 ± 3.93	60.67 – 129.00
7	1000 grain weight (g)	23.18 ± 0.17	20.63 - 26.87
8	Grain length (mm)	8.15 ± 0.01	7.81 - 8.39
9	Grain breadth (mm)	0.92 ± 0.01	0.78 - 1.39
10	L/B ratio of grain	9.22 ± 0.15	5.59 - 10.56
11	Single plant grain yield (g)	15.5 7 ± 0.44	14.65 - 16.99
12	Single plant straw yield (g)	16.80 ± 0.45	15.73 -18.25
13	Harvest index	0.48 ± 0.00	0.47 - 0.49
14	Angle of glume opening	27.00 ±1.18	20.00 - 34.33
15	Duration of anthesis (days)	5.19 ± 0.25	4.67 - 5.67
16	Duration of spikelet opening (hrs)	3.27 ± 0.04	3.18 - 3.36
17.	Stigma exertion percentage	62.70 ±1.39	29.67 -72.14

Table 28. Monthly weather data of CRS Pampadumpara 2011-2012

Month	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Relative humidity (%)	Sunshine hours	Rainfall (mm)
Apr-11	27.7	18.6	77.0	6.0	178.8
May-11	27.6	19.4	78.0	7.5	24.0
Jun-11	23.0	18.6	91.9	2.5	360.4
Jul-11	22.3	18.1	93.5	1.2	10.9
Aug-11	23.0	18.0	92.6	1.5	11.3
Sep-11	24.0	17.8	87.4	3.9	151.4
Oct-11	26.3	18.9	95.0	4.8	12.6
Nov-11	23.9	17.3	83.8	5.1	184.0
Dec-11	24.1	16.8	79.6	5.6	21.0
Jan-12	24.1	15.1	71.7	8.6	6.8
Feb-12	26.3	16.0	64.4	8.4	0.0
Mar-12	29.1	18.6	66.4	7.2	2.4

4.2 Evaluation of pollinator

Twenty two rice varieties were evaluated for various morphological and spikelet characters. Data were subjected to statistical analysis and the results are presented below.

4.2.1 Genetic variability

In the present study the extent of genetic variability with respect to various characters were estimated. Results of analysis of variance revealed significant difference among the 22 genotypes for all the characters studied.

Table 29. Mean, SEM and range of characters studied in pollinator parents

Sl.No	Characters	Mean ± SEM	Range
1	Days to 50% flowering	84.87 ± 5.29	70.67 - 103.33
2	Plant height (cm)	107.27 ± 2.77	86.00 - 144.00
3	Number of productive tillers plant^{-1}	9.90 ± 1.28	7.67 - 17.00
4	Panicle length (cm)	23.28 ± 1.43	19.67 - 30.00
5	Total number of spikelets panicle $^{-1}$	142.68 ± 15.28	101.33-182.00
6	Number of filled grains panicle^{-1}	101.63 ± 13.27	71.00-144.00
7	1000 grain weight (g)	24.14 ± 1.31	19.86-29.00
8	Grain length (mm)	7.27 ± 0.50	5.38-8.82
9	Grain breadth (mm)	2.64 ± 0.39	1.53-3.29
10	L/B ratio of grain	2.91 ± 0.40	2.04-4.63
11	Single plant grain yield (g)	13.03 ± 1.74	10.18-20.67
12	Single plant straw yield (g)	16.94 ± 2.56	11.48-30.08
13	Harvest index	0.44 ± 0.02	0.39-0.52

The range, mean and standard error of mean for different characters are shown in **Table 29.** The genotypes showed a large range of variation for all the characters studied.

Days to 50% flowering ranged from 70.67 -103.33 days average being 84.87. Plant height of the genotypes ranged from 86.00 cm to 144 cm average being 107.27 cm. Number of productive tillers plant $^{-1}$ varied from 7.67 to 17.00 with an mean value of 9.90.

Among the earhead characters earhead length showed a range of 19.67cm - 30.00 cm average being 23.28 cm. Total number of spikelets panicle^{-1} varied from 101.33 -182.00 with an average of 142.68. Number of filled grains panicle^{-1} ranged from 71-144 with an average 101.63

With respect to grain characters 1000 grain weight ranged from 19.86 g to 29.00 g with an average of 24.14g . Other characters namely grain length, and grain breadth varied from 5.38 mm to 8.82 mm and 1.53 mm to 3.29 mm with an average of 7.27 mm and 2.64 mm respectively. L/B ratio of grain ranged from 2.04 mm to 4.63 mm with an average of 2.91mm.

Economic characters namely single plant grain yield and straw yield varied from 10.18 g to 20.67 g and 11.48 g to 30.08 g with an average of 13.03 g and 16.94 g. Harvest index ranged from 0.39 to 0.52 average being 0.44

4.2.2 Mean performance

The observation on various characters studied in pollinator parents were subjected to Duncan's Multiple Range Test (DMRT) and the abstracts are given in **Table 30 to 33.**

Plant characters such as days to 50% flowering Manupriya recorded shorter days to 50% flowering and Uma and Bhadra recorded longest days to 50%

Table 30. Mean performance of pollinator parents for plant characters

Sl.No	Varieties	Days to 50 % flowering	Plant height(cm)	Number of productive tillersplant^{-1}
1	Ahalya	74.33^{b}	108.33^{def}	8.33^{cde}
2	Aiswarya	83.67^{e}	114.67^{ef}	11.33^{bcd}
3	Annapoorna	73.67^{ab}	86.00^{a}	11.67^{bc}
4	Bhadra	101.33^{h}	87.33^{a}	17.00^{a}
5	Gouri	94.67^{g}	100.33^{bcd}	6.33^{e}
6	Harsha	74.67^{bc}	100.67^{bcd}	10.00^{bcd}
7	Jyothi	78.00^{d}	103.67^{cde}	11.67^{bc}
8	Kunjukunju Varna	76.67^{bcd}	93.00^{abc}	11.33^{bcd}
9	Kairali	82.00^{e}	103.33^{cde}	8.33^{cde}
10	Kanakom	96.00^{g}	106.67^{de}	7.67^{de}
11	Kanchana	83.00^{e}	102.67^{cde}	13.33^{b}
12	Makom	77.67^{cd}	119.33^{f}	9.67^{cde}
13	Manupriya	70.67^{a}	101.33^{bcd}	8.33^{cde}
14	Matta Triveni	84.00^{e}	109.00^{def}	9.33^{cde}
15	Pavizham	94.00^{g}	96.67^{abcd}	9.67^{cde}
16	Prathyasa	89.67^{f}	104.33^{cde}	8.67^{cde}
17	Remanika	95.00^{g}	90.00^{ab}	9.00^{cde}
18	Samyuktha	83.67^{e}	142.33^{g}	8.33^{cde}
19	Swarnaprabha	83.67^{e}	144.00^{g}	9.33^{cde}
20	Uma	103.33^{h}	97.67^{abcd}	9.33^{cde}
21	Vaishak	84.00^{e}	140.00^{g}	10.00^{bcd}
22	Varsha	83.67^{e}	108.67^{def}	9.33^{cde}

Table 31. Mean performance of pollinator parents for ear head characters:

Sl.No	Varieties	Panicle length (cm)	Total number of Spikelets panicle $^{-1}$	Number of filled grains panicle $^{-1}$
1	Ahalya	23.83^{cde}	158.00^{abcd}	106.67^{def}
2	Aiswarya	21.30^{fghi}	130.33^{defg}	89.00^{fgh}
3	Annapoorna	23.77^{bcde}	125.67^{defg}	85.00^{fgh}
4	Bhadra	22.50^{defgh}	109.33^{fg}	71.00^{h}
5	Gouri	22.67^{defg}	142.33^{cdef}	73.33^{h}
6	Harsha	25.10^{bc}	129.67^{defg}	92.67^{efgh}
7	Jyothi	20.50^{ghi}	145.33^{cde}	83.33^{fgh}
8	Kunjukunju Varna	25.43^{b}	170.33^{abc}	141.33^{ab}
9	Kairali	20.37^{hi}	154.67^{bcd}	132.33^{abc}
10	Kanakom	23.67^{bcde}	182.00^{ab}	86.67^{fgh}
11	Kanchana	22.67^{defg}	131.00^{defg}	100.33^{defg}
12	Makom	22.30^{defgh}	152.67^{bcde}	138.33^{ab}
13	Manupriya	21.60^{efghi}	159.67^{abcd}	119.33^{bcd}
14	Matta Triveni	24.07^{bcd}	155.67^{bcd}	129.67^{abc}
15	Pavizham	19.67^{i}	117.67^{efg}	86.67^{fgh}
16	Prathyasa	25.00^{bc}	105.67^{g}	91.33^{efgh}
17	Remanika	22.0^{defgh}	175.33^{abc}	78.67^{gh}
18	Samyuktha	23.87^{bcde}	101.67^{g}	89.67^{efgh}
19	Swarnaprabha	28.37^{a}	167.67^{abc}	112.67^{cde}
20	Uma	20.67^{ghi}	101.33^{g}	82.33^{gh}
21	Vaishak	30.00^{a}	191.67^{a}	144.00^{a}
22	Varsha	23.03^{cdef}	131.33^{defg}	101.67^{defg}

Table 32. Mean performance of pollinator parents for grain characters

Sl.No	Varieties	1000 grain weight(g)	Grain length(mm)	Grain breadth(mm)	L/B ratio of grain
1	Ahalya	26.87^{c}	7.70^{e}	3.25^{abc}	2.37^{hi}
2	Aiswarya	19.86^{l}	6.18^{j}	1.78^{gh}	3.48^{d}
3	Annapoorna	21.80^{k}	7.71^{cd}	3.24^{abc}	2.38^{hi}
4	Bhadra	24.40^{f}	7.95^{b}	3.12^{bcd}	2.50^{gh}
5	Gouri	22.97^{ij}	6.70^{hi}	3.29^{a}	2.04^{j}
6	Harsha	21.60^{k}	8.58^{ab}	3.08^{d}	2.78^{f}
7	Jyothi	26.03^{d}	8.82^{a}	2.83^{f}	3.11^{e}
8	Kunjukunju Varna	23.13^{hij}	7.70^{fg}	3.10^{cd}	2.51^{gh}
9	Kairali	21.30^{k}	6.14^{jk}	1.75^{gh}	3.51^{d}
10	Kanakom	24.53^{f}	7.80^{c}	3.17^{abcd}	2.46^{ghi}
11	Kanchana	29.00^{a}	7.34^{ef}	1.59^{ij}	4.63^{a}
12	Makom	23.19^{hij}	7.58^{d}	3.03^{de}	2.50^{gh}
13	Manupriya	23.03^{ij}	7.70^{de}	3.25^{ab}	2.36^{i}
14	Matta Triveni	25.38^{e}	6.26^{i}	1.53^{j}	4.10^{b}
15	Pavizham	23.57^{ghi}	7.26^{f}	3.11^{bcd}	2.34^{i}
16	Prathyasa	26.29^{d}	6.29^{lm}	1.84^{g}	3.43^{d}
17	Remanika	26.23^{d}	7.41^{ef}	2.91^{ef}	2.55^{g}
18	Samyuktha	28.31^{b}	6.68^{b}	1.69^{hi}	3.94^{c}
19	Swarnaprabha	23.83^{g}	8.38^{abc}	2.94^{ef}	2.85^{f}
20	Uma	22.63^{j}	6.86^{gh}	2.91^{ef}	2.36^{i}
21	Vaishak	23.70^{gh}	7.71^{cd}	3.16^{abcd}	2.44^{ghi}
22	Varsha	23.61^{ghi}	5.38^{m}	1.54^{j}	3.49^{d}

Table 33. Mean performance of pollinator parents for economic characters

Sl.No	Varieties	Single plant grain yield (g)	Single plant straw yield (g)	Harvest index
1	Ahalya	20.67^{a}	24.37^{b}	0.45^{abcd}
2	Aiswarya	11.67^{fghi}	18.05^{cdef}	0.39^{d}
3	Annapoorna	10.18^{i}	12.31^{hij}	0.41^{cd}
4	Bhadra	12.61^{ef}	16.36^{efghi}	0.44^{bcd}
5	Gouri	10.26^{hi}	13.42^{ghij}	0.43^{bcd}
6	Harsha	11.75^{fghi}	16.83^{efg}	0.41^{cd}
7	Jyothi	11.58^{fghi}	16.54^{efgh}	0.41^{cd}
8	Kunjukunju Varna	16.19^{c}	21.56^{bcd}	0.43^{bcd}
9	Kairali	11.86^{fgh}	15.57^{fghij}	0.43^{bcd}
10	Kanakom	15.27^{cd}	14.06^{fghij}	0.52^{a}
11	Kanchana	11.98^{fg}	16.09^{fghi}	0.43^{bcd}
12	Makom	18.93^{b}	21.75^{bc}	0.47^{abc}
13	Manupriya	12.55^{ef}	16.36^{efghi}	0.43^{bcd}
14	Matta Triveni	13.80^{de}	20.51^{bcde}	0.40^{cd}
15	Pavizham	11.44^{fghi}	15.82^{fghij}	0.43^{bcd}
16	Prathyasa	$11.8\ 0^{fghi}$	13.69^{fghij}	0.47^{abc}
17	Remanika	11.15^{fghi}	11.48^{j}	0.48^{ab}
18	Samyuktha	13.80^{de}	13.19^{ghij}	0.51^{a}
19	Swarnaprabha	12.60^{ef}	12.09^{ij}	0.51^{a}
20	Uma	12.28^{efg}	17.61^{defg}	0.41^{bcd}
21	Vaishak	19.78^{ab}	30.08^{a}	0.40^{cd}
22	Varsha	10.65^{ghi}	15.00^{fghij}	0.42^{bcd}

flowering. Plant height was highest for Swarna Prabha and Samyuktha while Annapoorna recorded the lowest. Number of productive tillers plant $^{-1}$ was maximum for Bhadra , where as gouri had the lowest number. Among the earhead characters Vaishak had the longest panicle . Panicles were comparatively short for Remanika and Pavizham. Large number of total spikelets panicle $^{-1}$ was recorded for Vaishak where as Uma , Samyuktha had the lowest value. In case of number of filled grains panicle^{-1} Vaishak and makom showed the maximum value but Samyuktha showed the minimum value.

With respect to grain characters 1000 grain weight exhibited a maximum value for Kanchana and minimum value for Aiswarya . Swarnaprabha followed by Jyothi had the longest grains but Varsha had the smallest grains. Grains had more breadth in the case of Gouri but less breadth for Varsha and Matta Triveni. L/B ratio of grains was more for Kanchana while Gouri recorded the low values.

Economic characters such as single plant grain yield were maximum for Ahalya , Vaishak and single plant straw yield for Vaishak and Ahalya. Samyuktha recorded the lowest single plant grain yield and Remanika recorded lowest single plant straw yield. Kanakom, Samyuktha, Swarna Prabha recorded highest harvest index and Aiswarya showed the lowest value.

4.2.3 Phenotypic and genotypic coefficient of variation

The estimates of PCV, GCV, Heritability, genetic advance are given in **Table 34.** Among different characters studied number of productive tillers plant^{-1} (27.21,20.62) filled grains panicle^{-1} (24.79,21.45), single plant grain yield (23.30,23.38) , single plant straw yield (28.28, 23.75) recorded high magnitude of PCV and GCV .But days to 50 % flowering (10.96, 10.74), plant height (15.98, 14.83), panicle length (11.49, 10.28), grain length (12.00, 11.99) showed moderate values.

Low PCV and GCV values were observed for 1000 grain weight (9.50, 9.39) with respect to character total number of spikelets panicle^{-1} (21.38) high value of PCV and moderate value of GCV(16.96) . Harvest index recorded moderate value of PCV (10.76) and low value of GCV (7.44).

4.2.4 Heritability

Among the different characters studied heritability (broad sense) estimates varied from 47.80 (harvest index) to 99.8 (grain length).

High heritability in the broad sense was estimated for the characters days to 50 % flowering (96.0), plant height (86.2) ,panicle length (80.0), Number of filled grains panicle^{-1} (74.9) , single plant grain yield (92.3) , single plant straw yield(79.2), 1000 grain weight (97.7), grain length (99.8), grain breadth (98.7) , L/B ratio of grain (98.9).

The characters *viz* number of productive tillers plant $^{-1}$, harvest index (52.0, 47.8) respectively recorded moderate heritability values.

4.2.5 Correlation

The genotypic and phenotypic correlation coefficient among different morphological characters studied are given in **Table 35 & 36.**

Grain yield was found to be positively and significantly correlated both at genotypic and phenotypic levels with plant height (0.429 ,0.383), total number of spikelets panicle $^{-1}$ (0.564, 0.371) ,grain breadth (0.521, 0.271) negatively significant correlation with days to 50% flowering (-0.258, -0.242). At genotypic level single plant yield was positively and significantly correlated with number of productive tillers plant^{-1} (0.476), grain length(0.425) and positively and significantly correlated with panicle length (0.377) and straw yield (0.761)

Table 34. Estimates of genetic parameters for different characters studied in pollinator parents

Sl.No	Characters (unit)	PCV (%)	GCV(%)	Heritability	Genetic advance	Genetic gain
1	Days to 50% flowering	10.96	10.74	96.00	18.39	21.66
2	Plant height(cm)	15.98	14.83	86.20	30.42	28.35
3	Number of productive tillers plant^{-1}	27.21	19.62	52.00	2.89	29.19
4	Panicle length(cm)	11.49	10.28	80.00	4.41	18.94
5	Total number of spikelets panicle $^{-1}$	21.38	16.96	62.90	39.56	27.72
6	Number of filled grains panicle^{-1}	24.79	21.45	74.90	38.85	38.22
7	1000 grain weight(g)	9.50	9.39	97.70	4.62	19.13
8	Grain length(mm)	12.00	11.99	99.80	1.80	24.75
9	Grain breadth (mm)	26.24	26.07	98.70	1.41	53.40
10	L/B ratio of grain	23.88	23.75	98.90	1.42	48.79
11	Single plant grain yield (g)	23.30	23.38	92.30	5.90	45.28
12	Single plant straw yield (g)	28.28	25.16	79.20	7.81	46.10
13	Harvest index	10.76	7.44	47.80	0.05	11.36

Among the various yield components plant height was found to be positively and significantly correlated at both levels with number of filled grains panicle^{-1}(0.406,0.359), single plant straw yield (0.260,0.253) and harvest index (0.414,0.236). Negative significant correlation with number of productive tillers plant^{-1}(-0.325,0.250). At phenotypic level plant height was positively and significantly correlated with panicle length (0.516) ,L/B ratio of grain (0.246)

Number of productive tillers plant^{-1} was found to be positively and significantly correlated at genotypic level with number of filled grains panicle^{-1} (0.476), single plant straw yield (0.469), 1000 grain weight (0.379), negatively and significantly correlatd with panicle length (-0.326). At genotypic level number of productive tillers plant^{-1} was found positively and significantly correlated with grain length (0.245)

Total number of spikelets panicle^{-1} was found to be positively and significantly correlated at both levels with number of filled grains panicle^{-1} (0.552,0.577), single plant straw yield (0.459, 0.264) grain length (0.328,0.260), grain breadth (0.362,0.264). Negatively and significantly correlated with days to 50% flowering (-0.289,-0.239) positively significantly correlation with panicle length (0.315) at phenotypic level and negative significant correlation with L/B ratio of grain (-0.282) at genotypic level.

Number of filled grains panicle^{-1} was found to be positively and significantly correlated at both levels with single plant straw yield (0.706,0.556) and negatively and significantly correlated at both levels with days to 50% flowering (-0.553,-0.491). At phenotypic level positively and significantly correlated with panicle length (0.361)

Single plant straw yield was negatively and significantly correlated at both levels with days to 50% flowering (-0.282,-0.243). At genotypic level positively and negatively significant with 1000 grain weight (0.722) and grain length (-0.438) At

Table 35. Genotypic correlation coefficient between yield and yield component characters in pollinator parents

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	-0.186	1.000											
3	-0.221	0.596**	1.000										
4	0.076	-0.325*	-0.326*	1.000									
5	-0.289*	0.232	-0.148	-0.030	1.000								
6	-0.553**	0.406**	-0.109	0.476**	0.552**	1.000							
7	-0.258*	0.429**	0.122	0.441**	0.564**	0.654**	1.000						
8	-0.282*	0.260*	0.047	0.469**	0.459**	0.706**	0.082	1.000					
9	0.084	0.176	0.346*	0.379**	-0.070	-0.132	-0.250	0.722**	1.000				
10	-0.228	-0.026	-0.012	0.102	0.328*	-0.045	0.425**	-0.438**	-0.927**	1.000			
11	0.016	-0.223	0.185	0.252	0.362**	-0.093	0.521**	0.191	0.098	-0.047	1.000		
12	-0.146	0.260	-0.417**	0.138	-0.282*	0.116	0.084	-0.228	0.016	-0.146	0.844**	1.000	
13	0.231	0.414**	0.076	-0.043	0.162	-0.144	0.176	-0.026	-0.223	0.260*	0.186	-0.062	1.000

1.Days to50% flowering
2.Plant height (cm)
3.Panicle length(cm)
4. Number of productive tillers plant^{-1}
5.Total number of spikelets panicle^{-1}
6.Number of Filled grains panicle^{-1}
7.Single plant grain yield (g)
8. Single plant straw yield (g)
9.1000 grain weight (g)
10.Grain length (mm)
11.Grain breadth (mm)
12.L/B ratio grain
13.Harvest index

e 36. Phenotypic correlation coefficient between yield and yield component characters in pollinator parents

	1	2	3	4	5	6	7	8	9	10	11	12	13
	1.000												
	-0.145												
	-0.182	0.516**											
	0.036	-0.250*	-0.070										
	-0.239*	0.188	0.315*	-0.218									
	-0.491**	0.359**	0.361**	-0.141	0.577**								
	-0.242*	0.383**	0.377**	-0.072	0.371**	0.533**							
	-0.243*	0.253*	0.301*	0.058	0.264*	0.556**	0.761**						
	0.081	0.156	0.090	0.048	-0.054	-0.128	0.165	-0.065					
	-0.223	-0.023	0.220	0.245*	0.260*	-0.042	0.233	0.103	0.081				
	0.019	-0.213	0.111	-0.010	0.264*	-0.099	0.271*	0.150	-0.249*	0.718**			
	-0.145	0.246*	-0.030	0.122	-0.207	0.114	-0.210	-0.116	0.420**	-0.435**	-0.927**		
	0.156	0.236*	0.121	-0.238	0.132	-0.090	0.144	-0.481**	0.355*	0.120	0.072	-0.045	1.000

Days to 50% flowering — **6.Number of filled grains panicle^{-1}** — **11.Grain breadth (mm)**
Plant height (cm) — **7.Single plant grain yield (g)** — **12.L/B ratio grain**
Panicle length(cm) — **8. Single plant straw yield (g)** — **13.Harvest index**
Number of productive tillers plant^{-1} — **9.1000 grain weight (g)**
Total number of spikelets panicle^{-1} — **10.Grain length (mm)**

phenotypic level positively and negatively significant with panicle length (0.301) and harvest index (-0.481)

1000 grain weight was positively and negatively significantly correlated at genotypic level with panicle length (0.346), grain length (-0.927). At phenotypic level positively and significantly correlated with L/B ratio of grain (0.420), harvest index (0.355) and negatively significantly correlated with grain breadth (-0.249)

Grain length positively and significantly correlated at genotypic level with harvest index (0.260) and positively and negatively significantly correlated at phenotypic level with grain breadth (0.718) and L/B ratio of grain (0.435)

Grain breadth significantly correlated at both levels with l/b ratio of grain (0.849,-0.927) positively and negatively. At genotypic level L/B ratio of grain was found negatively and significantly correlated with panicle length (-0.417)

4.2.6 Path analysis

Path analysis was carried out using significant genotypic correlation of eight pollinator parent characters *viz.*, days to 50% flowering, plant height, number of productive tillers plant^{-1}, panicle length, total number of spikelets panicle $^{-1}$, number of filled grains panicle^{-1}, single plant straw yield and harvest index. Abstract of the results are given in **Table 37.**

The residual effect was -0.219. The highest positive direct effect was exhibited by single plant straw yield (3.374) on yield . This was followed by harvest index (3.022). The highest negative direct effect was exhibited by number of filled grains panicle^{-1} (-1.487) followed by plant height (-1.420) , days to 50% flowering (-0.729), total number of spikelets panicle^{-1} (-0.596)

Table 37. Direct and indirect effects of yield components on grain yield of pollinator parents

Characters	Days to 50% flowering	Plant height(cm)	Number of productive tillers plant^{-1}	Panicle length (cm)	Total number of spikelets panicle $^{-1}$	Filled grains panicle $^{-1}$	Single plant straw yield(g)	Harvest index
Days to 50% flowering	**-0.729**	0.264	-0.020	-0.088	0.173	0.823	-0.953	0.699
Plant height (cm)	0.135	**-1.420**	0.085	0.238	-0.138	-0.603	0.878	1.252
Number of productive tillers plant^{-1}	-0.056	0.462	**-0.260**	-0.012	0.195	0.221	0.411	-1.260
Panicle length (cm)	0.161	-0.847	0.008	**0.399**	-0.284	-0.656	1.280	0.635
Total number of spikelets panicle $^{-1}$	0.211	-0.329	0.085	0.190	**-0.596**	-0.821	1.548	0.489
Number of filled grains panicle $^{-1}$	0.403	-0.576	0.039	0.176	-0.329	**-1.487**	2.382	-0.436
Single plant straw yield (g)	0.206	-0.369	-0.032	0.151	-0.274	-1.050	**3.374**	-1.152
Harvest index	-0.169	-0.588	0.109	0.084	-0.097	0.215	-1.286	**3.022**

Bold figures indicate direct effects :Residual effect -0.2192

The highest positive indirect effect was observed for number of filled grains panicle^{-1} (2.382) *via* single plant straw yield followed by total number of spikelets panicle $^{-1}$ (1.548), panicle length (1.280) through single plant straw yield.

The highest negative indirect effect was observed for single plant straw yield (-1.152) via harvest index followed by harvest index (-1.286) *via* single plant straw yield , number of productive tillers plant^{-1} (-1.260) *via* harvest index.

4.3 Evaluation of two line hybrids

Evaluation of two line rice hybrids was carried out in two locations COH Vellanikkara and RARS Pattambi.

4.3.1 COH Vellanikkara

4.3.1.1 Genetic variability

Present investigation was carried out with 25 F_1 hybrids and their parents . The extent of genetic variability among these varieties were estimated for different quantitative and qualitative characters. Results for analysis of variance revealed highly significant differences for all the characters except grain breadth and harvest index. Mean , SEM and range of hybrids and parents are presented in **Table 38.**

Plant characters namely days to 50% flowering varied from 82.50 to 94 days with an average of 87.52 days. Plant height ranged from 79 cm to 119 cm average being 92.68cm .In case total number of productive tillers plant^{-1} the range of variation was 10.50 to 20 .50 with an average of 15.86.

Among the earhead characters length of panicle varied from 20.10 cm to 25.20 cm and had an average of 23.15 cm .Total number of spikelets panicle^{-1} and number of filled grains panicle^{-1} ranged from 93.50 to 201.50 and 74.00 to 191.50 with averages of 143.11 and 124.66.

Table 38. Mean, SEM and range of characters studied in two line hybrids in COH Vellanikkara

Sl.No	Characters (unit)	Mean ± SEM	Range
1	Days to 50% flowering	87.52 ± 1.24	82.50 – 94.00
2	Plant height(cm)	92.68± 1.82	79.00 - 119.00
3	Number of productive tillers plant^{-1}	15.86± 0.74	10.50- 20.50
4	Panicle length(cm)	23.15 ± 0.36	20.10- 25.20
5	Total number of spikelets panicle $^{-1}$	143.11± 11.97	93.50-201.50
6	Number of filled grains panicle^{-1}	124.66± 5.54	74.00-191.50
7	1000 grain weight(g)	25.04 ± 0.52	21.04 -30.55
8	Grain length(mm)	7.65 ± 0.07	5.53 -10.05
9	Grain breadth (mm)	1.47± 0.04	1.01 -2.01
10	L/B ratio of grain	5.50± 0.19	3.18-14.45
11	Single plant grain yield (g)	29.21± 1.10	16.08-38.96
12	Single plant straw yield (g)	34.51± 1.23	21.08-42.67
13	Harvest index	0.45 ± 0.01	0.40 -0.50

With respect to grain characters 1000 grain weight varied from 21.04 g to 30.55 g with a mean of 25.04 g. Grain length and breadth ranged from 5.53 mm to 8.40 mm and 1.01 mm to 2.01 mm average being 7.65 mm and 1.47 mm respectively. In the case of l/b ratio of grains ranged from 3.18 to 6.64 with an average of 4.82.

Economic characters namely single plant grain yield varied from 16.08 to 38.96 g average being 29.21 g .Single plant straw yield and harvest index exhibited a range of 21.08 to 42.67 and 0.40 to 0.50 with an average of 34.51 and 0.45 respectively.

4.3.1.2 Mean performance

The observations on various characters studied in the two line hybrids were subjected to Duncan's Multiple Range Test (DMRT) and the abstracts are given in **Table 39 to 42.**

Among the plant characters days to 50% flowering TGMS 91S x Kairali flowered earlier compared to TGMS 82S x Prathyasa. Plant height was lowest for TGMS 74S x Kairali where as TGMS 91S x Samyuktha recorded the highest. TGMS 82S x Prathyasa had the maximum total number of productive tillers plant^{-1} and TGMS 74S x Kanchana showed the minimum number .

Among the earhead characters TGMS 91S x Makom had the longest panicles where as TGMS 82S x Kanchana showed the shortest panicles.TGMS 91S x Samyuktha recorded the large number of total spikelets panicle $^{-1}$ and number filled grains panicle^{-1}.

Grain characters such as 1000 grain weight recorded a high values for TGMS 81S x Prathyasa and TGMS 91S x Makom and lowest values for TGMS 81S x Kairali. TGMS 91S x Kanchana had the longest grain but TGMS 81S x Kanchana showed the shortest grain. Grains had more breadth in the case of TGMS 91S x

Table 39. Mean performance of two line hybrids for plant characters in COH Vellanikkara

Sl.No	Varieties	Days to 50% flowering	Plant height(cm)	Number of productive tillersplant^{-1}
1	TGMS 74S x Aiswarya	87.50^{bcdef}	89.50^{cde}	14.50^{defgh}
2	TGMS 74S x Kanchana	88.00^{cdefg}	83.50^{abc}	10.50^{h}
3	TGMS 74S x Kairali	91.00^{fghi}	79.00^{a}	14.00^{efgh}
4	TGMS 74S x Makom	87.00^{abcdef}	112.50^{gh}	14.00^{efgh}
5	TGMS 74S x Samyuktha	89.50^{efgh}	111.50^{g}	12.00^{fgh}
6	TGMS 81S x Aiswarya	86.50^{abcdef}	88.50^{cde}	19.00^{abc}
7	TGMS 81Sx Kanchana	84.50^{abcd}	90.00^{cde}	16.00^{bcdef}
8	TGMS 81S x Kairali	85.50^{abcse}	92.20^{ef}	14.00^{efgh}
9	TGMS 81S x Makom	86.00^{abcde}	86.50^{bcde}	18.50^{abcd}
10	TGMS 81S x Samyuktha	84.50^{abcd}	118.00^{hi}	16.00^{bcdef}
11	TGMS 82S x Aiswarya	95.00^{i}	92.50^{ef}	19.50^{ab}
12	TGMS 82S x Kanchana	91.00^{fghi}	92.00^{ef}	15.00^{cdefg}
13	TGMS 82S x Kairali	91.00^{fghi}	82.00^{ab}	11.50^{gh}
14	TGMS 82S x Makom	83.50^{abc}	85.00^{abcd}	18.50^{abcd}
15	TGMS 82S x Samyuktha	92.50^{ghi}	89.50^{cde}	15.50^{bcdefg}
16	TGMS 91S x Aiswarya	85.50^{abcde}	91.50^{def}	14.00^{efgh}
17	TGMS 91S x Kanchana	85.50^{abcde}	83.50^{abc}	17.00^{abcde}
18	TGMS91S x Kairali	82.50^{a}	91.00^{de}	14.00^{efgh}
19	TGMS91S x Makom	84.50^{abcde}	97.50^{f}	18.00^{abcde}
20	TGMS91S x Samyuktha	86.50^{abcdef}	119.00^{i}	16.50^{abcde}
21	TGMS 81S x Matta Triveni	83.00^{ab}	86.00^{bcde}	19.00^{abc}
22	TGMS 81S x Prathyasa	93.00^{eggh}	88.00^{bcde}	16.50^{abcde}
23	TGMS 82S x Prathyasa	94.00^{hi}	90.50^{de}	20.50^{a}
24	TGMS 91S x Matta Triveni	84.00^{abcd}	89.00^{cde}	16.00^{bcdef}
25	TGMS 91S x Varsha	88.50^{defg}	89.00^{cde}	16.50^{abcde}

Table 40. Mean performance of two line hybrids for ear head characters in COH Vellanikkara

Sl.No	Varieties	Panicle length (cm)	Total number of Spikelets panicle $^{-1}$	Number of filled grains panicle $^{-1}$
1	TGMS 74S x Aiswarya	21.60^{ij}	121.50^{fghi}	99.50^{fgh}
2	TGMS 74S x Kanchana	23.15^{fgh}	182.00^{abcd}	170.00^{bc}
3	TGMS 74S x Kairali	23.04^{fgh}	192.00^{abc}	161.50^{bcd}
4	TGMS 74S x Makom	23.25^{efgh}	171.50^{abcde}	150.50^{d}
5	TGMS 74S x Samyuktha	25.20^{ab}	137.00^{efghi}	121.00^{e}
6	TGMS 81S x Aiswarya	23.85^{bcdef}	149.00^{cdefg}	120.00^{e}
7	TGMS 81Sx Kanchana	24.65^{abcd}	165.00^{abcde}	130.00^{e}
8	TGMS 81S x Kairali	23.25^{efgh}	97.00^{hi}	82.00^{hij}
9	TGMS 81S x Makom	21.50^{ij}	103.00^{hi}	86.00
10	TGMS 81S x Samyuktha	23.45^{defg}	171.50^{abcde}	156.50^{cd}
11	TGMS 82S x Aiswarya	22.25^{ghi}	112.50^{fghi}	97.00^{fghi}
12	TGMS 82S x Kanchana	20.10^{k}	94.00^{i}	74.00^{j}
13	TGMS 82S x Kairali	20.15^{k}	99.00^{hi}	74.50^{j}
14	TGMS 82S x Makom	22.10^{hi}	110.50^{ghi}	90.00^{ghij}
15	TGMS 82S x Samyuktha	24.75^{abc}	172.50^{abcde}	151.00^{d}
16	TGMS 91S x Aiswarya	24.90^{abc}	140.00^{defgh}	101.50^{fg}
17	TGMS 91S x Kanchana	24.15^{abcdef}	197.50^{ab}	176.50^{ab}
18	TGMS91S x Kairali	21.80^{ij}	170.50^{abcde}	157.50^{cd}
19	TGMS91S x Makom	25.05^{a}	173.00^{abcde}	129.50^{e}
20	TGMS91S x Samyuktha	23.40^{defg}	201.50^{a}	191.50^{a}
21	TGMS 81S x Matta Triveni	23.35^{efgh}	155.50^{bcdef}	113.50^{ef}
22	TGMS 81S x Prathyasa	25.10^{ab}	122.00^{fghi}	121.50^{e}
23	TGMS 82S x Prathyasa	20.70^{jk}	114.25^{fghi}	123.00^{e}
24	TGMS 91S x Matta Triveni	23.65^{cdef}	93.50^{i}	81.00^{ij}
25	TGMS 91S x Varsha	24.50^{abcde}	132.00^{efghi}	157.50^{cd}

Table 41. Mean performance of two line hybrids for grain characters in COH Vellanikkara

Sl.No	Varieties	1000 grain weight(g)	Grain length(mm)	Grain breadth(mm)	L/B ratio o grain
1	TGMS 74S x Aiswarya	25.88^{def}	7.86^{e}	1.37^{ef}	5.84^{d}
2	TGMS 74S x Kanchana	25.26^{defg}	7.31^{fg}	1.28^{f}	5.69^{de}
3	TGMS 74S x Kairali	21.04^{j}	7.07^{ghi}	1.27^{f}	5.54^{def}
4	TGMS 74S x Makom	24.53^{efgh}	8.68^{b}	1.55^{d}	5.61^{de}
5	TGMS 74S x Samyuktha	25.22^{defg}	8.45^{bcd}	1.57^{d}	5.39^{defg}
6	TGMS 81S x Aiswarya	26.49^{cde}	7.18^{gh}	1.27^{f}	5.64^{de}
7	TGMS 81Sx Kanchana	21.34^{ij}	5.53^{k}	1.74^{b}	3.18^{n}
8	TGMS 81S x Kairali	20.40^{j}	7.28^{fgh}	1.48^{de}	4.92^{fghij}
9	TGMS 81S x Makom	23.73^{gh}	8.23^{d}	1.48^{de}	5.58^{de}
10	TGMS 81S x Samyuktha	24.83^{efgh}	8.38^{cd}	1.56^{d}	5.39^{defg}
11	TGMS 82S x Aiswarya	23.08^{hi}	7.35^{fg}	1.73^{b}	4.24^{kl}
12	TGMS 82S x Kanchana	24.85^{efgh}	7.48^{f}	1.01^{g}	7.43^{b}
13	TGMS 82S x Kairali	24.34^{fgh}	7.11^{ghi}	1.51^{d}	4.72^{hijk}
14	TGMS 82S x Makom	21.58^{ij}	6.89^{i}	1.49^{de}	4.62^{ijk}
15	TGMS 82S x Samyuktha	26.36^{cdef}	8.26^{d}	1.25^{f}	6.64^{c}
16	TGMS 91S x Aiswarya	25.89^{def}	7.19^{gh}	1.71^{bc}	4.20^{kl}
17	TGMS 91S x Kanchana	28.19^{bc}	8.40^{cd}	1.59^{cd}	5.30^{defgh}
18	TGMS91S x Kairali	21.55^{ij}	6.02^{j}	1.08^{g}	5.57^{de}
19	TGMS91S x Makom	30.55^{a}	7.29^{fgh}	1.52^{d}	4.82^{ghijk}
20	TGMS91S x Samyuktha	25.11^{defgh}	8.55^{bc}	2.01^{a}	4.26^{kl}
21	TGMS 81S x Matta Triveni	25.58^{defg}	8.43^{bcd}	1.57^{d}	5.39^{defg}
22	TGMS 81S x Prathyasa	31.39^{a}	7.14^{ghi}	1.92^{a}	3.72^{lm}
23	TGMS 82S x Prathyasa	23.08^{hi}	10.05^{a}	0.69^{h}	14.45^{a}
24	TGMS 91S x Matta Triveni	27.05^{bcd}	8.28^{cd}	1.61^{bcd}	5.16^{efghi}
25	TGMS 91S x Varsha	28.72^{b}	7.01^{hi}	1.62^{bcd}	4.33^{jk}

Table 42. Mean performance of two line hybrids for economic characters in COH Vellanikkara

Sl.No	Varieties	Single plant grain yield(g)	Single plant straw yield (g)	Harvest index
1	TGMS 74S x Aiswarya	30.90^{defg}	36.43^{cdef}	0.45^{bcd}
2	TGMS 74S x Kanchana	31.17^{defg}	36.18^{cdef}	0.46^{abcd}
3	TGMS 74S x Kairali	35.10^{abcd}	40.11^{abc}	0.47^{ab}
4	TGMS 74S x Makom	29.74^{efg}	34.76^{defg}	0.46^{abcd}
5	TGMS 74S x Samyuktha	16.85^{k}	24.90^{ij}	0.40^{e}
6	TGMS 81S x Aiswarya	33.56^{bcde}	38.54^{abcde}	0.47^{abc}
7	TGMS 81Sx Kanchana	32.46^{cdef}	39.40^{abcd}	0.45^{bcd}
8	TGMS 81S x Kairali	16.08^{k}	21.08^{j}	0.43^{cde}
9	TGMS 81S x Makom	32.57^{cdef}	37.63^{bcde}	0.46^{abcd}
10	TGMS 81S x Samyuktha	30.70^{defg}	35.18^{defg}	0.47^{ab}
11	TGMS 82S x Aiswarya	29.81^{efg}	30.76^{gh}	0.50^{a}
12	TGMS 82S x Kanchana	23.15^{ij}	28.18^{hi}	0.45^{bcd}
13	TGMS 82S x Kairali	19.76^{hi}	25.18^{ij}	0.44^{bcd}
14	TGMS 82S x Makom	24.65^{jk}	30.67^{gh}	0.44^{bcd}
15	TGMS 82S x Samyuktha	32.63^{cdef}	38.17^{abcde}	0.46^{abcd}
16	TGMS 91S x Aiswarya	31.67^{cdef}	37.65^{bcde}	0.46^{abcd}
17	TGMS 91S x Kanchana	34.15^{bcde}	40.67^{abc}	0.45^{bcd}
18	TGMS91S x Kairali	19.92^{jk}	25.15^{ij}	0.44^{bcd}
19	TGMS91S x Makom	35.96^{abc}	41.65^{ab}	0.46^{abcd}
20	TGMS91S x Samyuktha	37.64^{ab}	42.65^{a}	0.47^{ab}
21	TGMS 81S xMatta Triveni	38.96^{a}	42.67^{a}	0.48^{ab}
22	TGMS 81S x Prathyasa	28.53^{fgh}	33.86^{efg}	0.45^{bcd}
23	TGMS 82S x Prathyasa	27.24^{ghi}	32.68^{fgh}	0.48^{ab}
24	TGMS 91S xMatta Triveni	24.65^{hi}	30.65^{gh}	0.44^{bcd}
25	TGMS 91S x Varsha	32.64^{cdef}	38.02^{abcde}	0.43^{de}

Samyuktha less breadth was 0.69. L/B ratio of grain was maximum for TGMS 82S x Samyuktha and TGMS 81S x Kanchana had the minimum value .

Economic characters *viz* single plant grain yield was maximum for TGMS 81S x Matta Triveni and TGMS 81S x Kairali recorded the minimum grain yield. Single plant straw yield was the highest for TGMS 81S x Matta Triveni while TGMS 81S x Kairali exhibited the lowest value. Harvest index was maximum for TGMS 82S x Aiswarya but TGMS 74S x Samyuktha was minimum .

4.3.1.3 Phenotypic and genotypic coefficient of variation:

The estimates of PCV, GCV , heritability, gentic advance and genetic gain of two line hybrids are given in **Table 43.** Among the different characters studied for two line hybrids high magnitude of PCV and GCV were observed for L/B ratio of grain (37.70, 37.37). Total number of spikelets panicle $^{-1}$ (25.90 ,23.04) . Number of filled grains panicle $^{-1}$ (28.12, 27.41) and single plant grain yield (21.68, 21.21). The characters grain breadth (19.39 ,18.91), single plant straw yield (17.91, 17.18) , Number of productive tillers plant $^{-1}$ (16.88, 15.48) recorded moderate values for PCV and GCV. Low variability was observed with respect to the characters panicle length, harvest index and days to 50% flowering.

4.3.1.4 Heritability

Among the quantitative characters heritability in broad sense ranged from 45.70 per cent (Harvest index) to 98.40 per cent (Grain length) except harvest index all characters showed high heritability.

The characters total number of filled grains panicle (68.61), total number of spikelets panicle^{-1}(60.40) plant height (21.39) showed high genetic advance. Single plant grain yield and single plant straw yield showed moderate genetic advance and remaining all characters showed less genetic advance.

Table 43. Estimates of genetic parameters for different characters studied in two line hybrids at COH Vellanikkara

Sl.No	Characters (unit)	PCV (%)	GCV(%)	Heritability	Genetic advance	Genetic gain
1	Days to 50% flowering	4.18	3.66	76.8	5.78	6.60
2	Plant height(cm)	11.86	11.53	94.5	21.39	23.07
3	Number of productive tillers plant^{-1}	16.88	15.48	84.1	4.64	29.25
4	Panicle length(cm)	6.81	6.43	89.3	2.90	12.52
5	Total number of spikelets panicle $^{-1}$	25.90	23.04	79.1	60.40	42.20
6	Number of filled grains panicle^{-1}	28.12	27.41	95.0	68.61	55.03
7	1000 grain weight(g)	11.41	11.02	93.2	5.49	21.92
8	Grain length(mm)	12.27	12.17	98.4	1.90	24.83
9	Grain breadth (mm)	19.39	18.91	95.1	0.56	38.09
10	L/B ratio of grain	37.70	37.37	98.3	4.20	76.36
11	Single plant grain yield (g)	21.68	21.21	93.9	12.25	41.93
12	Single plant straw yield (g)	17.91	17.18	92.0	11.72	33.96
13	Harvest index	4.90	3.31	45.7	0.02	4.44

4.3.1.5 Correlation

The genotypic and phenotypic correlation coefficient between grain yield and component characters studied are presented in **Table 44 and 45.**

The genotypic correlation with yield were found to be higher than phenotypic correlation for all the characters.

Single plant grain yield was found to be positively and significantly correlated both at genotypic and phenotypic levels with number of productive tillers plant^{-1} (0.464,0.406), panicle length (0.338,0.308), total number of spikelets panicle $^{-1}$ (0.640,0.532), number of filled spikelets panicle^{-1} (0.494, 0.474).

At phenotypic level yield was positively and significantly correlated with single plant straw yield (0.974) , 1000 grain weight (0.339) and harvest index (0.561).

Number of productive tillers plant^{-1} was found to be positively and significantly correlated at both levels with single plant straw yield (0.391, 0.361), harvest index (0.788,0.363). At genotypic level grain length (0.266), L/B ratio of grain (0.283) showed a positive and significant correlation.

Panicle length had a positive and significant correlation at genotypic and phenotypic levels with total number of spikelets panicle $^{-1}$ (0.475, 0.445), number of filled grains panicle $^{-1}$ (0.416,0.406) , single plant straw yield (0.417, 0.381) , 1000 grain weight (0.505,0.462) grain breadth (0.573, 0.524) . L/B ratio of grain (-0.479,-0.452) showed a negative significant correlation with panicle length. At genotypic level days to 50% flowering showed a negative significant (-0.286) with panicle length .

Total number of spikelets per panicle^{-1} showed a positive and significant correlation at both levels with number of filled grains panicle $^{-1}$(0.940, 0.881), single plant straw yield (0.676,0.571) and plant height (0.298, 0.255) .Harvest index (0.445)

Table 44. Genotypic correlation coefficient between yield and yield component characters in two line hybrids (COH Vellanikkara)

1	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	-0.144	1.000											
3	-0.286*	0.229	1.000										
4	-0.027	-0.094	-0.041	1.000									
5	-0.263*	0.298*	0.475**	-0.156	1.000								
6	-0.084	0.329**	0.416**	-0.109	0.940**	1.000							
7	-0.102	-0.021	0.338*	0.464**	0.640**	0.494**	1.000						
8	-0.182	-0.018	0.417**	0.391**	0.676**	0.527**	0.988**	1.000					
9	0.058	0.062	0.505**	0.145	0.113	0.154	0.372**	0.412**	1.000				
10	0.272	0.369**	-0.118	0.266*	-0.001	0.095	0.134	0.129	0.188	1.000			
11	-0.278*	0.319*	0.573**	-0.031	0.140	0.094	0.259*	0.262*	0.325*	-0.201	1.000		
12	0.443**	-0.057	-0.479**	0.283*	-0.161	-0.026	-0.112	-0.113	-0.155	0.632**	-0.807**	1.000	
13	0.311*	-0.039	-0.209	0.788**	0.445**	0.195	0.827**	0.736**	-0.058	0.299*	-0.043	0.253*	1.000

1.Days to 50 % flowering
2.Plant height (cm)
3.Panicle length(cm)
4. Number of productive tillers plant^{-1}
5.Total number of spikelets panicle^{-1}
6.Number of filled grains panicle^{-1}
7.Single plant grain yield (g)
8. Single plant straw yield (g)
9.1000 grain weight (g)
10.Grain length (mm)
11.Grain breadth (mm)
12.L/B ratio of grain
13.Harvest index

Table 45.Phenotypic correlation coefficient between yield and yield component characters in two line rice hybrids in (COH Vellanikkara)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	-0.081	1.000											
3	-0.212	0.222	1.000										
4	0.022	-0.040	-0.018	1.000									
5	-0.170	0.255*	0.445**	-0.101	1.000								
6	-0.060	0.303*	0.406**	-0.096	0.881**	1.000							
7	0.073	-0.019	0.308*	0.406**	0.532**	0.474**	1.000						
8	-0.120	-0.007	0.381**	0.361**	0.571**	0.504**	0.974**	1.000					
9	0.003	0.040	0.462**	0.097	0.099	0.161	0.339*	0.374**	1.000				
10	0.248	0.359**	-0.124	0.247	-0.013	0.086	0.128	0.126	0.178	1.000			
11	-0.264*	0.286*	0.524**	-0.008	0.134	0.095	0.241	0.242	0.299*	-0.187	1.000		
12	0.399**	-0.047	-0.452**	0.246	-0.155	-0.032	-0.106	-0.107	-0.148	0.623**	-0.807**	1.000	
13	0.137	-0.058	-0.164	0.363**	0.138	0.122	0.561**	0.413**	-0.002	0.194	-0.024	0.166	1.000

1.Days to 50% flowering
2.Plant height (cm)
3.Panicle length(cm)
4. Number of productive tillers plant^{-1}
5.Total number of spikelets panicle^{-1}
6.Number of filled grains panicle^{-1}
7.Single plant grain yield (g)
8. Single plant straw yield (g)
9.1000 grain weight (g)
10.Grain length (mm)
11.Grain breadth (mm)
12.L/B ratio of grain
13.Harvest index

and days to 50% flowering (-0.263) showed a positive and negative significant correlation at genotypic level.

Number of filled grains per panicle $^{-1}$ was found to be positively and significantly correlated at both levels with single plant straw yield (0.527, 0.504) plant height (0.329, 0.303).

1000 grain weight showed a positive and significant correlation with grain breadth (0.325, 0.299) and single plant straw yield (0.412, 0.374). Grain length was found to be positively and significantly associated at both levels with l/b ratio of grain (0.632, 0.623), plant height (0.369, 0.359). Harvest index (0.299) showed a significant positive correlation with grain length. Grain breadth recorded a positive and significant correlated with plant height (0.319, 0.286) and negative and significant correlated with days to 50% flowering (-0.278, -.264) l/b ratio of grain

(-0.807, -0.807)

Single plant straw yield (0.262) showed a positive and significant associated with grain breadth at genotypic level. l/b ratio of grain showed a positive and significant correlation at both levels with days to 50% flowering (0.443,0.399) . At genotypic level harvest index (0.253) showed a positive and significant correrlation.

Harvest index showed a positive and significant correlation at both levels with single plant straw yield (0.736, 0.413) .

4.4.1.6 Path analysis

Path analysis was carried out using significance genotypic correlation of eight pollinator parent characters *viz* days to 50% flowering, plant height, number of productive tillers plant $^{-1}$, panicle length, total number of spikelets panicle $^{-1}$, number of filled grains panicle^{-1}, single plant straw yield and harvest index. Abstract of the results are give in **Table 46.**

Table 46. Direct and indirect effects of yield components on grain yield of two line hybrids (COH Vellanikkara)

Characters	Days to 50% flowering	Plant height(cm)	Number of productive tillers plant^{-1}	Panicle length (cm)	Total number of spikelets panicle $^{-1}$	Filled grains panicle $^{-1}$	Single plant straw yield(g)	Harvest index
Days to 50% flowering	**0.129**	-0.010	-0.003	0.013	0.048	-0.012	-0.189	0.011
Plant height (cm)	-0.019	**0.067**	-0.011	-0.011	-0.054	0.047	-0.018	-0.001
Number of productive tillers plant^{-1}	-0.004	-0.006	**0.114**	0.002	0.028	-0.016	0.407	0.027
Panicle length (cm)	-0.037	0.015	-0.005	**-0.047**	-0.086	0.059	0.434	-0.007
Total number of spikelets panicle $^{-1}$	-0.034	0.020	-0.018	-0.022	**-0.181**	0.134	0.703	0.015
Number of filled grains panicle $^{-1}$	-0.011	0.022	-0.013	-0.020	-0.170	**0.142**	0.549	0.007
Single plant straw yield (g)	-0.023	-0.001	0.045	-0.020	-0.123	0.075	**1.041**	0.025
Harvest index	0.040	-0.003	0.090	0.010	-0.081	0.028	0.766	**0.034**

Bold figures indicate direct effects :Residual effect -0.0056

The residual effect was found to be -0.0056. The highest positive direct effect was exhibited by number of filled grains panicle $^{-1}$(0.142) followed by days to 50% flowering (0.129), number of productive tillers plant^{-1} (0.114) ,single plant straw yield (1.041) and harvest index (0.034)

The highest negative direct effect was exhibited by total number of spikelets panicle $^{-1}$ (-0.181) followed by panicle length (-0.047)

The highest positive indirect effect was observed for harvest index (0.766) , total number of spikelets panicle $^{-1}$(0.703) through single plant straw yield.

The highest negative indirect effect was observed for days to 50% flowering (-0.189) through single plant straw yield , number of filled grains panicle $^{-1}$ (-0.170) through total number of spikelets panicle^{-1}

4.4.1. 7 Line x tester analysis

Due to non uniform stand in the replicated trial out of 25 combinations only 20 combination along with their parents were subjected to line x tester analysis. ANOVA for combining ability were showed in **Table 47.**

General combining ability effects

The estimates of gca effect of lines and mean performance for different characters are given in **Table 48.**

a) Days to 50% flowering

Positive significant gca effects were observed for the parents Kanchana (2.05), Aiswarya (0.43), Makom (0.30) where as the effects were negative and significant for Samyuktha (-2.70) and Kairali (-0.07).

Table 47. Analysis of variance for combining ability for different quantitative traits in COH vellanikkara

Source of variance	df	Day to 50% flowering	Plant height (cm)	Total productive tillers	Panicle length(cm)	Number of spikelets/ panicle	Number of filled spikelets/ panicle	1000 grain weight (g)	Grain length (mm)	Grain breadth (mm)	L/B ratio of grain	Single plant grain yield (g)	Single plant straw yield (g)	Harvest index
Crosses	19	48.468	543.741	27.656	8.004	3521.020	3013.572	18.147	1.385	0.467	7.372	195.112	215.901	0.001
Lines	3	133.702	49.527	48.691	32.111	8017.191	4659.158	26.373	0.754	1.332	21.819	378.730	470.121	0.001
Testers	4	23.539	1895.102	16.712	6.450	4652.719	5029.250	15.710	2.112	0.382	4.823	278.636	302.525	0.001
L x T	12	35.470	216.842	26.045	2.495	2019.744	1930.283	16.902	1.301	0.280	4.609	121.366	123.471	0.001
Error	28	0.321	0.230	0.182	1.015	46.979	44.602	0.079	0.059	0.004	0.061	0.567	0.423	0.0001

Table 48. General combining ability effects (in bold) and mean performance of pollinator parents from 4 x 5 lines x tester

(Location: COH Vellanikkara)

Parents	Days to 50% flowering	Plant height (cm)	Total number of productive tillers plant^{-1}	Panicle length	Total number of spikelets panicle^{-1}	Number of filled spikelets panicle^{-1}	1000 grain weight	Grain length	Grain breadth	L/B ratio of grain	Single plant grain yield (g)	Single plant straw yield (g)	Harvest index
Aiswarya	**0.43**** 84.00	**26.42**** 114.00	**0.35**** 11.00	**1.56**** 21.35	**39.18**** 130.00	**44.00**** 89.00	**1.31**** 19.85	**0.48**** 6.18	**0.09**** 1.78	**-0.27**** 3.47	**7.87**** 11.67	**8.24**** 18.05	**0.01** 0.39
Kanchana	**2.05**** 83.00	**-5.67**** 102.00	**-0.40**** 13.00	**-0.31** 22.65	**-12.57**** 131.00	**-10.00**** 100.00	**-0.09*** 29.00	**-0.30**** 7.34	**0.12**** 1.59	**-0.95**** 4.61	**-2.02**** 11.98	**-1.82**** 16.09	**-0.01** 0.42
Kairali	**-.0.07**** 82.00	**-13.71**** 102.50	**1.48**** 8.00	**-0.24** 21.45	**-13.32**** 155.00	**-13.25**** 130.00	**1.22**** 21.30	**0.40**** 6.14	**-0.24**** 1.75	**1.07**** 3.50	**-1.47**** 11.86	**-1.42**** 15.26	**0.00** 0.44
Makom	**0.30**** 78.00	**-5.98**** 118.50	**-2.27**** 10.00	**-0.77**** 20.35	**-20.20** 152.50	**-17.00**** 138.00	**-2.13**** 23.19	**-0.74**** 7.58	**-0.22**** 3.03	**0.44*** 2.50	**-7.74**** 18.93	**-8.22**** 23.22	**-0.02*** 0.44
Samyuktha	**-2.70**** 84.00	**-1.96**** 142.00	**0.85**** 8.00	**-0.24** 22.10	**6.93** 102.00	**-3.75*** 90.00	**-0.31**** 28.31	**0.16**** 6.68	**0.25**** 1.69	**-0.30**** 3.95	**3.36**** 13.80	**3.22**** 12.13	**0.01** 0.53
TGMS 74S	**3.25**** 92.00	**-1.35** 85.00	**1.78**** 16.00	**0.57*** 18.70	**-7.50** 98.00	**-7.78** 90.00	**-0.75** 27.20	**-0.04** 7.88	**-0.06** 1.44	**-0.31** 5.47	**2.81**** 13.04	**3.45**** 17.06	**0.01** 0.43
TGMS 81S	**-1.35** 88.00	**2.97**** 83.50	**1.88**** 13.00	**2.27**** 20.40	**41.90**** 108.00	**32.12**** 93.00	**2.24**** 22.90	**-0.06** 8.08	**-0.10** 0.96	**-0.11** 8.42	**6.87**** 11.38	**7.29**** 16.34	**0.02** 0.41
TGMS 82S	**-4.55** 97.00	**2.23**** 96.00	**2.62**** 14.00	**-1.14** 19.80	**16.30**** 102.00	**10.07**** 82.00	**-1.53** 23.43	**-0.28** 8.23	**0.51** 0.81	**-1.68** 10.16	**-2.42** 11.98	**-2.34** 15.32	**-0.02** 0.44
TGMS 91S	**2.65**** 86.00	**0.27** 100.00	**-1.02** 14.00	**-1.69** 19.10	**18.10**** 101.00	**14.28**** 85.00	**0.04** 21.83	**0.38** 8.15	**-0.35** 0.99	**1.92**** 8.23	**7.26**** 11.59	**8.40**** 14.73	**-0.01** 0.44
SE of gca (Tester)	**0.15**	**0.13**	**0.11**	**0.26**	**1.80**	**1.75**	**0.07**	**0.06**	**0.02**	**0.07**	**0.20**	**0.17**	**0.01**
SE of gca (lines)	**0.00**	**0.11**	**0.10**	**0.23**	**1.56**	**1.52**	**0.06**	**0.06**	**0.01**	**0.06**	**0.17**	**0.15**	**0.01**

** Significant at 1% level * Significant at 5% level

a) Plant height

The Parent Aiswarya recorded maximum positive and significant gca effect (26.42) where as all other parents recorded negative significant gca effects.

b) Total number of productive tillers plant^{-1}

The parents Kairali (1.48), Aiswarya (0.35) and Samyuktha (0.85) recorded positive gca effect where as the effects were negative and significant for Makom (-2.27), Kanchana (-0.40)

c) Panicle length

The parent Aiswarya only recorded a significant positive gca effect (1.56) where as Makom (-0.77) exhibited significant negative effect.

d) Total number of spikelets panicle^{-1}

The parent Aiswarya only recoded a positive significant gca effect (39.18) where as Kanchana (-12.57), Kairali (-13.32)showed a significant negative gca effects.

e) Number of filled grains panicle $^{-1}$

The parent Aiswarya only recorded a positive significant effect(44.00) where as Kanchana , Kairali, Makom, Samyuktha recored a negative significant effect.

f) 1000 grain weight

Positive significant gca effects were observed for Aiswarya (1.31), Kairali (1.22) where as Kanchana (-0.09), Makom (-2.13), Samyuktha (-0.31) exhibited significant negative effects.

g) Grain length

The positive significant gca effects were observed for Aiswarya (0.48), Kairali (0.40) and Samyuktha (0.16) where as Kanchana (-0.30) and Makom (-0.74)showed negative significant gca effects.

h) Grain breadth

Aiswarya (0.09), Kanchana (0.12) and Samyuktha (0.25) showed positive significant gca effects where as Kairali (-0.24) and makom (-0.22) showed negative significant gca effects.

i) L/B ratio of grain

Positive significant gca effects were recorded for the parents Kairali (1.07) and Makom (0.44) Negative significant gca effects were observed for Aiswarya (-0.27), Kanchana (-0.95) and Samyuktha (-0.30)

j) Single plant grain yield

Positive significant gca effects were recorded for the parents Aiswarya (7.87) and Samyuktha (3.36) where as Kanchana (-2.02), Kairali (-1.47) and Makom (-7.74) showed negative significant gca effects.

k) Single plant straw yield

The parents Aiswarya (8.24) Samyuktha (3.22) showed positive significant gca effects where as Kanchana (-1.82) , Kairali (-1.42) and Makom (-8.22) showed negative significant gca effects.

l) Harvest index

The only one parent Makom (-0.02) showed negative significant gca effects where as rest of the other parents were non significant.

Specific combining ability effects

a) Days to 50% flowering

The specific combining ability effects ranged between -6.03 (TGMS 91S x Aiswarya) and 7.47 (TGMS 81S x Aiswarya). Out of 20 hybrids, 10 hybrids were observed with significant negative sca effects and 9 with significant positive sca effects **(Table 49)**

b) Plant height

The sca effect ranged from -9.25 (TGMS 81S x Aiswarya) to 16.63 (TGMS 81S x Samyuktha). Out of twenty five hybrids eleven hybrids showed significant positive sca effects eight hybrids were observed with significant negative sca effects.

c) Total number of productive tillers plant^{-1}

The sca effects ranged between -5.35 (TGMS 91S x Aiswarya) to 8.25 (TGMS 82S x Aiswarya). Out of twenty five hybrids, ten hybrids were observed with negative sca effects. All other showed positive significant sca effects

d) Panicle length

The sca effects ranged from -1.69 (TGMS 82S x Kanchana) to 1.75 (TGMS 81S x Kanchana). Out of 20 hybrid combinations, four hybrid combinations showed negative significant sca effect and two combinations were observed with positive significant sca effects.

e) Total number of spikelets panicle^{-1}

Table 49. Specific combining abiklity effects (in bold) and mean performance of two line hybrids from 4 x5 line x tester analysis

Two line hybrids	Day to 50% flowering	Plant height (cm)	Total productive tillers	Panicle length (cm)	Number of spikelets / panicle	Number of filled spikelets / panicle	1000 grain weight(g)	Grain length (mm)	Grain breadth (mm)	L/B ratio of grain	Single plant grain yield (g)	Single plant straw yield (g)	Harvest index
Two line hybrids of TGMS 74S													
TGMS 74S x Aiswarya	**-3.62****	**-0.22**	**-2.65****	**-0.02**	**21.62****	**22.40****	**-0.41****	**0.38****	**-0.02**	**0.42****	**-1.51****	**-1.45****	**0.01**
	87.50	89.50	14.50	21.60	121.50	99.50	25.88	7.86	1.37	5.84	30.90	36.43	0.45
TGMS 74S x Kanchana	**1.75****	**-1.13****	**1.10****	**0.85**	**-1.12**	**-9.60****	**-0.30***	**0.20**	**0.13****	**-0.01**	**-1.14****	**-1.01****	**0.01**
	88.00	83.50	10.50	23.15	182.00	170.00	25.26	7.31	1.28	5.69	31.17	36.18	0.46
TGMS 74S x Kairali	**2.88****	**12.91****	**-0.28****	**-1.02****	**-38.88****	**-38.85****	**-0.37****	**-0.20**	**-0.20****	**1.07****	**-1.83****	**-2.93****	**0.01**
	91.00	79.00	14.00	23.04	192.00	161.50	21.04	7.07	1.27	5.54	35.10	40.11	0.47
TGMS 74S x Makom	**-1.50****	**3.28****	**0.47****	**-0.19**	**-4.50**	**2.40**	**3.16****	**0.22***	**0.31****	**-1.24****	**-0.52**	**0.05**	**-0.01**
	87.00	112.50	14.00	23.25	171.50	150.50	24.53	8.68	1.55	5.61	29.74	34.76	0.46
TGMS 74S x Samyuktha	**0.50***	**-14.84****	**1.35****	**0.38**	**22.88****	**23.65****	**-2.09****	**-0.60****	**-0.23****	**-0.25***	**5.00****	**5.35****	**0.01**
	89.50	111.50	12.00	25.20	171.50	121.00	25.22	8.48	1.57	5.39	16.85	24.90	0.40
Two line hybrids of TGMS 81S													
TGMS 81S x Aiswarya	**7.47****	**-9.25****	**-0.25***	**-0.92***	**-35.28****	**-36.00****	**-1.90****	**0.44****	**-0.30****	**1.81****	**-6.56****	**-7.82****	**0.00**
	86.50	88.50	19.00	23.85	149.00	120.00	26.49	7.18	1.27	5.64	33.56	38.54	0.47
TGMS 81S x Kanchana	**-1.65****	**6.50****	**-1.50****	**1.75****	**-3.03**	**5.00**	**0.98****	**0.10**	**0.11****	**0.06**	**2.95****	**2.85****	**0.01**
	84.50	90.00	16.00	24.65	165.00	130.00	21.34	5.53	1.74	3.18	32.46	39.40	0.45
TGMS 81S x Kairali	**-2.03****	**-1.62****	**0.62****	**0.98***	**38.22****	**41.75****	**-0.19**	**0.53****	**0.39****	**-1.08****	**5.27****	**6.70****	**0.01**
	85.50	92.20	14.00	23.25	97.00	82.00	20.40	7.28	1.48	4.92	16.08	21.08	0.43
TGMS 81S x Makom	**-4.90****	**-12.25****	**-0.62****	**-1.39****	**-7.90***	**-1.00**	**-3.25****	**-1.14****	**-0.13****	**-0.61****	**-8.86****	**-9.12****	**-0.03****

Table 49.(Contd...)

	86.00	86.50	18.50	21.50	103.00	86.00	23.73	8.23	1.48	5.58	32.57	37.63	0.46
	1.10**	**16.63****	**1.75****	**-0.42**	**7.97***	**-9.75****	**4.35****	**0.08**	**-0.08****	**-0.85****	**7.20****	**7.39****	**0.01**
TGMS 81S x Samyuktha	84.50	118.00	16.00	23.45	171.50	156.50	24.83	8.38	1.56	5.39	30.70	35.18	0.47
Two line hybrids of TGMS 82S													
	2.17**	**8.98****	**8.25****	**0.19**	**55.42****	**53.20****	**0.06**	**0.78****	**-0.11****	**0.79****	**15.43****	**15.03****	**0.04****
TGMS 82S x Aiswarya	95.00	92.50	19.50	22.25	112.50	97.00	23.08	7.35	1.73	4.24	29.81	30.76	0.50
	-0.45	**-0.93****	**0.01**	**-1.69****	**-5.33**	**-6.80***	**-3.25****	**-0.68****	**-0.39****	**0.78****	**-4.73****	**-4.24****	**-0.03****
TGMS 82S x Kanchana	91.00	92.00	15.00	20.10	94.00	74.00	24.85	7.48	1.01	7.43	23.15	28.18	0.45
	0.67**	**-11.89****	**-3.88****	**-0.01**	**-19.58****	**-20.55****	**3.61****	**-0.20**	**-0.22****	**-0.09**	**-4.17****	**-5.04****	**0.01**
TGMS 82S x Kairali	91.00	82.00	11.50	20.15	99.00	74.50	24.34	7.11	1.51	4.72	19.76	25.18	0.44
	-0.70**	**8.48****	**-2.12****	**1.02***	**-6.70***	**-11.80****	**-0.74****	**-0.25***	**-0.04**	**-0.63****	**1.78****	**2.00****	**-0.02***
TGMS 82S x Makom	83.50	85.00	18.50	22.10	110.50	90.00	21.58	6.89	1.49	4.62	24.65	30.67	0.01
	-1.70**	**-4.64****	**-2.25****	**0.49**	**-23.83****	**-14.05****	**0.32***	**0.34****	**0.75****	**-0.85****	**-8.31****	**-7.76****	**-0.02***
TGMS 82S x Samyuktha	92.50	89.50	15.50	24.75	172.50	151.00	26.36	8.26	1.25	6.64	32.63	38.17	-0.02
Two line hybrids of TGMS 91S													
	-6.03**	**0.48***	**-5.35****	**0.74**	**-41.78****	**-39.60****	**2.25****	**-1.60****	**0.42****	**-3.02****	**-7.36****	**-5.76****	**-0.05****
TGMS 91S x Aiswarya	85.50	91.50	14.00	24.90	140.00	101.50	25.89	7.19	1.71	4.20	31.67	37.65	0.46
	0.35	**-4.43****	**0.40***	**-0.90**	**9.47****	**11.40****	**2.56****	**0.37****	**0.14****	**-0.83****	**2.93****	**2.40****	**0.01**
TGMS 91S x Kanchana	85.50	83.50	17.00	24.15	197.50	176.50	28.19	8.40	1.59	5.30	34.15	40.67	0.45
	-1.53**	**0.61****	**3.52****	**0.04**	**20.22****	**17.65****	**-3.05****	**-0.13**	**0.02**	**0.10**	**0.73***	**1.28****	**-0.01**
TGMS 91S x Kairali	82.50	91.00	14.00	21.80	170.50	157.50	21.55	6.02	1.08	5.57	19.92	25.15	0.44
	7.10**	**0.48***	**2.27****	**0.57**	**19.10****	**10.40****	**0.83****	**1.17****	**-0.15****	**2.47****	**7.59****	**7.06****	**0.04****
TGMS 91S x Makom	85.50	97.50	18.00	25.05	173.00	129.50	30.55	7.29	1.52	4.82	35.96	41.65	0.46
	0.10	**2.86****	**-0.85****	**-0.46**	**-7.03***	**0.15**	**-2.59****	**0.18**	**-0.44****	**1.28****	**-3.89****	**-4.98****	**0.01**
TGMS 91S x Samyuktha	86.50	119.00	16.50	23.40	201.50	191.50	25.11	8.55	2.01	4.26	37.64	42.65	0.47
SE of SCA	**0.26**	**0.22**	**0.19**	**0.46**	**3.12**	**3.04**	**0.13**	**0.11**	**0.03**	**0.11**	**0.34**	**0.30**	**0.01**

Significant positive and negative sca effects were recorded in eight and eight cross combinations respectively. The range was between -41.78 (TGMS91S x Aiswarya) and 55.42 (TGMS 82S x Aiswarya)

a) Number of filled grains panicle^{-1}

The sca effects ranged from -38.85 (TGMS 74S x Kairali) to 53.20 (TGMS 82S x Aiswarya). Out of twenty five cross combinations only nine showed negative significant sca effects where seven cross combinations showed positive sca effects.

b) 1000 grain weight

The cross combination TGMS 81S x Samyuktha recorded the highest sca effect (4.35) while TGMS 81S x Makom , TGMS 82S x Kanchana recorded the lowest sca effect (-3.25) . In total eight cross combinations were found to express significant positive sca effects while ten exhibited negative sca effects.

c) Grain length

The sca effects of the cross combinations ranged from TGMS 91S x Aiswarya (-1.60) and TGMS 91S x Makom (1.17) .Out of 20 cross combinations eight cross combinations showed positive significant sca effects while five cross combinations showed negative significant sca effects.

d) Grain breadth

The sca effects of the cross combination ranged from -0.44 (TGMS 91S x Samyuktha) and 0.75 (TGMS 82S x Samyuktha).out of 20 cross combinations significant positive sca effects were found in seven cross combinations while ten cross combinations recorded significant negative sca effects

j) L/B ratio of grain

The cross combination TGMS 91S x Makom recoded the highest sca effects(2.47) while TGMS 91S x Aiswarya recorded the lowest sca effect (-3.02) . Out of 20 cross combinations seven cross combination were found to express significant positive sca effects while eight exhibited negative sca effects

k) Single plant grain yield

The sca effects of the cross combinations ranged from -8.86 (TGMS 81S x Makom) to 15.43 (TGMS 82S x Aiswarya) .Out of twenty cross combinations ten cross combinations were found to express significant negative sca effects while eight exhibited positive sca effects

l) Single plant straw yield

The sca effects of the cross combinations ranged from -9.12 (TGMS 82S x Makom) to 15.03 (TGMS 82S x Aiswarya). Out of twenty cross combinations ten showed negative sca effects while nine exhibited positive sca effects.

m) Harvest index

Out of 20 cross combinations five showed significant negative sca effects while two cross combinations exhibited positive significant sca effects

4.4.1.8 Estimation of heterosis : (COH Vellanikkara)

Mean performance of two line rice hybrids and their parents are presented in **Table 50.** The extent of heterosis for individual traits are given in **Table 51 to 56.**

Table 50. ***Per se*** **performance of parents and hybrids (COH Vellanikkara)**

Sl.No	Parents	Days to 50% flowering	Plant Height (cm)	Total number of Productive tillers^{-1}	Panicle length (cm)	Total number of Spikelets panicle^{-1}	Number of Filled Spikelets panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain breadth (mm)	L/B ratio of grain	Single plant grain yield (g)	Single plant straw yield (g)	Harvest index
	LINES													
1	TGMS 74S	92.00	85.00	16.00	18.70	98.00	90.00	27.20	7.88	1.44	5.47	13.04	17.06	0.43
2	TGMS 81S	88.00	83.50	13.00	20.40	108.00	93.00	22.90	8.08	0.96	8.42	11.38	16.34	0.41
3	TGMS 82S	97.00	96.00	14.00	19.80	102.00	82.00	23.43	8.23	0.81	10.16	11.98	15.32	0.44
4	TGMS 91S	86.00	100.00	14.00	19.10	101.00	85.00	21.83	8.15	0.99	8.23	11.59	14.73	0.44
	TESTERS													
1	Aiswarya	84.00	114.00	11.00	21.35	130.00	89.00	19.85	6.18	1.78	3.47	11.67	18.05	0.39
2	Kanchana	83.00	102.00	13.00	22.65	131.00	100.00	29.00	7.34	1.59	4.61	11.98	16.09	0.42
3	Kairali	83.00	102.50	8.00	21.45	155.00	130.00	21.30	6.14	1.75	3.50	11.86	15.26	0.44
4	Makom	78.00	118.50	10.00	20.35	152.50	138.00	23.19	7.58	3.03	2.50	18.93	23.22	0.44
5	Samyuktha	84.00	142.00	8.00	22.10	102.00	90.00	28.31	6.68	1.69	3.95	13.80	12.13	0.53
	HYBRIDS													
1	TGMS 74S x Aiswarya	87.50	89.50	14.50	21.60	121.50	99.50	25.88	7.86	1.37	5.84	30.90	36.43	0.45

Table 50. (Contd...)

2	TGMS 74S x Kanchana	88.00	83.50	10.50	23.15	182.00	170.00	25.26	7.31	1.28	5.69	31.17	36.18	0.46
3	TGMS 74S x Kairali	91.00	79.00	14.00	23.04	192.00	161.50	21.04	7.07	1.27	5.54	35.10	40.11	0.47
4	TGMS 74S x Makom	87.00	112.50	14.00	23.25	171.50	150.50	24.53	8.68	1.55	5.61	29.74	34.76	0.46
5	TGMS 74S x Samtyuktha	89.50	111.50	12.00	25.20	171.50	121.00	25.22	8.48	1.57	5.39	16.85	24.90	0.40
6	TGMS 81S x Aiswarya	86.50	88.50	19.00	23.85	149.00	120.00	26.49	7.18	1.27	5.64	33.56	38.54	0.47
7	TGMS 81S x Kanchana	84.50	90.00	16.00	24.65	165.00	130.00	21.34	5.53	1.74	3.18	32.46	39.40	0.45
8	TGMS 81S x Kairali	85.50	92.20	14.00	23.25	97.00	82.00	20.40	7.28	1.48	4.92	16.08	21.08	0.43
9	TGMS 81S x Makom	86.00	86.50	18.50	21.50	103.00	86.00	23.73	8.23	1.48	5.58	32.57	37.63	0.46
10	TGMS 81S x Samtyuktha	84.50	118.00	16.00	23.45	171.50	156.50	24.83	8.38	1.56	5.39	30.70	35.18	0.47
11	TGMS 82S x Aiswarya	95.00	92.50	19.50	22.25	112.50	97.00	23.08	7.35	1.73	4.24	29.81	30.76	0.50
12	TGMS 82S x Kanchana	91.00	92.00	15.00	20.10	94.00	74.00	24.85	7.48	1.01	7.43	23.15	28.18	0.45
13	TGMS 82S x Kairali	91.00	82.00	11.50	20.15	99.00	74.50	24.34	7.11	1.51	4.72	19.76	25.18	0.44
14	TGMS 82S x Makom	83.50	85.00	18.50	22.10	110.50	90.00	21.58	6.89	1.49	4.62	24.65	30.67	0.44
15	TGMS 82S x Samtyuktha	92.50	89.50	15.50	24.75	172.50	151.00	26.36	8.26	1.25	6.64	32.63	38.17	0.46
16	TGMS 91S x Aiswarya	85.50	91.50	14.00	24.90	140.00	101.50	25.89	7.19	1.71	4.20	31.67	37.65	0.46
17	TGMS 91S x Kanchana	85.50	83.50	17.00	24.15	197.50	176.50	28.19	8.40	1.59	5.30	34.15	40.67	0.45
18	TGMS 91S x Kairali	82.50	91.00	14.00	21.80	170.50	157.50	21.55	6.02	1.08	5.57	19.92	25.15	0.44

Table 50. (Contd…)

19	TGMS 91S x Makom	85.50	97.50	18.00	25.05	173.00	129.50	30.55	7.29	1.52	4.82	35.96	41.65	0.46
20	TGMS 91S x Samyuktha	86.50	119.00	16.50	23.40	201.50	191.50	25.11	8.55	2.01	4.26	37.64	42.65	0.47
21	TGMS 81S x Matta Triveni	83.00	86.00	19.00	23.35	155.50	113.50	25.58	8.43	1.56	5.39	38.95	42.66	0.47
22	TGMS 81S x Prathyasa	90.00	88.00	16.50	25.10	162.00	121.50	31.39	7.13	1.92	3.71	28.53	33.86	0.45
23	TGMS 82S x Prathyasa	94.00	90.50	20.50	20.70	140.00	123.00	23.07	10.05	0.69	14.45	27.23	32.68	0.47
24	TGMS 91S x Matta Triveni	84.00	89.00	16.00	23.65	100.50	81.00	27.05	8.28	1.60	5.16	24.65	30.65	0.44
25	TGMS 91S x Varsha	88.50	89.00	16.50	24.50	179.50	157.00	28.72	7.01	1.62	4.33	32.62	38.02	0.46

a) Days to 50% flowering

The range of relative heterosis was from -4.57 (TGMS 82S x Makom) to 4.97 per cent (TGMS 82S x Aiswarya). The magnitude of positive significant heterosis was observed for seventeen crosses where as negative significant heterosis was observed for seven crosses one cross showed non significant.

The magnitude of heterobeltiosis ranged between -1.19 (TGMS 81S x Matta Triveni) to 13.09 per cent (TGMS 82S x Aiswarya). Early flowering parent considered as better parent in the present investigation. Significant heterobeltiosis for days to 50% flowering was exhibited by 24 cross combination except TGMS 81S x Matta Triveni all other cross combinations showed positive significant heterobeltiosis.

Standarad heterosis ranged from -17.8 (TGMS 91S x Kairali) to 13.09 (TGMS 82S x Aiswarya) except 2 crosses TGMS 82S x Makom, and TGMS 81S x Matta Triveni, all other crosses showed significant positive heterosis.

b) Plant height

The extent of heterosis over mid parental value varied from -24.78(TGMS 82S x Samyuktha) to -1.65 (TGMS 91S x Samyuktha). Out of 25 cross combinations except TGMS 81S x Samyuktha (4.65), TGMS 74S x Makom (10.56) all others showed a negative significant heterosis.

The extent of heterobeltiosis ranged between -16.50 (TGMS 91S x Kanchana) and 41.31 (TGMS 81S x Samyuktha). Dwarf parent was consider as the better parent. 11 crosses showed negative significant.

Standard heterosis ranged from -44.36 (TGMS 74S x Kairali) to -16.19 (TGMS 91S x Samyuktha). All cross combinations showed a negative significant standard heterosis.

Table 51. Magnitude of heterosis for days to flowering and plant height (COH Vellanikkara)

Sl. No.	Hybrids	Days to 50% flowering			Plant height (cm)		
		d_i	d_{ii}	d_{iii}		d_{ii}	$d_{iii\,(1)}$
1	TGMS 74S xAiswarya	-0.56**	4.16**	4.16**	-10.05**	5.29**	-36.97**
2	TGMS 74S x Kanchana	0.57	6.02**	4.76**	-10.69**	-1.76**	-41.19**
3	TGMS 74S x Kairali	4.59**	10.97**	8.33**	-15.73**	-7.05**	-44.36**
4	TGMS 74S x Makom	2.35**	11.53**	3.57**	10.56**	32.35**	-20.77**
5	TGMS 74S x Samyuktha	1.70**	6.54**	6.54**	-1.76**	31.17**	-21.47**
6	TGMS 81S xAiswarya	0.58**	2.97**	2.97**	-10.37**	5.98**	-37.67**
7	TGMS 81S x Kanchana	-1.16**	1.80**	0.59**	-2.96**	7.78**	-36.61**
8	TGMS 81S x Kairali	0.58**	4.26**	1.78**	-0.86**	10.41**	-35.07**
9	TGMS 81S x Makom	3.61**	10.25**	2.38**	-14.35**	3.59**	-39.08**
10	TGMS 81S x Samyuktha	-1.74**	0.59**	0.59**	4.65**	41.31**	-16.90**
11	TGMS 82S xAiswarya	4.97**	13.09**	13.09**	-11.90**	-3.64**	-34.85**
12	TGMS 82S x Kanchana	1.11**	9.63**	8.33**	-7.07**	-4.16**	-35.21**
13	TGMS 82S x Kairali	1.67**	10.97**	8.33**	-17.38**	-14.58**	-42.25**
14	TGMS 82S x Makom	-4.57**	7.05**	-0.59**	-20.74**	-11.45**	-40.14**
15	TGMS 82S x Samyuktha	2.20**	10.11**	10.11**	-24.78**	-6.77**	-36.97**
16	TGMS 91S xAiswarya	0.58**	1.78**	1.78**	-14.48**	-8.50**	-35.56**
17	TGMS 91S x Kanchana	1.18**	3.01**	1.78**	-17.32**	-16.50**	-41.19**
18	TGMS 91S x Kairali	-1.78**	0.60**	-1.78**	-10.12**	-9.00**	-35.91**
19	TGMS 91S x Makom	4.26**	9.61**	1.78**	-10.75**	-2.50**	-31.33**
20	TGMS 91S x Samyuktha	1.76**	2.97**	2.97**	-1.65**	19.00**	-16.19**
21	TGMS 81S x Matta Triveni	-3.48**	-1.19**	-1.19**	-10.64**	2.99**	-39.43**
22	TGMS 81S x Prathyasa	1.12**	2.27**	7.14**	-5.88**	5.38**	-38.02**
23	TGMS 82S x Prathyasa	0.53**	4.44**	11.90**	-9.27**	-5.72**	-36.26**
24	TGMS 91S x Matta Triveni	-1.17**	0.00	0.00**	-14.83**	-11.00**	-37.32**
25	TGMS 91S x Varsha	4.11**	5.35**	5.35**	-14.42**	-11.00**	-37.32**

Table 52. Magnitude of heterosis for total productive tillers and panicle length (COH Vellanikkara)

Sl. No.	Hybrids	Number of productive tillers plant^{-1}			Panicle length (cm)		
		d_i	d_{ii}	diii	d_i	d_{ii}	d_{iii}
1	TGMS 74S x Aiswarya	7.40**	-9.37**	81.25**	7.86**	1.17**	-2.26**
2	TGMS 74S x Kanchana	-27.58**	-34.37**	31.25**	11.97**	2.20**	4.75**
3	TGMS 74S x Kairali	16.66**	-12.50**	75.00**	15.31**	7.92**	4.75**
4	TGMS 74S x Makom	7.69**	-12.50**	75.00**	19.07**	14.25**	5.20**
5	TGMS 74S x Samyuktha	0.00**	-25.00**	50.00**	23.52**	14.02**	14.02**
6	TGMS 81S x Aiswarya	58.33**	46.15**	137.50**	14.25**	11.70**	7.91**
7	TGMS 81S x Kanchana	23.07**	23.07**	100.00**	14.54**	8.83**	11.53**
8	TGMS 81S x Kairali	33.33**	7.69**	75.00**	11.11**	8.39**	5.20**
9	TGMS 81S x Makom	60.86**	42.30**	131.25**	5.52**	5.65**	-2.71**
10	TGMS 81S x Samyuktha	52.38**	23.07**	100.00**	10.35**	6.10**	6.10**
11	TGMS 82S xAiswarya	56.00**	39.28**	143.75**	8.14**	4.21**	0.67**
12	TGMS 82S x Kanchana	11.11**	7.14**	87.5**	-5.30**	-11.28**	-9.00**
13	TGMS 82S x Kairali	4.54**	-17.84**	43.75**	-2.30**	-6.06**	-8.82**
14	TGMS 82S x Makom	54.16**	32.14**	131.25**	10.08**	8.59**	0.00**
15	TGMS 82S x Samyuktha	40.90**	10.71**	93.75**	18.13**	11.99**	11.99**
16	TGMS 91S xAiswarya	12.00	0.00	75.00**	23.11**	16.62**	12.66**
17	TGMS 91S x Kanchana	25.92**	21.42**	112.5**	15.68**	6.62**	9.27**
18	TGMS 91S x Kairali	27.27**	0.00	75.00**	7.52**	1.63**	-1.35**
19	TGMS 91S x Makom	50.00**	28.57**	125.00**	26.99**	23.09**	13.34**
20	TGMS 91S x Samyuktha	50.00**	17.85**	106.25**	13.59**	5.88**	5.88**
21	TGMS 81S x Matta Triveni	72.72**	46.15	137.5**	5.18**	-2.70**	5.65**
22	TGMS 81S x Prathyasa	50.00**	26.92**	106.25**	10.57**	0.40**	13.57**
23	TGMS 82S x Prathyasa	78.26**	46.42**	156.25**	-7.58**	-17.20**	-6.33**
24	TGMS 91S x Matta Triveni	39.13**	14.28**	100.00**	9.74**	-1.45**	7.01**
25	TGMS 91S x Varsha	43.47**	17.85**	106.25**	12.51**	0.20**	10.85**

Table 53. Magnitude of heterosis for Total number of spikelets panicle^{-1} and number of filled grains panicle^{-1} (COH Vellanikkra)

Sl. No.	Hybrids	Total number of spikelets panicle^{-1}			Number of filled grains panicle^{-1}		
		d_I	d_{II}	d_{III}	d_I	d_{II}	d_{III}
1	TGMS 74S xAiswarya	6.57**	-6.53**	19.11**	11.17**	11.79**	10.55**
2	TGMS 74S x Kanchana	58.95**	38.93**	78.43**	78.94**	70.00**	88.88**
3	TGMS 74S x Kairali	50.19**	22.58**	86.27**	46.81**	24.23**	79.44**
4	TGMS 74S x Makom	36.92**	12.45**	68.13**	32.01**	9.05**	67.22**
5	TGMS 74S x Samyuktha	37.00**	34.31**	34.31**	34.44**	34.44**	34.44**
6	TGMS 81S xAiswarya	25.21**	14.61**	46.07**	31.86**	34.83**	33.33**
7	TGMS 81S x Kanchana	38.07**	25.95**	61.76**	34.71**	30.00**	44.44**
8	TGMS 81S x Kairali	-26.23**	-37.41**	-4.90**	-26.45**	-36.92**	-8.88**
9	TGMS 81S x Makom	-20.92**	-32.45**	0.98**	-25.54**	-37.68**	-4.44**
10	TGMS 81S x Samyuktha	63.33**	68.13**	68.13**	71.03**	73.88**	73.88**
11	TGMS 82S xAiswarya	-3.01**	-13.46**	10.29**	13.45**	8.98**	7.77**
12	TGMS 82S x Kanchana	-19.31**	-28.24**	-7.84**	-18.68**	-26.00**	-17.74**
13	TGMS 82S x Kairali	-22.95**	-36.12**	-2.94**	-29.71**	-42.69**	-17.22**
14	TGMS 82S x Makom	-13.16**	-27.54**	8.33**	-18.18**	-34.78**	0.00**
15	TGMS 82S x Samyuktha	69.11**	69.11**	69.11**	75.58**	67.77**	67.77**
16	TGMS 91S xAiswarya	21.21**	7.69**	37.25**	16.66**	14.04**	12.77**
17	TGMS 91S x Kanchana	70.25**	50.76**	93.62**	90.81**	76.50**	96.11**
18	TGMS 91S x Kairali	33.20**	10.00**	67.15**	46.51**	21.15**	75.00**
19	TGMS 91S x Makom	36.48**	13.44**	69.60**	16.14**	-6.15**	43.88**
20	TGMS 91S x Samyuktha	98.52**	97.54**	97.54**	118.85**	112.77**	112.77**
21	TGMS 81S x Matta Triveni	15.61**	-3.41**	52.45**	1.79**	-12.69**	26.11**
22	TGMS 81S x Prathyasa	51.75**	50.00**	58.82**	31.35**	32.06**	35.00**
23	TGMS 82S x Prathyasa	34.93**	32.70**	37.25**	41.37**	33.69**	36.66**
24	TGMS 91S x Matta Triveni	-23.28**	-37.57**	-1.47**	-24.65**	-37.69**	-10.00**
25	TGMS 91S x Varsha	54.74**	37.02**	75.98**	68.90**	55.17**	75.00**

Table 54. Magnitude of heterosis for 1000 grain weight and grain length (COH Vellanikkara)

Sl. No.	Hybrids	1000 grain weight(g)			Grain length (mm)		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1	TGMS 74S xAiswarya	9.98**	-4.87**	-8.60**	11.80**	-0.25**	17.66**
2	TGMS 74S x Kanchana	-2.63**	-12.87**	-10.75**	-3.94**	-7.23**	9.43**
3	TGMS 74S x Kairali	-5.92**	-10.20**	-25.68**	0.85**	-10.27**	5.83**
4	TGMS 74S x Makom	8.99**	5.79**	-13.33**	12.28**	10.15**	29.94**
5	TGMS 74S x Samyuktha	-9.13**	-10.91**	-10.91**	16.07**	7.23**	26.49**
6	TGMS 81S xAiswarya	23.92**	15.67**	-6.42**	0.77**	-11.07**	7.55**
7	TGMS 81S x Kanchana	-18.59**	-26.41**	-24.62**	-28.21**	-31.49**	-17.14**
8	TGMS 81S x Kairali	-5.37**	-6.52**	-27.92**	2.46**	-9.83**	9.05**
9	TGMS 81S x Makom	-5.81**	-12.75**	-16.17**	5.04**	1.79**	23.12**
10	TGMS 81S x Samyuktha	-3.02**	-12.29**	-12.29**	13.48**	3.65**	25.37**
11	TGMS 82S xAiswarya	6.67**	-1.47**	-18.45**	1.94**	-10.75**	9.95**
12	TGMS 82S x Kanchana	-2.20**	-14.29**	-12.20**	-3.98**	-9.17**	11.90**
13	TGMS 82S x Kairali	0.37**	-10.51**	-14.02**	-0.97**	-13.54**	6.51**
14	TGMS 82S x Makom	-6.33**	-6.92**	-23.75**	-12.84**	-16.28**	3.14**
15	TGMS 82S x Samyuktha	1.91**	-6.87**	-6.87**	10.79**	0.36**	23.65**
16	TGMS 91S xAiswarya	24.20**	18.57**	-8.56**	0.34**	-11.77**	7.63**
17	TGMS 91S x Kanchana	0.32**	-2.79**	-0.42**	8.45**	3.06**	25.74**
18	TGMS 91S x Kairali	-2.48**	-5.89**	-23.87**	-15.67**	-26.07**	-9.80**
19	TGMS 91S x Makom	31.05**	30.38**	7.91**	-7.31**	-10.55**	9.13**
20	TGMS 91S x Samyuktha	0.17**	-90.27**	-11.28**	15.30**	4.90**	27.99**
21	TGMS 81S x Matta Triveni	5.98**	0.80**	-9.62**	17.64**	4.39**	26.27**
22	TGMS 81S x Prathyasa	27.62**	19.39**	10.87**	-0.69**	-11.69**	6.81**
23	TGMS 82S x Prathyasa	-7.18**	-12.22**	-18.49**	38.42**	22.11**	50.44**
24	TGMS 91S x Matta Triveni	10.83**	6.57**	-4.45**	14.98**	1.65**	24.02**
25	TGMS 91S x Varsha	26.40**	21.64**	1.44**	3.69**	-13.92**	5.01**

Table 55. Magnitude of heterosis for Grain breadth and L/B ratio of grain (COH Vellanikkara)

S. No.	Hybrids	Grain breadth (mm)			L/B ratio of grain		
		d_I	d_{II}	d_{III}	d_I	d_{II}	d_{III}
1	TGMS 74S x Aiswarya	-15.21**	-23.31**	-12.77**	30.57**	6.76**	8.24**
2	TGMS 74S x Kanchana	-15.18**	-19.18**	-17.89**	12.84**	4.02**	5.46**
3	TGMS 74S x Kairali	-20.06**	-27.14**	-18.53**	23.45**	1.27**	2.68**
4	TGMS 74S x Makom	-30.64**	-48.84**	-0.95**	40.65**	2.46**	3.89**
5	TGMS 74S x Samyuktha	0.00**	-7.39**	0.00**	14.48**	-1.37**	0.00**
6	TGMS 81S x Aiswarya	-6.93**	-28.37**	-18.53**	-5.25**	-33.07**	4.44**
7	TGMS 81S x Kanchana	36.47**	9.43**	11.18**	-51.20**	-62.23**	-41.05**
8	TGMS 81S x Kairali	9.22**	-15.42**	-5.43**	-17.48**	-41.56**	-8.80**
9	TGMS 81S x Makom	-26.06**	-51.32**	-5.75**	2.19**	-33.72**	3.42**
10	TGMS 81S x Samyuktha	17.35**	-7.98**	-0.63**	-12.96**	-36.04**	-0.18**
11	TGMS 82S x Aiswarya	33.59**	-2.80**	10.54**	-37.73**	-58.21**	-21.31**
12	TGMS 82S x Kanchana	-15.83**	-36.47**	-35.46**	0.57**	-26.87**	37.72**
13	TGMS 82S x Kairali	17.96**	-13.71**	-3.51**	-30.91**	-53.54**	-12.51**
14	TGMS 82S x Makom	-22.39**	-50.82**	-4.79**	-27.01**	-54.52**	-14.36**
15	TGMS 82S x Samyuktha	-0.40**	-26.33**	-20.44**	-5.91**	-34.64**	23.07**
16	TGMS 91S xAiswarya	23.46**	-3.93**	9.26**	-28.12**	-48.89**	-21.99**
17	TGMS 91S x Kanchana	22.86**	-0.31**	1.27**	-17.50**	-35.64**	-1.76**
18	TGMS 91S x Kairali	-21.16**	-38.28**	-30.99**	-5.02**	-32.30**	3.33**
19	TGMS 91S x Makom	-24.62**	-50.00**	-3.19**	-10.20**	-41.46**	-10.65**
20	TGMS 91S x Samyuktha	49.62**	18.63**	28.11**	-30.02**	-48.20**	-20.94**
21	TGMS 81S x Matta Triveni	25.70**	2.28**	-7.39**	-13.88**	-35.92**	36.58**
22	TGMS 81S x Prathyasa	37.14**	4.34**	13.60**	-37.24**	-55.87**	-5.94**
23	TGMS 82S x Prathyasa	-47.54**	-62.22**	-58.87**	112.88**	42.27**	265.94**
24	TGMS 91S x Matta Triveni	27.38**	4.90**	-5.02**	-16.28**	-37.24**	30.75**
25	TGMS 91S x Varsha	28.06**	5.19**	-4.14**	-26.10**	-47.38**	9.62**

Table 56. Magnitude of heterosis for single plant grain yield, single plant straw yield and harvest index (COH Vellanikkara)

Sl. No.	Hybrids	Single plant grain yield (g)			Single plant straw yield (g)			Harvest index		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1	TGMS 74S x Aiswarya	150.14**	137.00**	123.94**	107.51**	101.82**	46.30**	10.97**	5.81**	-14.15**
2	TGMS 74S x Kanchana	149.20**	139.07**	125.90**	118.28**	112.07**	45.30**	8.23**	6.97**	-13.20**
3	TGMS 74S x Kairali	181.92**	169.17**	154.34**	148.23**	135.14**	61.10**	8.04**	6.81**	-11.32**
4	TGMS 74S x Makom	86.01**	57.07**	115.47**	72.61**	49.72**	39.61**	5.74**	4.54**	-13.20**
5	TGMS 74S x Samyuktha	25.55**	22.10**	22.10**	70.60**	45.95**	0.00**	-16.66**	-24.52**	-24.52**
6	TGMS 81S x Aiswarya	191.14**	187.53**	143.15**	124.16**	113.54**	54.79**	16.25**	13.41**	-12.26**
7	TGMS 81S x Kanchana	177.91**	170.95**	135.21**	143.01**	141.15**	58.25**	8.43**	7.14**	-15.09**
8	TGMS 81S x Kairali	38.42**	35.62**	16.55**	33.38**	28.97**	-15.36**	1.17**	-2.27**	-18.86**
9	TGMS 81S x Makom	114.91**	72.05**	136.01**	90.24**	62.05**	51.12**	8.23**	4.54**	-13.20**
10	TGMS 81S x Samyuktha	143.84**	122.46**	122.46**	147.13**	115.29**	41.28**	0.00**	-11.32**	-11.32**
11	TGMS 82S x Aiswarya	152.09**	148.83**	116.01**	84.38**	70.44**	23.55**	19.27**	12.50**	-6.60**
12	TGMS 82S x Kanchana	93.28**	93.28**	67.78**	79.43**	75.13**	13.17**	4.65**	2.27**	-15.09**
13	TGMS 82S x Kairali	65.81**	64.98**	43.22**	64.68**	64.36**	1.12**	0.00**	0.00	-16.98
14	TGMS 82S x Makom	59.52**	30.24**	78.65**	59.15**	32.08**	23.17**	1.13	1.13	-16.03
15	TGMS 82S x Samyuktha	153.14**	136.44**	136.44**	178.10**	149.15**	53.29**	-5.15**	-13.20**	-13.20**
16	TGMS 91S x Aiswarya	172.27**	171.33**	129.45**	129.68**	108.55**	51.18**	10.84**	4.54**	-13.20**
17	TGMS 91S x Kanchana	189.77**	185.05**	147.46**	163.91**	152.76**	63.33s**	5.81**	3.40**	-14.15**
18	TGMS 91S x Kairali	69.85**	67.91**	44.31**	67.72**	64.80**	1.00**	0.00**	0.00	-16.98
19	TGMS 91S x Makom	135.64**	89.96**	160.57**	119.49**	79.37**	67.26**	4.54**	4.54**	-13.20**
20	TGMS 91S x Samyuktha	196.49**	172.75**	172.75**	217.57**	189.54**	71.28**	-3.09**	-11.32**	-11.32**
21	TGMS 81S x Matta Triveni	209.41**	182.28**	182.28**	128.92**	105.64**	90.67**	17.28**	15.85**	-10.37**
22	TGMS 81S x Prathyasa	146.16**	150.70**	106.73**	120.77**	102.87**	49.79**	4.00**	-2.15**	-14.15**
23	TGMS 82S x Prathyasa	129.05**	127.33**	97.35**	121.85**	110.05**	45.41**	4.97**	2.15**	-10.37**
24	TGMS 91S x Matta Triveni	94.17**	78.62**	78.62**	76.67**	51.77**	40.66**	5.95**	1.13	-16.03
25	TGMS 91S x Varsha	193.48**	181.57**	136.48**	165.18**	162.80**	78.12**	7.60**	4.54**	-13.20**

Table 57. Mean, SEM and range of characters studied in two line hybrids in RARS Pattambi

Sl.No	Characters (unit)	Mean ± SEM	Range
1	Days to 50% flowering	88.24 ± 0.79	81.00 – 95.00
2	Plant height (cm)	100.09± 0.83	80.50- 133.00
3	Number of productive tillers plant^{-1}	13.72 ± 0.72	7.50- 19.00
4	Panicle length (cm)	22.85 ± 0.70	19.70- 27.10
5	Total number of spikelets panicle $^{-1}$	138.34 ± 5.68	82.00-199.00
6	Number of filled grains panicle^{-1}	120.20 ± 5.27	65.00-190.00
7	1000 grain weight (g)	25.07 ± 0.43	20.83 -31.30
8	Grain length (mm)	7.62 ± 0.16	5.65 -10.05
9	Grain breadth (mm)	1.49± 0.04	0.69-2.02
10	L/B ratio of grain	5.44 ± 0.19	3.27 -7.34
11	Single plant grain yield (g)	26.83 ± 0.77	9.66-40.26
12	Single plant straw yield (g)	32.50± 0.79	18.25 -45.81
13	Harvest index	0.44 ± 0.01	0.39 -0.47

c) Total number of productive tillers plant^{-1}

The lowest relative heterosis was observed in – 27.58(TGMS 74S x Kanchana) and the maximum was recorded by 78.26 per cent (TGMS 82S x Prathyasa). More number of productive tillers plant $^{-1}$ was taken as the better parent. The hybrid TGMS 82S x Prathyasa (46.42 per cent) over the better parent. The range of standard heterosis over the check was between 31.25 (TGMS 74S x Kanchana) and TGMS 82S x Aiswarya(143.75 per cent)

d) Panicle length

TGMS 91S x Makom expressed a maximum relative heterosis and heterosbeltiosis (26.99, 23.09 per cent) and TGMS 82S xPrathyasa (-7.58, -17.20 per cent)the lowest relative heterosis and heterobeltiosis respectively.

The highest standard heterosis was observed in TGMS 74S x Samyuktha (14.02 per cent) followed by TGMS 81S x Prathyasa (13.57) and TGMS 91S x Makom (13.34). The hybrid TGMS 82S x Kanchana recorded the lowest standard heterosis (-9.00 per cent)

e) Total number of spikelets panicle $^{-1}$

The relative heterosis and heterobeltiosis were the highest in TGMS 91S x Samyuktha with 98.52 and 97.54 per cent respectively. TGMS 81 S x Kairali (-26.23 %), TGMS 91 S x Matta Triveni (-37.57%) recorded the lowest relative heterosis and heterobeltiosis respectively.

The highest standard heterosis was observed in TGMS 91S x Samyuktha where as TGMS 82S x Kanchana showed the lowest standard heterosis (-7.84 %)

f) Number of filled grains panicle^{-1}

TGMS 91S x Samyuktha showed the highest relative heterosis , heterobeltiosis, and standard heterosis (118.85,112.77,112.77 per cent where as TGMS 82S x Kairali showed a minimum value of relative heterosis ,heterobeltiosis and standard heterosis (-29.71, -42.69, -17.22 per cent)

g) 1000 grain weight

The hybrid TGMS 91S x Makom showed the maximum relative heterosis and heterobeltiosis (31.05, 30.08) where as TGMS 81S x Kanchana and TGMS 91S x Samyuktha showed the minimum relative heterosis and heterobeltiosis (-18.59, -90.27).Twnty two hybrids exhibited significant negative heterosis over the check variety.

h) Grain length

The extent of heterosis over mid parental value ranged from -28.21 (TGMS 81S x Kanchana) to 38.42 (TGMS 82S x Prathyasa).For heterobeltiosis ranged between -31.49 (TGMS 81S x Kanchana) to 22.11 (TGMS 82S x Prathyasa) . Standard heterosis ranged from -17.14 (TGMS 81S x Kanchana) to 50.44 (TGMS 82S x Prathyasa)

i) Grain breadth

The extent of heterosis over mid parental value ranged from -47.54 (TGMS 82S x Prathyasa) to 49.62 (TGMS 91S x Samyuktha) . For heterobeltiosis ranged between -62.22 (TGMS 82S xPrathyasa) to 18.63 (TGMS 91S x Samyuktha). Standard heterosis ranged from-58.87 (TGMS 82S x Prathyasa) to 28.11(TGMS 91S x Samyuktha)

j) L/B ratio of grain

The extent of heterosis over mid parental value ranged from -51.20 (TGMS 81S x Kanchana) to 112.88 (TGMS 82S x Prathyasa). Heterobeltiosis ranged from -62.23 (TGMS 81S x Kanchana) to 42.27 (TGMS 82S x Prathyasa). Standard heterosis ranged from -41.05 (TGMS 81S x Kanchana) to 265.94 (TGMS 82S x Prathyasa.

k) Single plant grain yield.

The relative heterosis ranged from 25.55(TGMS 74S x Samyuktha) to 209.41 (TGMS 81S x Matta Triveni). Heterobeltiosis ranged from 22.10 (TGMS 74S x Samyuktha) to 1587.53 (TGMS 81S x Aiswarya)

The standard heterosis ranged from 16.55 (TGMS 81S x Kairali) to 182.28 (TGMS 81S x Matta Triveni)

l) Single plant straw yield

The relative heterosis ranged from 33.38 (TGMS 81S x Kairali) to 217.57 (TGMS91S x Samyuktha). Heterobeltiosis ranged from 32.07 (TGMS 82S x Makom)189.54 (TGMS 91S x Samyuktha). The standard heterosis ranged from -15.36 (TGMS 81S x Kairali) to 90.67 (TGMS 81S x Matta Triveni).

m) Harvest index

The relative heterosis ranged from -16.66 (TGMS 74S x Samyuktha) to 19.27 (TGMS 82S x Aiswarya). The heterobeltiosis ranged from -24.52 (TGMS 74S x Samyuktha) to 15.85 (TGMS 81S x Matta Triveni). The standard heterosis ranged from -24.52 (TGMS 74S x Samyuktha) to -6.60 (TGMS 82S x Aiswarya)

4.3.2 RARS Pattambi

4.3.2.1 Genetic variability

Present investigation was carried out with 25 F_1 hybrids and their parents .The extent of genetic variability among these varieties were estimated for different quantitative and qualitative characters.

Results for analysis of variance revealed highly significant differences for all the characters except grain breadth and harvest index.

Mean , SEM and range of hybrids and parents are presented **in Table 57.**

Plant characters namely days to 50% flowering varied from 88.00 to 100 days with an average of 92.64 days. Plant height ranged from 80.50 cm to 133 cm average being 100.09cm .In case of total number of productive tillers plant^{-1}, the range of variation was 7.50 to 19.00 with an average of 13.72.

Among the earhead characters, length of panicle varied from 19.70 cm to 26.60 cm and had an average of 22.65 cm .Total number of spikelets panicle $^{-1}$ and number of filled grains panicle $^{-1}$ ranged from 60.58 to 193.91 and 50.58 to 169.31 with averages of 137.86 and 118.27 respectively.

With respect to grain characters, 1000 grain weight varied from 20.83 g to 31.30 g with a mean of 25.07 g. Grain length and breadth ranged from 5.48 mm to 8.65 mm and 1.09 mm to 2.02 mm average being 7.62 mm and 1.49 mm respectively. L/B ratio of grains ranged from 3.27 to 7.34 with an average of 5.44.

Economic characters namely single plant grain yield varied from 9.66 to 40.26 g, average being 26.83 g .Single plant straw yield and harvest index exhibited a, range of 18.25 to 45.81 and 0.39 to 0.47 with an average of 32.50 and 0.44 respectively.

4.3.3.2 Mean performance

The observations on various characters studied in the two line hybrids were subjected to Duncan's Multiple Range Test (DMRT) and the abstracts are given in **Table 58 to 61.**

Among the plant characters days to 50% flowering TGMS 81S x Matta Triveni flowered earlier compared to TGMS 82S x Aiswarya. Plant height was lowest for TGMS 91S x Kairali where as TGMS 82S x Samyuktha recorded the highest. TGMS 82S x Prathyasa and TGMS 81S x Aiswarya had the maximum number of productive tillers plant^{-1} and TGMS 74S x Samyuktha showed the minimum number.

Among the earhead characters,TGMS 81S x Matta Triveni had the longest panicles where as TGMS 74S x Aiswarya, TGMS 81S x Makom showed the shortest panicles. TGMS 91S x Samyuktha recorded the maximum number of total spikelets panicle^{-1} and number of filled grains panicle^{-1} and TGMS 82S x Kanchana recorded the minimum number of total spikelets panicle^{-1} and number of filled grains panicle^{-1}.

Grain characters such as 1000 grain weight recorded high values for TGMS 81S x Prathyasa and TGMS 74S x Kairali had the lowest value. TGMS 74S x Makom had the longest grain but TGMS 91S x Kairali showed the shortest grain. Grains had more breadth in the case of TGMS 91S x Samyuktha, less breadth in TGMS 91S x Kairali . L/B ratio of grain was maximum for TGMS 82S x Kanchana and TGMS 81S x Kanchana had the minimum value

Economic characters *viz* single plant grain yield was maximum for TGMS 91S x Samyuktha and TGMS 91S x Kairali recorded the minimum grain yield. Single plant straw yield was the highest for TGMS 81S x Matta Triveni while

Table 58. Mean performance of two line hybrids for plant characters in RARS Pattambi

Sl.No	Varieties	Days to 50% flowering	Plant height(cm)	Number of productive tillersplant^{-1}
1	TGMS 74S x Aiswarya	90.50^{efgh}	96.25^{efgh}	14.5^{cdef}
2	TGMS 74S x Kanchana	91.00^{fghi}	88.7^{abcd}	14.5^{cdef}
3	TGMS 74S x Kairali	91.50^{ghi}	89.25^{abcde}	12.5^{efgh}
4	TGMS 74S x Makom	89.00^{defg}	121^{ijk}	16.5^{bc}
5	TGMS 74S x Samyuktha	88.50^{def}	120^{ij}	7.5^{j}
6	TGMS 81S x Aiswarya	86.50^{cd}	100.5^{fghi}	19.0^{a}
7	TGMS 81Sx Kanchana	87.00^{cd}	90.5^{bcdef}	11.0^{ghi}
8	TGMS 81S x Kairali	87.00^{cd}	100.75^{fghi}	9.0^{ij}
9	TGMS 81S x Makom	86.50^{cd}	87^{abc}	15.5^{cd}
10	TGMS 81S x Samyuktha	87.50^{cd}	130^{jk}	10.5^{hi}
11	TGMS 82S x Aiswarya	95.00^{j}	95.75^{efgh}	13.5^{defg}
12	TGMS 82S x Kanchana	93.50^{ij}	101^{hi}	15.0^{cde}
13	TGMS 82S x Kairali	90.00^{efg}	100.5^{fghi}	11.0^{ghi}
14	TGMS 82S x Makom	89.00^{defg}	86^{abc}	15.5^{cd}
15	TGMS 82S x Samyuktha	93.50^{ij}	115.5^{fghi}	14.0^{cdef}
16	TGMS 91S x Aiswarya	87.00^{cd}	98.67^{fghi}	12.0^{fgh}
17	TGMS 91S x Kanchana	83.50^{b}	82.5^{ab}	15.5^{cd}
18	TGMS91S x Kairali	81.00^{a}	80.5^{a}	11.0^{ghi}
19	TGMS91S x Makom	85.00^{bc}	112.5^{fghi}	15.5^{cd}
20	TGMS91S x Samyuktha	85.00^{bc}	133^{k}	18.0^{ab}
21	TGMS 81S x Matta Triveni	82.50^{ab}	90^{bcdef}	13.5^{defg}
22	TGMS 81S x Prathyasa	90.50^{efgh}	87.5^{abc}	12.5^{efgh}
23	TGMS 82S x Prathyasa	93.00^{hij}	88.5^{abcd}	19.0^{a}
24	TGMS 91S x Matta Triveni	85.00^{bc}	104^{i}	12.5^{efgh}
25	TGMS 91S x Varsha	88.00^{de}	102.5^{hi}	14.0^{cdef}

Table 59. Mean performance of two line hybrids for ear head characters in RARS Pattambi

Sl.No	Varieties	Panicle length (cm)	Total number of Spikelets panicle $^{-1}$	Number of filled grains panicle $^{-1}$
1	TGMS 74S x Aiswarya	19.70^{j}	82^{j}	65^{i}
2	TGMS 74S x Kanchana	21.75^{ghij}	159^{cdef}	135^{cde}
3	TGMS 74S x Kairali	22.00^{fghij}	183^{abc}	167^{b}
4	TGMS 74S x Makom	23.50^{cdefg}	160^{def}	137^{cd}
5	TGMS 74S x Samyuktha	24.50^{bcd}	120^{i}	114^{f}
6	TGMS 81S x Aiswarya	22.25^{defghi}	129^{hi}	127^{cdef}
7	TGMS 81Sx Kanchana	26.40^{ab}	156^{ghi}	144^{c}
8	TGMS 81S x Kairali	22.35^{defghi}	89^{j}	74^{hi}
9	TGMS 81S x Makom	19.70^{j}	92^{j}	88^{g}
10	TGMS 81S x Samyuktha	23.50^{cdefg}	174^{bcde}	161^{b}
11	TGMS 82S x Aiswarya	22.50^{defghi}	100^{j}	75^{hi}
12	TGMS 82S x Kanchana	20.70^{hij}	61^{k}	43^{j}
13	TGMS 82S x Kairali	21.00^{hij}	89^{j}	80^{hi}
14	TGMS 82S x Makom	22.10^{efghi}	143^{fg}	115^{f}
15	TGMS 82S x Samyuktha	24.30^{bcdef}	167^{cde}	143^{c}
16	TGMS 91S x Aiswarya	25.10^{abc}	147^{fg}	130^{cdef}
17	TGMS 91S x Kanchana	24.40^{bcde}	188^{ab}	163^{b}
18	TGMS91S x Kairali	21.50^{ghij}	135^{hi}	117^{f}
19	TGMS91S x Makom	23.00^{cdefgh}	178^{bcd}	121^{def}
20	TGMS91S x Samyuktha	22.00^{fghij}	199^{a}	190^{a}
21	TGMS 81S x Matta Triveni	27.10^{a}	146^{fg}	119^{ef}
22	TGMS 81S x Prathyasa	25.10^{abc}	159^{ef}	135^{cde}
23	TGMS 82S x Prathyasa	20.15^{ij}	130^{hi}	116^{f}
24	TGMS 91S x Matta Triveni	22.10^{efghi}	87^{j}	75^{hi}
25	TGMS 91S x Varsha	24.50^{bcd}	180^{bc}	166^{b}

Table 60. Mean performance of two line hybrids for grain characters in RARS Pattambi

Sl.No	Varieties	1000 grain weight(g)	Grain length(mm)	Grain breadth(mm)	L/B ratio of grain
1	TGMS 74S x Aiswarya	27.44^{def}	7.86^{de}	1.37^{de}	5.84^{c}
2	TGMS 74S x Kanchana	24.92^{defg}	7.24^{fg}	1.29^{e}	5.60^{cd}
3	TGMS 74S x Kairali	20.83^{j}	7.03^{g}	1.28^{e}	5.47^{cde}
4	TGMS 74S x Makom	24.76^{efgh}	8.65^{b}	1.60^{bc}	5.40^{cde}
5	TGMS 74S x Samyuktha	25.55^{defg}	8.41^{bc}	1.57^{bc}	5.38^{cde}
6	TGMS 81S x Aiswarya	26.03^{cde}	7.18^{fg}	1.28^{e}	5.59^{cd}
7	TGMS 81Sx Kanchana	21.19^{ij}	5.65	1.73^{b}	3.27^{j}
8	TGMS 81S x Kairali	21.14^{j}	7.34^{fg}	1.50^{cd}	4.88^{defgh}
9	TGMS 81S x Makom	23.83^{gh}	8.10^{cde}	1.50^{cd}	5.39
10	TGMS 81S x Samyuktha	24.85^{efgh}	8.25^{bcd}	1.54^{c}	5.35^{cdef}
11	TGMS 82S x Aiswarya	23.56^{hi}	7.30^{fg}	1.72^{b}	4.23^{hi}
12	TGMS 82S x Kanchana	24.80^{efgh}	7.59^{ef}	1.04^{g}	7.34^{b}
13	TGMS 82S x Kairali	24.98^{fgh}	6.87^{g}	1.57^{bc}	4.39^{gh}
14	TGMS 82S x Makom	21.55^{ij}	6.96^{g}	1.50^{cd}	4.65^{fgh}
15	TGMS 82S x Samyuktha	26.35^{cdef}	8.28^{bcd}	1.23^{ef}	6.76^{b}
16	TGMS 91S x Aiswarya	27.83^{def}	7.16^{fg}	1.66^{bc}	4.32^{h}
17	TGMS 91S x Kanchana	27.97^{bc}	8.29^{bcd}	1.59^{bc}	5.22^{cdef}
18	TGMS91S x Kairali	21.56^{ij}	5.48	1.09^{fg}	5.05^{defg}
19	TGMS91S x Makom	30.97^{a}	7.60^{ef}	1.61^{bc}	4.74^{efgh}
20	TGMS91S x Samyuktha	24.54^{defgh}	8.41^{bc}	2.02^{a}	4.16^{hi}
21	TGMS 81S x Matta Triveni	25.55^{defg}	8.43^{bc}	1.57^{bc}	5.37^{cde}
22	TGMS 81S x Prathyasa	31.30^{a}	7.17^{fg}	2.00^{a}	3.60^{ij}
23	TGMS 82S x Prathyasa	21.58^{hi}	10.05^{a}	0.69^{h}	14.45^{a}
24	TGMS 91S x Matta Triveni	26.04^{bcd}	8.23^{bcd}	1.60^{bc}	5.16^{cdef}
25	TGMS 91S x Varsha	27.74^{b}	7.01^{g}	1.63^{bc}	4.31^{h}

Table 61. Mean performance of two line hybrids for economic characters in RARS Pattambi

Sl.No	Varieties	Single plant grain yield(g)	Single plant straw yield (g)	Harvest index
1	TGMS 74S x Aiswarya	31.15[bcde]	35.76[ef]	0.47[ab]
2	TGMS 74S x Kanchana	36.12[abc]	36.12[def]	0.45[cd]
3	TGMS 74S x Kairali	37.58[ab]	42.63[ab]	0.47[ab]
4	TGMS 74S x Makom	17.25[ij]	21.82[jk]	0.44[d]
5	TGMS 74S x Samyuktha	15.41[ik]	20.62[kl]	0.41[e]
6	TGMS 81S x Aiswarya	32.04[bcde]	37.90[de]	0.46[bc]
7	TGMS 81Sx Kanchana	33.32[bcde]	40.80[bc]	0.45[cd]
8	TGMS 81S x Kairali	13.58[ik]	18.25[l]	0.41[f]
9	TGMS 81S x Makom	33.53[bcde]	38.58[cd]	0.47[ab]
10	TGMS 81S x Samyuktha	28.55[defg]	35.11[fg]	0.44[d]
11	TGMS 82S x Aiswarya	19.03[ghi]	25.49[i]	0.43[e]
12	TGMS 82S x Kanchana	18.89[hi]	23.98[ij]	0.44[d]
13	TGMS 82S x Kairali	13.93[jk]	20.16[kl]	0.41[fg]
14	TGMS 82S x Makom	30.55[cdef]	36.90[def]	0.45[cd]
15	TGMS 82S x Samyuktha	27.56[efg]	32.60[h]	0.46[bc]
16	TGMS 91S x Aiswarya	27.18[fgh]	33.19[gh]	0.45[cd]
17	TGMS 91S x Kanchana	30.05[cdef]	37.45[def]	0.45[cd]
18	TGMS91S x Kairali	09.66[k]	14.83[m]	0.39[g]
19	TGMS91S x Makom	36.82[abc]	42.78[b]	0.46[bc]
20	TGMS91S x Samyuktha	40.26[a]	45.81	0.47[ab]
21	TGMS 81S x Matta Triveni	37.82[ab]	42.90[b]	0.47[a]
22	TGMS 81S x Prathyasa	27.30[efg]	32.42[h]	0.46[bc]
23	TGMS 82S x Prathyasa	34.60[abcd]	41.57[b]	0.45[cd]
24	TGMS 91S x Matta Triveni	17.25[ij]	23.65[ij]	0.43[e]
25	TGMS 91S x Varsha	27.77[efg]	31.26[h]	0.47[ab]

TGMS 91S x Kairali exhibited the lowest value. Harvest index was maximum for TGMS 91S x Varsha but TGMS 91S x Kairali was minimum

4.3.3.3 Phenotypic and genotypic coefficient of variation

The estimates of PCV, GCV , heritability , gentic advance and genetic gain of two line hybrids are given in **Table 62.** Among various different characters studied for two line hybrids, high magnitude of PCV and GCV were observed for L/B ratio of grain (38.36, 37.99), single plant grain yield(32.60, 32.34) number of filled grains panicle $^{-1}$ (31.01, 30.08) total number of spikelets panicle $^{-1}$ (28.29 ,27.69) and single plant straw yield (27.56,27.34) and number of productive tillers plant^{-1}(21.62,20.29). The characters grain breadth (19.59,18.99), plant height (14.53,14.48), grain length (12.71,12.36) and 1000 grain weight (11.53,11.27) recorded moderate values for PCV and GCV . Low variability was observed for panicle length (9.16, 8.05) harvest index (4.89, 4.74) and days to 50% flowering (4.16,3.96)

4.3.3.4 Heritability

Among the quantitative characters heritability in broad sense ranged from 77.30 per cent (Panicle length) to 99.30 per cent (Plant height) .

The characters, total number of spikelets panicle^{-1}(77.23) total number of filled grains panicle (73.70) plant height (29.76) showed high genetic advance. Single plant straw yield (18.16) and single plant grain yield(17.74) showed moderate genetic advance and remaining all characters showed less genetic advance.

4.3.3.5 Correlation

The genotypic and phenotypic correlation coefficient among different morphological characters studied are given in **Table 63 and 64.**

Table 62. Estimates of genetic parameters for different characters studied in two line hybrids in RARS Pattambi

Sl.No	Characters (unit)	PCV (%)	GCV(%)	Heritability	Genetic advance	Genetic gain
1	Days to 50% flowering	4.16	3.96	90.0	6.85	7.76
2	Plant height (cm)	14.53	14.48	99.3	29.76	29.73
3	Number of productive tillers plant^{-1}	21.62	20.29	88.1	5.38	39.21
4	Panicle length (cm)	9.16	8.05	77.3	3.33	14.57
5	Total number of spikelets panicle $^{-1}$	28.29	27.69	95.8	77.23	55.82
6	Number of filled grains panicle^{-1}	31.01	30.38	96.0	73.70	61.31
7	1000 grain weight (g)	11.53	11.27	95.5	5.69	22.69
8	Grain length (mm)	12.71	12.36	94.7	1.89	24.80
9	Grain breadth (mm)	19.59	18.99	94.0	0.56	37.58
10	L/B ratio of grain	38.36	37.99	98.1	4.21	77.38
11	Single plant grain yield (g)	32.60	32.34	98.4	17.74	66.12
12	Single plant straw yield (g)	27.56	27.34	98.4	18.16	55.87
13	Harvest index	4.89	4.74	93.9	0.04	9.09

Table 63. Genotypic correlation coefficient between yield and yield component characters in two line hybrids (RARS Pattambi)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	0.026	1.000											
3	-0.317*	0.105	1.000										
4	0.092	-0.043	-0.321**	1.000									
5	-0.259*	0.216	0.550**	0.199	1.000								
6	-0.268*	0.247	0.501**	0.180	0.969**	1.000							
7	-0.052	-0.039	0.147	0.563**	0.546**	0.520**	1.000						
8	-0.061	-0.058	0.153	0.556**	0.545**	0.517**	0.995**	1.000					
9	-0.104	0.205	0.333**	0.109	0.208	0.104	0.140	0.119	1.000				
10	0.180	0.384**	-0.162	0.437**	0.006	0.017	0.249	0.246	0.160	1.000			
11	-0.286*	0.302*	0.525**	-0.224	0.308*	0.291*	0.095	0.092	0.411**	-0.191	1.000		
12	0.361**	-0.098	-0.436**	0.438**	-0.173	-0.154	0.127	0.139	-0.247	0.642**	-0.796**	1.000	
13	0.081	0.054	0.237	0.571**	0.508**	0.487**	0.900**	0.866**	0.342**	0.310*	0.159	0.053	1.000

1.Days to 50% flowering
2.Plant height (cm)
3.Panicle length(cm)
4. Number of productive tillers plant^{-1}
5.Total number of spikelets panicle^{-1}
6.Number of filled grains panicle^{-1}
7.Single plant grain yield (g)
8. Single plant straw yield (g)
9.1000 grain weight (g)
10.Grain length (mm)
11.Grain breadth (mm)
12.L/B ratio of grain
13.Harvest index

Table 64. Phenotypic correlation coefficient between yield and yield component characters in two line rice hybrids (RARS Pattambi)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	0.021	1.000											
3	-0.258*	0.097	1.000										
4	0.116	-0.035	-0.337**	1.000									
5	-0.251*	0.207	0.478**	0.179	1.000								
6	-0.256*	0.236	0.450**	0.146	0.953**	1.000							
7	-0.064	-0.037	0.108	0.524**	0.527**	0.502	1.000						
8	-0.062	-0.056	0.108	0.524**	0.523**	0.497**	0.994**	1.000					
9	-0.096	0.195	0.264*	0.111	0.194	0.089	0.143	0.123	1.000				
10	0.166	0.372**	-0.101	0.362**	0.031	0.029	0.238	0.234	0.155	1.000			
11	-0.264*	0.294*	0.472**	-0.228	0.287*	0.286*	0.089	0.084	0.386**	-0.158	1.000		
12	0.346**	-0.099	-0.384**	0.409**	-0.157	-0.147	0.124	0.137	-0.239	0.622*	-0.792**	1.000	
13	0.039	0.058	0.203	0.513**	0.486**	0.468**	0.880**	0.837**	0.326*	0.294*	0.146	0.052	1.000

1.Days to 50 % flowering
2.Plant height (cm)
3.Panicle length(cm)
4. Number of productive tillers plant^{-1}
5. Total number of spikelets panicle^{-1}
6.Number of filled grains panicle^{-1}
7.Single plant grain yield (g)
8. Single plant straw yield (g)
9.1000 grain weight (g)
11.Grain length (mm)
12.Grain breadth (mm)
13.L/B ratio of grain
14. Harvest index

Single plant grain yield was positively and significantly correlated both at genotypic and phenotypic levels with number of productive tillers plant^{-1} (0.563,0.524), total number of spikelets panicle $^{-1}$ single plant straw yield (0.995, 0.994) and harvest index (0.900,0.880) and number of filled grains panicle^{-1} (0.520,0.502)

Among the various yield components total number of productive tillers plant^{-1} was found to be positively and significantly correlated at both levels with single plant straw yield (0.556, 0.524) grain length (0.437,0.362) L/B ratio of grain (0.438,0.409) and harvest index (0.571,0.513). Panicle length (-0.321,-0.337) exhibited a negative significant correlation with total number of productive tillers plant $^{-1}$

Panicle length was positively and significantly correlated at both levels with total number of spikelets panicle $^{-1}$(0.550,0.478), number of filled grains panicle^{-1} (0.501,0.450), grain breadth (0.525,0.472), L/B ratio of grain (-0.436, -0.384). Days to 50% flowering (-0.317,-0.258). L/B ratio of grain (-0.436,-0.384) exhibited a negative significant correlation. At genotypic level panicle length was positively and significantly correlated with 1000 grain weight (0.333)

Total number of spikelets panicle^{-1} exhibited a positive and significant correlation at both levels with number of filled grains panicle $^{-1}$ (0.969, 0.953) , single plant straw yield (0.545,0.523),grain breadth (0.308,0.287), harvest index (0.508, 0.486) and negatively and significantly correlated at both levels with days to 50% flowering (-0.259, -0.251).

Number of filled grains panicle^{-1} was found to be positively and significantly correlated at genotypic and phenotypic levels with single plant straw yield (0.517, 0.497) , grain breadth (0.291,0.286) , harvest index (0.487,0.468) and negatively and significantly correlated with days to 50% flowering (-0.268, -0.256).

Harvest index showed a positive and significant correlation at genotypic and phenotypic levels with single plant straw yield (0.866, 0.837), 1000 grain weight (0.342,0.326) and grain length (0.310, 0.294).

Grain length showed a positive and significant correlation at genotypic and phenotypic levels with plant height (0.384, 0.372) L/B ratio of grain (0.642, 0.622) grain breadth exhibited a positive and significant correlation at both levels with plant height (0.302, 0.294) and 1000 grain weight (0.411, 0.386) negative and significant correlation at both levels with days to50% flowering (-0.286, -0.264) , L/B ratio of grain (-0.796, -0.792).

L/B ratio of grain showed a positive and significant correlation at both levels with days to 50% flowering (0.361, 0.346).

4.3.3.6 Path analysis

Path analysis was carried out using significance genotypic correlation of eight pollinator parent characters *viz* days to 50% flowering, plant height, number of productive tillers plant $^{-1}$, panicle length, total number of spikelets panicle $^{-1}$, number of filled grains panicle^{-1}, single plant straw yield and harvest index. Abstract of the results are give in **Table 65**

The residual effect was found to be -0.0004. The highest positive direct effect was exhibited by single plant straw yield (0.738) followed by harvest index (0.337), total number of spikelets panicle $^{-1}$ (0.206) and plant height (0.003)

The highest negative direct effect was exhibited by number of filled grains panicle^{-1} (-0.188), panicle length (-0.095), total number of productive tillers plant $^{-1}$ and days to 50% flowering (-0.072)

Table 65. Direct and indirect effects of yield components on grain yield of two line hybrids (RARS Pattambi)

Characters	Days to 50 % flowering	Plant height(cm)	Number of productive tillers plant^{-1}	Panicle length (cm)	Total number of spikelets panicle $^{-1}$	Filled grains panicle $^{-1}$	Single plant straw yield(g)	Harvest index
Days to 50 % flowering	**-0.072**	0.001	-0.007	0.030	-0.054	0.050	-0.045	0.027
Plant height (cm)	-0.002	**0.003**	0.003	-0.010	0.045	-0.047	-0.043	0.018
Number of productive tillers plant^{-1}	-0.007	-0.001	**-0.072**	0.031	0.041	-0.034	0.410	0.192
Panicle length (cm)	0.023	0.003	0.023	**-0.095**	0.113	-0.094	0.113	0.080
Total number of spikelets panicle $^{-1}$	0.019	0.005	-0.014	-0.052	**0.206**	-0.182	0.402	0.171
Number of filled grains panicle $^{-1}$	0.019	0.006	-0.013	-0.048	0.200	**-0.188**	0.381	0.164
Single plant straw yield (g)	0.004	-0.001	-0.040	-0.015	0.112	-0.097	**0.738**	0.291
Harvest index	-0.006	0.001	-0.041	-0.023	0.105	-0.092	0.639	**0.337**

Bold figures indicate direct effects :Residual effect -0.0004

The highest positive indirect effect was observed for harvest index (0.639) followed by total number of productive tillers plant^{-1} (0.410), total number of spikelets panicle $^{-1}$(0.402) through single plant straw yield.

The highest negative indirect effect was observed for single plant straw yield (-0.097) followed by harvest index (-0.092) through number of filled grains panicle^{-1}, total number of spikelets panicle $^{-1}$ (-0.052) through panicle length.

4.3.3.7 Line x Tester analysis

General combining ability effects

Analysis of variance for combining ability for different characters are given in **Table 66.** The estimation of gca effects of lines and mean performance for different characters are given in **Table 67.**

a) Days to 50% flowering

Positive significant gca effects were observed for parents Samyuktha (1.40), Kanchana (0.40) where as the effects were negative and significant for Kairali (-0.97) and Makom (-0.97)

b) Plant height

The parent Aiswarya recorded the maximum and positive significant gca effect (23.13) where as Kanchana (-10.82) , Kairali (-8.74)and Samyuktha (-3.70) recorded negative significant gca effect

c) Total number of productive tillers plant

The parent Makom (2.18) recorded positive significant gca effect where as the parents Aiswarya (-1.07), Kairali (-2.70), Samyuktha (-1.07) recorded negative significant gca effect.

Table 66. Analysis of variance for combining ability for different quantitative traits in RARS Pattambi

Source of variance	df	Day to 50% flowering	Plant height (cm)	Total productive tillers	Panicle length (cm)	Number of spikelets/ panicle	Number of filled spikelets/ panicle	1000 grain weight (g)	Grain length (mm)	Grain breadth (mm)	L/B ratio of grain	Single plant grain yield(g)	Single plant straw yield(g)	Harvest index
Crosses	19	24.899	484.513	17.593	6.136	3272.868	2972.224	14.173	1.479	0.110	1.649	162.391	172.204	0.0094
Lines	3	122.297	18.345	4.291	2.478	5881.900	4760.483	17.951	0.153	0.072	1.743	94.680	100.840	0.0003
Testers	4	8.085	1484.562	29.474	5.132	3044.469	3155.656	19.271	0.589	0.072	0.371	150.391	167.727	0.0015
L x T	12	6.154	267.705	16.958	7.385	2696.744	2464.015	11.529	1.133	0.131	2.051	183.319	191.537	0.0008
Error	28	1.389	1.413	1.077	0.736	51.592	2972.224	0.124	0.060	0.006	0.094	1.213	1.227	0.0003

** Significant at 1% level * Significant at 5% level

Table 67. General combining ability effects (in bold) and mean performance of pollinator parents from 4 x 5 lines x tester (Location: RARS Pattambi)

Parents	Days to 50% flowering	Plant height (cm)	Total number of productive tillers plant^{-1}	Panicle length	Total number of spikelets panicle^{-1}	Number of filled spikelets panicle^{-1}	1000 grain weight	Grain length	Grain breadth	L/B ratio of grain	Single plant grain yield (g)	Single plant straw yield (g)	Harvest index
Aiswarya	**0.15** 86.00	**23.13**** 90.50	**-1.07**** 09.00	**0.96**** 18.25	**27.60**** 87.00	**32.45**** 76.00	**0.59**** 26.22	**0.86**** 6.18	**0.10**** 1.77	**-0.26**** 3.47	**7.87**** 11.67	**1.50**** 16.48	**0.01** 0.38
Kanchana	**0.40*** 84.00	**-10.82**** 71.50	**0.43** 5.50	**0.70**** 20.00	**3.35** 72.00	**1.70** 59.00	**-0.01** 24.72	**-0.29**** 7.35	**-0.07**** 1.59	**0.20**** 4.62	**-2.02**** 11.98	**2.55**** 16.06	**0.01** 0.41
Kairali	**-.0.97*** 83.00	**-8.74**** 100.50	**-2.70**** 4.00	**-0.90**** 20.50	**-13.65**** 78.00	**-9.93**** 64.00	**-2.61**** 22.13	**-0.80**** 6.16	**-0.12**** 1.78	**-0.20*** 3.46	**-1.47**** 11.86	**-8.07**** 16.32	**-0.02*** 0.40
Makom	**-0.97**** 78.00	**0.13** 91.00	**2.18**** 7.00	**-0.54**** 20.50	**5.73**** 88.00	**-4.05*** 75.00	**0.55**** 25.28	**-0.34**** 7.64	**0.07**** 3.05	**-0.11** 2.51	**-7.74**** 18.93	**2.98**** 18.01	**0.01** 0.40
Samyuktha	**1.40**** 84.00	**-3.70**** 127.00	**-1.18**** 5.00	**-0.23** 22.00	**-23.02**** 100.50	**-20.18**** 93.00	**1.48**** 25.32	**-0.11**** 6.69	**0.02** 1.69	**-0.16**** 3.96	**3.36**** 13.80	**1.05**** 18.96	**0.01** 0.39
TGMS 74S	**-1.80**** 93.00	**-3.05**** 89.50	**1.38**** 10.50	**-0.16** 18.50	**-7.50*** 100.00	**3.92**** 90.00	**0.16**** 27.20	**-0.16** 7.88	**-0.09** 1.44	**-0.24** 5.47	**-1.76**** 13.04	**-1.38** 17.06	**-0.01** 0.43
TGMS 81S	**1.90**** 89.00	**-6.15** 86.50	**0.68**** 10:50	**0.88**** 19.50	**41.90**** 110.00	**5.32**** 93.00	**0.17**** 22.90	**-0.04** 8.08	**-0.08** 0.96	**0.15**** 8.42	**2.51**** 11.38	**2.23**** 16.34	**0.00** 0.41
TGMS 82S	**0.70**** 97.50	**4.15**** 95.50	**-0.23** 10.50	**-0.19** 19.50	**16.30*** 102.00	**2.53**** 82.00	**-0.17** 23.43	**0.35**** 8.23	**0.19**** 0.81	**0.33**** 10.16	**2.86**** 11.98	**3.20**** 15.32	**0.00** 0.44
TGMS 91S	**-0.80** 88.00	**5.05**** 100.50	**-1.82** 10.50	**-0.53** 19.00	**18.10**** 103.00	**11.78**** 85.00	**-0.16** 21.83	**-0.15** 8.15	**-0.01** 0.99	**-0.24** 8.23	**-3.62** 11.59	**4.05**** 14.73	**0.00** 0.44
SE of gca (Tester)	**0.31**	**0.31**	**0.27**	**0.23**	**1.89**	**2.00**	**0.09**	**0.06**	**0.02**	**0.08**	**0.29**	**0.29**	**0.01**
SE of gca (Lines)	**0.46**	**0.96**	**0.34**	**0.17**	**1.56**	**1.37**	**-0.16**	**0.03**	**0.01**	**0.05**	**-3.62**	**-4.05**	**0.00**

** Significant at 1% level * Significant at 5% level

d) Panicle length

The parents Aiswarya (0.96) and Kanchana (0.70) recorded significant positive gca effects where as Kairali (-0.90), and Makom (-0.54) recorded negative gca effect

e) Total number of spikelets panicle $^{-1}$

Aiswarya (27.60) and Makom (5.73) recorded significant positive gca effects where as Samyuktha (-23.02) and Kairali (-13.6) recorded negative significant gca effect.

f) Number of filled grains panicle^{-1}

Aiswarya (32.45) recorded the positive significant gca effects while Kairali (-9.93), Makom (-4.05) and Samyuktha (-20.18) recorded negative significant gca effects.

g) 1000 grain weight

The parents Aiswarya (0.59) , Samyuktha (1.48) and Makom (0.55) recorded positive significant gca effect where as Kairali (-2.61) recorded negative gca effect.

h) Grain length

Aiswarya (0.86) and Makom (0.34) recorded positive significant gca effect where as Kanchana (-0.29), and Kairali (-0.80) recorded negative significant gca effects

i) Grain breadth

Aiswarya (0.10) and Makom (0.07) recorded positive significant gca effects. Kanchana (-0.07) and Kairali (-0.12) recorded the negative significant gca effects

j) L/B ratio of grain

Aiswarya (0.26) and Kanchana (0.20) recorded the positive significant gca effect whereas Aiswarya (-0.16) and Kairali (-0.20) recorded the negative significant gca effects.

k) Single plant grain yield

The parent Kairali (-7.62) only recorded negative significant gca effects. All other parents recorded positive significant gca effects

l) Single plant straw yield

Kairali (-8.07) showed negative significant gca effects, all other parents recorded positive significant gca effects.

m) Harvest index

The only one parent Kairali (-0.02) recorded negative significant gca effect.

Specific combining ability effects

The sca effects of twenty crosses for different characters are presented in **Table 68.**

Table 68. Specific combining ability effects (in bold) and mean performance of two line hybrids from 4 x5 line x tester analysis (RARS Pattambi)

Two line hybrids	Day to 50 % flowering	Plant height (cm)	Total productive tillers	Panicle length (cm)	Number of spikelets/ panicle	Number of filled spikelets/ panicle	1000 grain weight (g)	Grain length (mm)	Grain breadth (mm)	L/B ratio of grain	Single plant grain yield (g)	Single plant straw yield(g)	Harvest index
Two line hybrids of TGMS 74S													
	-1.00**	**-3.09****	**0.22**	**-2.36****	**-35.88****	**-38.62****	**1.26****	**0.13**	**-0.08***	**0.46****	**3.87****	**3.33****	**0.01**
T8GMS 74S x Aiswarya	90.50	96.25	14.50	19.70	82.00	65.00	27.44	7.86	1.37	5.84	31.15	35.76	0.47
	0.50	**-3.52****	**0.97***	**-1.24****	**14.75****	**9.50****	**0.23**	**-0.31****	**-0.06***	**-0.14**	**1.87****	**2.18****	**0.00**
TGMS 74S x Kanchana	91.00	88.70	14.50	21.75	159.00	135.00	24.92	7.24	1.29	5.60	29.83	36.12	0.45
	2.38**	**-5.05****	**2.10****	**0.61***	**55.75****	**53.62****	**-1.26****	**0.00**	**-0.01**	**0.14**	**18.95****	**19.31****	**0.04**
TGMS 74S x Kairali	91.50	89.25	12.50	22.00	183.00	167.50	20.83	7.03	1.28	5.47	37.58	42.63	0.47
	-0.12	**17.83****	**1.22****	**1.75****	**13.38****	**17.75****	**-0.49****	**0.47****	**0.11****	**-0.02**	**- 12.22****	**-12.55****	**-0.02**
TGMS 74S x Makom	89.00	121.00	16.50	23.5	160.00	137.50	24.76	8.65	1.60	5.40	17.25	21.82	0.44
	-1.75**	**-6.17****	**-4.53****	**1.25****	**-48.00****	**-42.25****	**0.26**	**-0.28****	**0.04**	**-0.42****	**-12.47****	**-12.27****	**-0.03**
TGMS 74S x Samyuktha	88.50	120.00	7.50	24.50	120.50	114.00	25.55	8.41	1.57	5.38	15.41	20.62	0.43
Two line hybrids of TGMS 81S													
	-1.70**	**2.45****	**4.82****	**-0.36**	**24.12****	**28.58****	**1.14****	**-0.01**	**-0.25****	**0.85****	**2.80****	**2.72****	**0.01**
TGMS 81S x Aiswarya	86.50	100.50	19.00	22.25	129.50	127.50	26.03	7.18	1.28	5.59	32.04	37.90	0.46
	-0.20	**-0.43**	**-2.43****	**2.86****	**24.25****	**23.20****	**-2.21****	**-1.36****	**0.29****	**-1.83****	**3.40****	**4.12****	**0.00**
TGMS 81S x Kanchana	87.00	90.50	11.10	26.40	156.00	144.00	21.19	5.65	1.73	3.27	33.32	40.80	0.45
	-1.17**	**7.74****	**-1.30****	**0.41**	**-25.25****	**-35.17****	**0.34***	**0.83****	**0.12****	**0.18**	**-7.00****	**-7.81****	**-0.01**
TGMS 81S x Kairali	87.00	100.75	9.00	22.35	89.50	74.00	21.14	7.34	1.50	4.88	13.58	18.25	0.41
	0.67*	**-14.88****	**0.32**	**-2.60****	**-41.62****	**-26.55****	**-0.12**	**0.45****	**-0.08***	**0.60****	**2.10****	**1.47****	**0.01**
TGMS 81S x Makom	86.50	87.00	15.50	19.70	92.50	88.50	23.83	810	1.50	5.39	33.53	38.58	0.47
	0.05	**5.12****	**-1.43****	**-0.30**	**18.50****	**-24.22****	**0.85****	**0.09**	**-0.07**	**0.19**	**-1.29****	**-0.51**	**-0.01**
TGMS 81S x Samyuktha	87.00	130.00	10.50	23.50	174.50	161.50	24.85	8.25	1.54	5.35	28.55	35.11	0.44
Two line hybrids of TGMS 82S													

Table 68. (Contd…)

TGMS 82S x Aiswarya	**1.40****	**-0.30**	**-1.48****	**0.61***	**10.82****	**4.28**	**-2.17****	**0.01**	**0.29****	**-1.09****	**-4.01****	**-3.38****	**-0.02**
	95.00	95.75	13.50	22.50	100.00	75.50	23.56	7.30	1.72	4.23	19.03	25.49	0.43
	0.90**	**12.07****	**0.77**	**-2.12****	**-54.05****	**-50.10****	**0.57****	**0.48****	**-0.30****	**1.66****	**-4.82****	**-6.39****	**0.00**
TGMS 82S x Kanchana	93.50	101.00	15.00	20.70	61.50	43.00	24.80	7.59	1.04	7.34	18.89	23.98	0.44
	-1.22**	**9.49****	**-0.10**	**-0.22**	**-9.55****	**-0.97**	**3.34****	**0.28****	**0.28****	**-0.88****	**-0.44**	**0.41**	**-0.01**
TGMS 82S x Kairali	90.00	100.50	11.00	21.10	89.00	80.50	24.98	6.87	1.57	4.39	13.93	20.16	0.41
	-2.22**	**-13.88****	**-0.48**	**0.52**	**25.57****	**27.65****	**-3.25****	**-0.79****	**0.02**	**-0.72****	**5.33****	**6.09****	**0.00**
TGMS 82S x Makom	89.00	86.00	15.50	22.10	143.50	115.00	21.55	6.95	1.50	4.65	30.55	36.90	0.45
	1.15**	**-7.38****	**1.27****	**1.22****	**27.20****	**19.15****	**1.51****	**0.03**	**-0.29****	**1.02****	**3.93****	**3.27****	**0.02***
TGMS 82S x Samyuktha	93.50	115.50	14.00	24.30	167	143.00	26.35	8.28	1.23	6.76	27.56	32.60	0.46
Two line hybrids of TGMS 91S													
	1.30**	**0.93**	**-3.57****	**2.12****	**0.92**	**5.78**	**-0.23**	**-0.12**	**0.04**	**-0.22**	**-2.65****	**-2.67****	**0.00**
TGMS 91S x Aiswarya	87.00	98.67	12.00	25.10	147.50	130.00	27.83	7.16	1.66	4.32	27.18	33.19	0.45
	-1.20**	**-8.11****	**0.68**	**0.50**	**15.05****	**17.40****	**1.41****	**1.19****	**0.07**	**0.31***	**-0.46**	**0.09**	**0.00**
TGMS 91S x Kanchana	83.50	82.50	15.50	24.40	188.00	163.50	27.97	8.29	1.59	5.22	30.05	37.45	0.45
	-2.33**	**-12.19****	**-0.70**	**-0.80***	**-20.95****	**-17.47****	**-2.41****	**-1.11****	**-0.38****	**0.56****	**-11.51****	**-11.91****	**-0.03**
TGMS 91S x Kairali	81.00	80.50	11.00	21.50	135.00	117.00	21.56	5.48	1.09	5.05	9.66	14.83	0.39
	1.67**	**10.94****	**-1.07***	**0.34**	**2.67**	**-18.85****	**3.85****	**-0.13**	**-0.05**	**0.15**	**4.80****	**4.99****	**0.00**
TGMS 91S x Makom	85.00	112.50	15.50	23.00	178.00	121.50	30.97	7.60	1.61	4.74	36.82	42.78	0.46
	0.55*	**8.49****	**4.68****	**-2.16****	**2.30**	**13.15****	**-2.62****	**0.17**	**0.32****	**-0.80****	**9.83****	**9.50****	**0.02***
TGMS 91S x Samyuktha	85.00	133.00	18.00	22.00	199.50	190.00	24.54	8.41	2.02	4.16	40.26	45.81	0.47
SE of SCA	**0.31**	**0.54**	**0.47**	**0.39**	**3.27**	**3.46**	**0.16**	**0.11**	**0.04**	**0.14**	**0.50**	**0.50**	**0.01**

a) Days to 50% flowering

The specific combining ability affects ranged between -2.33 (TGMS 91S x Kairali) and 2.38 (TGMS 74S x Kairali). Out of 20 hybrids eight combinations showed positive and negative significant sca effects.

b) Plant height

The sca effect ranged from -14.88 (TGMS 81S x Makom) to 17.83 (TGMS 74S x Makom). Out of 20 cross combinations seven combinations were observed with significant negative sca effects where as six combinations obsereved positive significant sca effect

c) Total number of productive tillers plant^{-1}

The sca effects ranged between -4.53 (TGMS 74S x Samyuktha) and 4.68 (TGMS 91S x Samyuktha) .Out of 20 cross combinations, seven combinations were observed with negative significant and six combinations with significant negative sca effects.

d) Panicle length

The sca effects ranged from -2.60 (TGMS 81S x Makom) and 2.86 (TGMS 81S x Kanchana). Out of twenty cross combinations, seven combinations were observed with positive significant and six with negative significant.

e) Total number of spikelets panicle $^{-1}$

The sca effects ranged from -54.05 (TGMS 82S x Kanchana) and 55.75(TGMS 74S x Kairali) .Out of 20 cross combinations ten combinations were observed with positive significance and seven showed negative significance

f) Number of filled grains panicle^{-1}

The sca effect ranged from -50.10(TGMS 82S x Kanchana) to 53.62(TGMS 74S x Kairali). Out of 20 cross combinations, nine combinations were observed with positive significant and eight combinations were observed with negative significant.

g) 1000 grain weight

The sca effects ranged from -3.25 (TGMS 82S x Makom) and 3.85 (TGMS 91S x Makom). Out of 20 cross combinations, nine showed positive significance and seven showed negative significance.

h) Grain length

The sca effect ranged from -1.36 (TGMS 81S x Kanchana) and 1.19 (TGMS 91S x Kanchana). Out of 20 cross combinations, six showed positive significance and five showed negative significance.

i) Grain breadth

The sca effects ranged from -0.38 (TGMS 91S x Kairali) and 0.32 (TGMS 91S x Samyuktha) .Out of twenty cross combinations, seven showed positive and seven combinations showed negative significance.

j) L/B ratio of grain

The sca effect ranged from -1.83 (TGMS 81S x Kanchana) to 1.66 (TGMS 82S x Kanchana) . Out of 20 cross combinations, seven combinations showed positive and six combinations showed negative significant.

k) Single plant grain yield

The sca effects ranged from -12.47 (TGMS 74S x Samyuktha) to 18.95 (TGMS 74S x Kairali) .Out of twenty cross combinations, ten combinations showed positive and eight showed negative significant.

l) Single plant straw yield

The sca effects ranged from -12.55 (TGMS 74S x Makom) to 19.31 (TGMS 74S x Kairali) . Out of twenty cross combinations, ten cross combinations showed positive significant sca effect and seven showed negative significant sca effect.

m) Harvest index

The sca effects ranged from -0.03 (TGMS 74S x Samyuktha)and TGMS 91S x Kairali to 0.04 (TGMS 74S x Kairali). Out of twenty cross combinations, only two combinations showed significant sca effects.

4.3.3.8 Estimation of heterosis

The mean performance of hybrids and parents are given in **Table 69**. The extent of heterosis for individual traits are given in **Table 70 to 75**

a) Days to50% flowering

The range of relative heterosis was from -5.26 (TGMS 91S x Kairali) to 3.97(TGMS 74S x Kairali) The magnitude of heterobeltiosis range between -4.70 (TGMS 91S x Kairali) and 11.76 (TGMS 82S x Aiswarya). Standard heterosis ranged from -2.40 (TGMS 91S x Kairali) to 12.65 (TGMS 74S x Makom) TGMS 82S x Makom (12.65)

b) Plant height

The extent of heterosis over mid parental value varied from -19.90 (TGMS 91S x Kairali) and 21.77 (TGMS 81S x Samyuktha). The magnitude of heterobeltiosis ranged between -19.90 (TGMS 91S x Kairali) and 50.28 (TGMS 81S x Samyuktha) Standard heterosis ranged from -36.61 (TGMS 91S x Kairali) and 4.72 (TGMS 91S x Samyuktha)

Table 69. *Per se* performance of parents and hybrids (RARS Pattambi)

Sl.No	Parents	Days to 50% flowering	Plant Height (cm)	Total number of Productive tillers^{-1}	Panicle length (cm)	Total number of Spikelets panicle^{-1}	Number of Filled Spikelets panicle^{-1}	1000 grain weight (g)	Grain length (mm)	Grain breadth (mm)	L/B ratio of grain	Single plant grain yield (g)	Single plant straw yield (g)	Harvest index
	LINES													
1	TGMS 74S	93.0	89.5	10.50	18.5	100.00	90.00	27.20	7.88	1.44	5.47	13.04	17.06	0.43
2	TGMS 81S	89.0	86.5	15.50	19.5	110.00	93.00	22.90	8.08	0.96	8.42	11.38	16.34	0.41
3	TGMS 82S	97.5	95.5	10.50	19.5	102.00	82.00	23.43	8.23	0.81	10.16	11.98	15.32	0.44
4	TGMS 91S	88.0	100.5	10.50	19.0	103.00	85.00	21.83	8.15	0.99	8.23	11.59	14.73	0.44
	TESTERS													
1	Aiswarya	86.0	90.5	9.00	18.2	87.00	76.00	19.83	6.18	1.77	3.47	10.21	16.48	0.38
2	Kanchana	84.0	71.5	5.50	20.0	72.00	59.00	28.00	7.35	1.59	4.62	11.32	16.08	0.41
3	Kairali	83.0	100.5	4.00	20.5	78.00	64.00	20.30	6.16	1.78	3.46	11.01	16.32	0.40
4	Makom	79.0	91.0	7.00	20.5	88.00	75.00	23.18	7.64	3.05	2.51	12.01	18.01	0.40
5	Samyuktha	85.0	127.0	5.00	22.0	100.50	93.00	28.30	6.69	1.69	3.96	12.63	18.96	0.39

Table 69. (Contd...)

1	TGMS 74S xAiswarya	90.50	96.25	14.50	19.70	82.00	65.00	27.44	7.86	1.37	5.84	31.15	35.76	0.47
2	TGMS 74S x Kanchana	91.00	88.70	14.50	21.75	159.00	135.00	24.92	7.24	1.29	5.60	29.83	36.12	0.45
3	TGMS 74S x Kairali	91.50	89.25	12.50	22.00	183.00	167.00	20.83	7.03	1.28	5.47	37.58	42.63	0.47
4	TGMS 74S x Makom	89.00	121.00	16.50	23.50	160.00	137.00	24.76	8.65	1.60	5.40	17.25	21.82	0.44
5	TGMS 74S x Samyuktha	88.50	120.00	7.50	24.50	120.00	114.00	25.55	8.41	1.57	5.38	15.41	20.62	0.41
6	TGMS 81S xAiswarya	86.50	100.50	19.00	22.25	129.00	127.00	26.03	7.18	1.28	5.59	32.04	37.90	0.46
7	TGMS 81S x Kanchana	87.00	90.50	11.00	26.40	156.00	144.00	21.19	5.65	1.73	3.27	33.32	40.80	0.45
8	TGMS 81S x Kairali	87.00	100.75	9.00	22.35	89.00	74.00	21.14	7.34	1.50	4.88	13.58	18.25	0.41
9	TGMS 81S x Makom	86.50	87.00	15.50	19.70	92.00	88.00	23.83	8.10	1.50	5.39	33.53	38.58	0.47
10	TGMS 81S x Samyuktha	87.50	130.00	10.50	23.50	174.00	161.00	24.85	8.25	1.54	5.35	28.55	35.11	0.44
11	TGMS 82S xAiswarya	95.00	95.75	13.50	22.50	100.00	75.00	23.56	7.30	1.72	4.23	19.03	25.49	0.43
12	TGMS 82S x Kanchana	93.50	101.00	15.00	20.70	61.00	43.00	24.80	7.59	1.04	7.34	18.89	23.98	0.44
13	TGMS 82S x Kairali	90.00	100.50	11.00	21.00	89.00	80.00	24.98	6.87	1.57	4.39	13.93	20.16	0.41
14	TGMS 82S x Makom	89.00	86.00	15.50	22.10	143.00	115.00	21.55	6.96	1.50	4.65	30.55	36.90	0.45
15	TGMS 82S x Samyuktha	93.50	115.50	14.00	24.30	167.00	143.00	26.35	8.28	1.23	6.76	27.56	32.60	0.46
16	TGMS 91S xAiswarya	87.00	98.67	12.00	25.10	147.00	130.00	27.83	7.16	1.66	4.32	27.18	33.19	0.45
17	TGMS 91S x Kanchana	83.50	82.50	15.50	24.40	188.00	163.00	27.97	8.29	1.59	5.22	30.05	37.45	0.45

Table 69. (Contd...)

18	TGMS 91S x Kairali	81.00	80.50	11.00	21.50	135.00	117.00	21.56	5.48	1.09	5.05	09.66	14.83	0.39
19	TGMS 91S x Makom	85.00	112.50	15.50	23.00	178.00	121.00	30.97	7.60	1.61	4.74	36.82	42.78	0.46
20	TGMS 91S x Samyuktha	85.00	133.00	18.00	22.00	199.00	190.00	24.54	8.41	2.02	4.16	40.26	45.81	0.47
21	TGMS 81S x Matta Triveni	82.50	90.00	13.50	27.10	146.00	119.00	25.55	8.43	1.57	5.37	37.82	42.90	0.47
22	TGMS 81S x Prathyasa	90.50	87.50	12.50	25.10	159.00	135.00	31.30	7.17	2.00	3.60	27.30	32.42	0.46
23	TGMS 82S x Prathyasa	93.00	88.50	19.00	20.15	130.00	116.00	21.58	10.05	0.69	14.45	34.60	41.57	0.45
24	TGMS 91S x Matta Triveni	85.00	104.00	12.50	22.10	87.00	75.00	26.04	8.23	1.60	5.16	17.25	23.65	0.43
25	TGMS 91S x Varsha	88.00	102.50	14.00	24.50	180.00	166.00	27.74	7.01	1.63	4.31	27.77	31.26	0.47

Table 70. Magnitude of heterosis for days to 50 % flowering and plant height (RARS Pattambi)

Sl. No.	Hybrids	Days to flowering			Plant height		
		d_i	d_{ii}	$d_{iii(1)}$		d_{ii}	$d_{iii(1)}$
1	TGMS 74S xAiswarya	1.11**	6.47**	5.23**	6.94**	7.54**	-24.21**
2	TGMS 74S x Kanchana	2.82**	7.05**	8.33**	10.18**	24.05**	-30.15**
3	TGMS 74S x Kairali	3.97**	7.64**	10.24**	-6.05**	-0.27**	-29.72**
4	TGMS 74S x Makom	3.48**	4.70**	12.65**	34.07**	35.19**	-4.72**
5	TGMS 74S x Samyuktha	-0.56**	4.11**	4.11**	10.85**	34.07**	-5.51**
6	TGMS 81S xAiswarya	-1.14**	1.76**	0.58**	13.55**	16.18**	-20.86**
7	TGMS 81S x Kanchana	0.57**	2.35**	3.57**	14.55**	26.57**	-28.74**
8	TGMS 81S x Kairali	1.16**	2.35**	4.81**	7.75**	16.47**	-20.66**
9	TGMS 81S x Makom	2.97**	1.76**	9.49**	-1.97**	0.57**	-31.49**
10	TGMS 81S x Samyuktha	0.00**	2.35**	2.35**	21.77**	50.28**	2.36**
11	TGMS 82S xAiswarya	3.54**	11.76**	10.46**	2.95**	5.80**	-24.60**
12	TGMS 82S x Kanchana	3.03**	10.00**	11.30**	20.95**	41.25**	-20.47**
13	TGMS 82S x Kairali	-0.27**	5.88**	8.43**	2.55**	5.23**	-20.86**
14	TGMS 82S x Makom	0.84**	4.70**	12.65**	-7.77**	-5.49**	-32.28**
15	TGMS 82S x Samyuktha	2.46**	10.00**	10.00**	3.82**	20.94**	-9.05**
16	TGMS 91S xAiswarya	0.00	2.35**	1.16**	3.31**	9.02**	-22.30**
17	TGMS 91S x Kanchana	-2.90**	-1.76**	-0.59**	-4.06**	15.38**	-35.03**
18	TGMS 91S x Kairali	-5.26**	-4.70**	-2.40**	-19.90**	-19.90**	-36.61**
19	TGMS 91S x Makom	1.79**	0.00**	7.59**	17.49**	23.62**	-11.41**
20	TGMS 91S x Samyuktha	-1.73**	0.00	0.00**	16.92**	32.33**	4.72**
21	TGMS 81S x Matta Triveni	-4.62**	-2.94**	-1.78**	10.09**	4.04**	-29.13**
22	TGMS 81S x Prathyasa	1.11**	6.47**	0.55**	8.35**	1.15**	-31.10**
23	TGMS 82S x Prathyasa	-0.80**	9.41**	3.33**	3.81**	-7.32**	-30.31**
24	TGMS 91S x Matta Triveni	-1.16**	0.00**	1.19**	17.14**	3.48**	-18.11**
25	TGMS 91S x Varsha	2.32**	3.52**	4.76**	18.15**	1.99**	-19.29**

Table 71. Magnitude of heterosis for total number of productive tillers plant^{-1}and panicle length (RARS Pattambi)

Sl. No.	Hybrids	Total productive tillers			Panicle length		
		d_i	d_{ii}		d_i	d_{ii}	$d_{iii\,(1)}$
1	TGMS 74S xAiswarya	48.71**	38.09**	190.00**	7.21**	7.94**	-10.45**
2	TGMS 74S x Kanchana	81.21**	38.09**	190.00**	12.98**	8.75**	-1.13**
3	TGMS 74S x Kairali	72.41**	19.04**	150.00**	12.82**	7.31**	0.00
4	TGMS 74S x Makom	88.57**	57.14**	230.00**	20.51**	14.63**	6.81**
5	TGMS 74S x Samyuktha	-3.22**	-28.57**	500.00**	20.98**	11.36**	11.36**
6	TGMS 81S xAiswarya	55.10**	22.58**	280.00**	17.88**	21.91**	1.13**
7	TGMS 81S x Kanchana	4.76**	-29.03**	120.00**	33.67**	32.00**	20.00**
8	TGMS 81S x Kairali	-7.69**	-41.93**	80.00**	11.75**	9.02**	1.59**
9	TGMS 81S x Makom	37.77**	0.00	210.00**	-1.50**	-3.90**	-10.45**
10	TGMS 81S x Samyuktha	2.43**	-32.25**	110.00**	13.25**	6.81**	6.81**
11	TGMS 82S xAiswarya	38.46**	28.57**	170.00**	19.20**	23.28**	2.27**
12	TGMS 82S x Kanchana	87.50**	42.85**	200.00**	4.81**	3.50**	-5.90**
13	TGMS 82S x Kairali	51.72**	4.76**	120.00**	5.00**	2.43**	-4.54**
14	TGMS 82S x Makom	77.14**	47.61**	210.00**	10.50**	7.80**	0.45**
15	TGMS 82S x Samyuktha	80.64**	33.33**	180.00**	17.10**	10.45**	10.45**
16	TGMS 91S xAiswarya	23.07**	14.28**	140.00**	34.76**	37.53**	14.09**
17	TGMS 91S x Kanchana	93.75**	47.61**	210.00**	25.12**	22.00**	10.90**
18	TGMS 91S x Kairali	51.72**	4.76**	120.00**	8.86**	4.87**	-2.27**
19	TGMS 91S x Makom	77.14**	47.61**	210.00**	16.45**	12.19**	4.54**
20	TGMS 91S x Samyuktha	132.25**	71.42**	260.00**	7.31**	0.00	0.00
21	TGMS 81S x Matta Triveni	25.58**	-12.90**	170.00**	35.50**	32.19**	23.18**
22	TGMS 81S x Prathyasa	-12.28**	-19.35**	150.00**	19.52**	11.55**	14.09**
23	TGMS 82S x Prathyasa	61.70**	80.95**	280.00**	-4.04**	-10.44**	-8.40**
24	TGMS 91S x Matta Triveni	51.51**	19.04**	150.00**	11.89**	7.80**	0.45**
25	TGMS 91S x Varsha	80.64**	33.33**	180.00**	25.64**	22.50**	11.36**

Table 72. Magnitude of heterosis for total number of spikelets panicle^{-1} and number of filled grains panicle^{-1}(RARS Pattambi)

Sl. No.	Hybrids	Total number of spikelets panicle-1			Number of filled grains panicle^{-1}		
		d_i	d_{ii}	$d_{iii\,(1)}$	d_i	d_{ii}	$d_{iii\,(1)}$
1	TGMS 74S xAiswarya	-12.29**	-18.00**	-18.40**	-21.68**	-27.77**	-30.10**
2	TGMS 74S x Kanchana	84.88**	59.00**	58.20**	81.20**	50.00**	45.16**
3	TGMS 74S x Kairali	105.61**	83.00**	82.08**	117.53**	86.11**	80.10**
4	TGMS 74S x Makom	70.21**	60.000**	59.20**	66.66**	52.77**	47.84**
5	TGMS 74S x Samyuktha	20.19**	20.50**	19.90**	24.59**	22.58**	22.58**
6	TGMS 81S xAiswarya	31.47**	17.72**	28.85**	50.88**	37.09**	37.09**
7	TGMS 81S x Kanchana	71.42**	41.81**	55.22**	89.47**	54.83**	54.83**
8	TGMS 81S x Kairali	-4.78**	-18.63**	-10.94**	-5.73**	-20.43**	-20.43**
9	TGMS 81S x Makom	-6.56**	-15.90**	-7.96**	5.35**	-4.83**	-4.83**
10	TGMS 81S x Samyuktha	65.79**	58.63**	73.63**	73.65**	73.65**	73.65**
11	TGMS 82S xAiswarya	5.82**	-1.96**	-0.49**	-4.43**	-7.92**	-18.81**
12	TGMS 82S x Kanchana	-29.31**	-39.70**	-38.80**	-39.00**	-47.56**	-53.76**
13	TGMS 82S x Kairali	-1.11**	-12.74**	-11.44**	10.27**	-1.82**	-13.44**
14	TGMS 82S x Makom	51.05**	40.68**	42.78**	46.49**	40.24**	23.65**
15	TGMS 82S x Samyuktha	64.93**	63.72**	66.16**	63.42**	53.76**	53.76**
16	TGMS 91S xAiswarya	55.26**	43.20**	46.76**	61.49**	52.94**	39.78**
17	TGMS 91S x Kanchana	114.85**	82.52**	87.06**	127.08**	92.35**	75.80**
18	TGMS 91S x Kairali	49.17**	31.06**	34.32**	57.04**	37.64**	25.80**
19	TGMS 91S x Makom	86.38**	72.81**	77.11**	51.87**	42.94**	30.64**
20	TGMS 91S x Samyuktha	96.06**	93.68**	98.50**	113.48**	104.30	104.30**
21	TGMS 81S x Matta Triveni	52.08**	32.72**	45.27**	39.18**	27.95**	27.95**
22	TGMS 81S x Prathyasa	109.86**	45.00**	58.70**	109.30**	45.16**	45.16**
23	TGMS 82S x Prathyasa	80.55**	27.45**	29.35**	96.61**	41.46**	24.73**
24	TGMS 91S x Matta Triveni	-5.40**	-15.04**	-12.93**	-7.97**	-11.76**	-19.35**
25	TGMS 91S x Varsha	111.76**	74.75**	79.10**	141.30**	95.88**	79.03**

Table 73. Magnitude of heterosis for 1000 grain weight and Grain length (RARS Pattambi)

Sl. No.	Hybrids	1000 grain weight(g)			Grain length		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1	TGMS 74S x Aiswarya	16.69**	0.88**	-3.03**	11.80**	-0.25**	17.48**
2	TGMS 74S x Kanchana	-9.71**	-11.00**	-11.94**	-4.92**	-8.12**	8.22**
3	TGMS 74S x Kairali	-12.29**	-23.41**	-26.39**	0.14**	-10.78**	5.08**
4	TGMS 74S x Makom	-1.70**	-8.97**	-12.50**	11.46**	9.77**	29.29**
5	TGMS 74S x Samyuktha	-7.92**	-9.71**	-9.71**	15.44**	6.72**	25.71**
6	TGMS 81S xAiswarya	24.96**	19.23**	-8.02**	0.66**	-11.19**	7.32**
7	TGMS 81S x Kanchana	-14.95**	-24.32**	-25.12**	-26.78**	-30.11**	-15.54**
8	TGMS 81S x Kairali	0.35**	-3.16**	-25.30**	3.05**	-9.21**	9.71**
9	TGMS 81S x Makom	5.88**	2.80**	-15.79**	3.02**	0.18**	21.07**
10	TGMS 81S x Samyuktha	-0.85**	-12.19**	-12.19**	11.67**	2.04**	23.31**
11	TGMS 82S x Aiswarya	8.92**	0.55**	-16.74**	1.31**	-11.30**	9.11**
12	TGMS 82S x Kanchana	-3.55**	-11.42**	-12.36**	-2.56**	-7.77**	13.45**
13	TGMS 82S x Kairali	14.24**	6.61**	-11.73**	-4.51**	-16.52**	2.69**
14	TGMS 82S x Makom	-7.53**	-8.02**	-23.85**	-12.24**	-15.37**	4.11**
15	TGMS 82S x Samyuktha	1.87**	-6.89**	-6.89**	10.99**	0.60**	23.76**
16	TGMS 91S xAiswarya	30.25**	21.52**	-1.66**	-0.06**	-12.14**	7.02**
17	TGMS 91S x Kanchana	9.90**	-0.10**	-1.16**	6.96**	1.71**	23.91**
18	TGMS 91S x Kairali	-0.18**	-5.85**	-23.81**	-23.41**	-32.76**	-18.08**
19	TGMS 91S x Makom	34.45**	33.60**	9.43**	-3.73**	-6.74**	13.60**
20	TGMS 91S x Samyuktha	-4.14**	-13.28**	-13.28**	13.34**	3.19**	25.71**
21	TGMS 81S x Matta Triveni	8.23**	0.66**	-9.71**	17.00**	4.33**	26.00**
22	TGMS 81S x Prathyasa	30.11**	19.10**	10.60**	-0.20**	-11.26**	7.17**
23	TGMS 82S x Prathyasa	-13.17**	-17.88**	-23.74**	38.42**	22.11**	50.22**
24	TGMS 91S x Matta Triveni	7.87**	2.60**	-7.98**	13.67**	0.98	23.01**
25	TGMS 91S x Varsha	19.31**	17.54**	-1.97**	3.54**	-13.98**	4.78**

Table 74. Magnitude of heterosis for Grain breadth and L/B ratio of grain (RARS Pattambi)

Sl. No.	Hybrids	Grain breadth			L/B ratio of grain		
		d_I	d_{II}	d_{III}	d_I	d_{II}	d_{III}
1	TGMS 74S x Aiswarya	-14.64**	-22.59**	-18.93**	30.64**	6.76**	47.47**
2	TGMS 74S x Kanchana	-14.85**	-18.86**	-23.66**	11.00**	2.37**	41.41**
3	TGMS 74S x Kairali	-20.49**	-28.08**	-24.26**	22.50**	0.00**	38.13**
4	TGMS 74S x Makom	-28.73**	-47.54**	-5.32**	35.33**	-1.27**	36.36**
5	TGMS 74S x Samyuktha	0.31**	-7.10**	-7.10**	14.10**	-1.64**	35.85**
6	TGMS 81S xAiswarya	-6.22**	-27.68**	-24.26**	-5.97**	-33.61**	41.16**
7	TGMS 81S x Kanchana	35.68**	8.80**	2.36**	-49.84**	-61.16**	-17.42**
8	TGMS 81S x Kairali	9.48**	-15.73**	-11.24**	-17.84**	-42.04**	23.23**
9	TGMS 81S x Makom	-25.18**	-50.81**	-11.24**	-1.37**	-35.98**	36.11**
10	TGMS 81S x Samyuktha	16.22**	-8.87**	-8.87**	-13.57**	-36.46**	35.10**
11	TGMS 82S xAiswarya	33.33**	-2.82**	1.77**	-37.93**	-58.36**	6.81**
12	TGMS 82S x Kanchana	-13.33**	-34.59**	-38.46**	-0.67**	-27.75**	85.35**
13	TGMS 82S x Kairali	21.23**	-11.79**	-7.10**	-35.53**	-56.79**	10.85**
14	TGMS 82S x Makom	-22.27**	-50.81**	-11.24**	-26.59**	-54.23**	17.42**
15	TGMS 82S x Samyuktha	-1.60**	-27.21**	-27.21**	-4.24**	-33.46**	70.70**
16	TGMS 91S x Aiswarya	20.28**	-6.21**	-1.77**	-26.15**	-47.50**	9.09**
17	TGMS 91S x Kanchana	23.25**	0.00	-5.91**	-18.75**	-36.57**	31.81**
18	TGMS 91S x Kairali	-21.29**	-38.76**	-35.50**	-13.60**	-38.63**	27.52**
19	TGMS 91S x Makom	-20.29**	-47.21**	-4.73**	-11.73**	-42.40**	19.69**
20	TGMS 91S x Samyuktha	50.74**	19.52**	19.52**	-31.74**	-49.45**	5.05**
21	TGMS 81S x Matta Triveni	26.10**	2.61**	-7.10**	-14.49**	-36.22**	35.60**
22	TGMS 81S x Prathyasa	60.64**	30.71**	18.34**	-39.18**	-57.24**	-9.09**
23	TGMS 82S x Prathyasa	-47.92**	-62.50**	-59.17**	112.81**	42.22**	264.89**
24	TGMS 91S x Matta Triveni	25.49**	2.56**	-5.32**	-27.83**	-49.21**	30.30**
25	TGMS 91S x Varsha	27.84**	4.48**	-3.55**	-26.26**	-47.63**	8.83**

Table 75. Magnitude of heterosis for single plant grain yield, single plant straw yield and harvest index(RARS Pattambi)

Sl. No.	Hybrids	Single plant grain yield			Single plant straw yield			Harvest index		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1	TGMS 74S x Aiswarya	167.95**	138.88**	146.63**	113.23**	109.61**	88.60**	16.04**	0.00**	20.51**
2	TGMS 74S x Kanchana	144.90**	128.75**	136.18**	117.98**	111.72**	90.50**	7.14**	0.00**	15.38**
3	TGMS 74S x Kairali	212.51**	188.19**	197.54**	155.42**	149.88**	124.84**	13.25**	0.00**	20.51**
4	TGMS 74S x Makom	37.724**	32.28**	36.57**	24.43**	21.15**	15.08**	6.02**	0.00**	12.82**
5	TGMS 74S x Samyuktha	20.06**	18.17**	22.01**	14.49**	8.75**	8.75**	0.73**	-3.95**	5.89**
6	TGMS 81S x Aiswarya	196.80**	181.54**	153.68**	130.95**	129.97**	99.89**	16.45**	0.00**	17.94**
7	TGMS 81S x Kanchana	193.56**	192.79**	163.81**	151.69**	149.69**	115.18**	9.75**	0.00**	15.38**
8	TGMS 81S x Kairali	21.30**	19.33**	7.52**	11.75**	11.68**	-3.74**	1.23**	0.00	5.12**
9	TGMS 81S x Makom	186.70**	179.18**	165.47**	2145.00**	204.92**	193.63**	16.04**	0.00**	20.51**
10	TGMS 81S x Samyuktha	137.81**	126.04**	126.04**	98.92**	85.17**	85.17**	10.00**	0.00**	12.82**
11	TGMS 82S x Aiswarya	71.51**	58.84**	50.67**	60.31**	54.67**	34.44**	4.87**	-2.27**	10.25**
12	TGMS 82S x Kanchana	62.14**	57.67**	49.56**	52.73**	49.12**	26.47**	3.52**	0.00**	12.82**
13	TGMS 82S x Kairali	21.18**	16.27**	10.29**	27.43**	23.52**	6.32**	-2.38**	-6.81**	5.12**
14	TGMS 82S x Makom	154.68**	154.37**	141.88**	121.42**	104.88**	94.62**	7.14**	0.00**	15.38**
15	TGMS 82S x Samyuktha	123.97**	118.21**	118.21**	90.19**	71.94**	71.94**	10.84**	0.00**	17.94**
16	TGMS 91S x Aiswarya	149.35**	134.51**	115.20**	112.68**	101.39**	75.05**	9.75**	0.00**	15.38**
17	TGMS 91S x Kanchana	162.33**	159.27**	137.92**	143.10**	132.89**	97.52**	5.88**	0.00**	15.38**
18	TGMS 91S x Kairali	-14.51**	-16.65**	-23.51**	-4.47**	-9.12**	-21.78**	-7.14**	-11.36**	0.00
19	TGMS 91S x Makom	212.03**	206.57**	191.52**	161.33**	137.53**	125.63**	9.52**	0.00**	17.94**
20	TGMS 91S x Samyuktha	232.45**	218.76**	218.76**	171.95**	141.61**	141.61**	13.25**	0.00**	20.51**
21	TGMS 81S x Matta Triveni	249.53**	232.33**	199.44**	222.55**	162.54**	126.26**	20.51**	0.00**	20.51**
22	TGMS 81S x Prathyasa	139.47**	139.05**	116.15**	133.57**	98.40**	70.99**	8.23**	0.00**	17.94**
23	TGMS 82S x Prathyasa	195.72**	188.81**	173.95**	210.92**	171.34**	119.25**	2.27**	0.00**	15.38**
24	TGMS 91S x Matta Triveni	57.89**	48.83**	36.57**	89.27**	60.55**	24.73**	6.17**	-2.27**	10.25**
25	TGMS 91S x Varsha	141.79**	139.60**	119.87**	139.44**	112.22**	64.87**	8.04**	0.00**	20.51**

a) Total number of productive tillers plant^{-1}

The range of relative heterosis ranged from -12.28 (TGMS 81S x Prathyasa) and 132.25 (TGMS 91S x Samyuktha) . The magnitude of heterobeltiosis ranged between -41.93 (TGMS 81S x Kairali) and 80.95 (TGMS 82S x Prathyasa). The standard heterosis ranged from 80.00 (TGMS 81S x Kairali) and 500 (TGMS 74S x Samyuktha)

b) Panicle length

The range of relative heterosis ranged from -4.04 (TGMS 82S x Prathyasa) to 35.50 (TGMS 81S x Matta Triveni). The magnitude of heterobeltiosis ranged between -10.44 (TGMS 82S x Prathyasa) and 37.53 (TGMS 91S x Aiswarya). The standard heterosis ranged from -10.45 (TGMS 74S x Aiswarya, TGMS 81S x Makom) to 23.18 (TGMS 81S x Matta Triveni)

c) Total Number of spikelets panicle^{-1}

The range of relative heterosis ranged from -29.31 (TGMS 82S x Kanchana) to 114.85 (TGMS 91S x Kanchana). The magnitude of heterobeltiosis ranged from 39.70 (TGMS 82S x Kanchana) to 93.68 (TGMS 91S x Samyuktha) . Standard heterosis ranged from -38.80 (TGMS 82S x Kanchana) to 98.50 (TGMS 91S x Samyuktha)

d) Number of filled grains panicle $^{-1}$

The range of relative heterosis ranged from -39.00 (TGMS 82S x Kanchana) and 141.30 (TGMS 91S x Varsha) . The magnitude of heterobeltiosis ranged from -47.56 (TGMS 82S x Kanchana) to 104.30

(TGMS 91S x Samyuktha). Standard heterosis ranged from -53.76 (TGMS 82S x Kanchana) to 104.30 (TGMS 91S x Samyuktha)

e) 1000 grain weight

The range of relative heterosis ranged from -14.95 (TGMS 81S x Kanchana) and 34.45 (TGMS 91S x Makom), the magnitude of heterobeltiosis ranged from -24.32 (TGMS 81S x Kanchana) and 33.60 (TGMS 91S x Makom) . The standard heterosis ranged from -26.39 (TGMS 74S x Kairali) to 10.60 (TGMS 81S x Prathyasa).

f) Grain length

The range of relative heterosis ranged from -26.78 (TGMS 81S x Kanchana) and 38.42 (TGMS 82S x Prathyasa). The magnitude of heterobeltiosis ranged from -32.76 (TGMS 91S x Kairali) to 22.11 (TGMS 82S x Prathyasa). The standard heterosis ranged from -18.08 (TGMS 91S x Kairali) to 50.22 (TGMS 82S x Prathyasa)

g) Grain breadth

The range of relative heterosis ranged from -47.92 (TGMS 82S x Prathyasa) to 60.64 (TGMS 81S x Prathyasa). The magnitude of heterobeltiosis ranged from -62.50 (TGMS 82S x Prathyasa) to 30.71 (TGMS 81S x Prathyasa) Standard heterosis ranged from -59.17 (TGMS 82S x Prathyasa) to 19.52 (TGMS 91S x Samyuktha)

h) L/B ratio of grain

The extent of relative heterosis ranged from -49.84 (TGMS 81S x Kanchana) to 112.81 (TGMS 82S x Prathyasa), the magnitude of heterobeltiosis ranged from -61.16 (TGMS 81S x Kanchana) to 42.22 (TGMS

82S x Prathyasa). Standard heterosis ranged from -17.42 (TGMS 81S x Kanchana) to 264.89 (TGMS 82S x Prathyasa).

i) Single plant grain yield

The range of relative heterosis ranged from -14.51 (TGMS 91S x Kairali) to 212.51 (TGMS 74S x Kairali). The heterobeltiosis ranged from -16.65(TGMS 91S x Kairali) to 232.33 (TGMS 81S x Matta Triveni). Standard heterosis ranged from -23.51 (TGMS 91 S x Kairali) to 218.76 (TGMS 91S x Samyuktha)

j) Single plant straw yield

The range of relative heterosis ranged from -4.47 (TGMS 91S x Kairali) to 21.45 (TGMS 81S x Makom). The range of heterobeltiosis ranged from -9.12(TGMS 91S x Kairali) to 204.92(TGMS 81S x Makom). The standard heterosis ranged from -21.78 (TGMS91S x Kairali) to 1933.63 (TGMS 81S x Makom)

k) Harvest index

The relative heterosis ranged from -7.14 (TGMS 91S x Kairali) to 20.51(TGMS 81S x Matta Triveni).the minimum value of heterobeltiosis showed by -7.14 (TGMS 91S x Kairali). Standard heterosis ranged from 0.00 (TGMS 91S x Kairali) to 20.52 (TGMS 91S x Varsha)

4.4 Quality analysis

The physical and cooking quality characters of superior two line rice hybrids produced in the study and their parents are presented in **Table. 76**

Table 76. Quality traits of promising two line hybrids

Sl. No	Two line rice hybrids	Kernel colour	Kernel length (mm)	Kernel width (mm)	Hulling %	Milling %	Head rice recovery	Amylose content	Alkali spreading value	Volume expansion	Elongation ratio
1	TGMS 91S x Samyuktha	Red	5.70	2.43	76.74	68.60	58.17	24.5	2.6	2.13	1.25
2	TGMS 81S x Matta triveni	Red	5.99	1.14	72.32	58.82	31.13	23.0	1.9	2.30	1.28
3	TGMS 91S x Kanchana	Red	6.51	0.51	75.43	61.40	45.33	25.0	3.1	2.11	1.32
4	TGMS 74S x Kairali	Red	4.35	1.07	71.76	64.71	59.71	21.2	5.0	2.16	1.32
5	TGMS91S x Makom	Red	5.64	1.03	79.17	66.67	45.33	23.6	3.9	2.23	1.13
6	TGMS 82S x Prathyasa	Red	5.19	0.22	83.33	53.66	46.15	25.8	4.3	2.50	1.23
7	TGMS 81S x Makom	Red	4.93	1.09	72.41	68.96	56.00	24.6	3.7	2.29	1.27
8	TGMS 81Sx Kanchana	Red	6.34	0.48	66.67	63.32	47.17	22.0	3.1	2.14	1.31
9	TGMS 81S x Aiswarya	Red	4.34	1.26	75.00	67.50	51.92	24.5	3.6	2.00	1.28
10	TGMS 74S x Aiswarya	Red	4.62	1.17	55.56	48.00	37.49	26.2	3.9	2.32	1.15
11	Aisawarya	Red	4.85	1.10	70.5	62.3	52.34	27.5	3.8	2.13	1.20
12	Kanchana	Red	4.71	1.12	71.5	64.9	56.00	26.5	4.3	2.35	1.30
13	Kairali	Red	3.73	1.08	77.8	50.1	37.49	24.5	2.7	2.21	1.13
14	Matta Triveni	Red	4.94	1.15	71.7	63.1	52.01	23.6	1.0	2.15	1.32
15	Makom	Red	4.65	1.25	77.2	57.1	36.43	27.4	3.3	2.00	1.27

Table 76. (Contd...)

16	Prathyasa	Red	3.41	1.86	80.00	65.65	46.16	24.5	3.4	2.50	1.22
17	Samyuktha	Red	4.43	1.52	78.56	67.65	52.34	25.6	3.2	2.20	1.15
18	Varsha	Red	3.55	1.09	75.55	62.33	45.33	26.5	3.6	2.01	1.27
19	TGMS 74S	White	4.61	1.16	73.42	67.62	42.50	22.3	4.3	2.26	1.25
20	TGMS 81S	White	5.35	1.19	75.52	68.68	47.17	21.6	3.9	2.31	1.27
21	TGMS 82S	White	4.92	1.08	74.38	61.35	·52.19	23.3	2.1	2.09	1.29
22	TGMS 91S	White	5.02	1.15	76.45	63.10	59.61	21.5	2.5	2.10	1.28

1) Colour of kernel

The female parents having white kernels and the male parents had red kernels. But all the promising hybrids exhibited red kernels.

2) Kernel length

The length of kernels ranged from 4.34 (TGMS81Sx Aiswarya) to 6.51(TGMS 91Sx Kanchana) for hybrids and 3.41 (Prathyasa) to 4.94 (Matta Triveni) for parental average being 5.36 and 4.49 for hybrids and parents.

3) Kernel width

Kernel width ranged from (TGMS 81S x Kanchana) to 2.43 (TGMS 91S x Samyuktha) for hybrids and 1.08 (Kairali) to 1.86(Prathyasa) for parents average being 1.04 and 1.22 for hybrids and parents

4) Hulling percentage

The hulling percentage ranged from 55.56 (TGMS 74S x Aiswarya) to 83.33(TGMS 82S x Prathyasa) for hybrids and 70.5(Aiswarya) to 80 (Prathyasa) for parents average being 72.83 and 75.21 for hybrids and parents

5) Milling percentage

The milling percentage exhibited a range of 48.00 (TGMS 74S x Aiswarya) to 68.96 (TGMS 81S x Makom) for hybrids with a mean value of 62.16. maximum milling percentage was recorded by the parent TGMS 81S (68.88) and Kairali (50.1) showed the minimum value average being 62.82.

6) Amylose content

Amylose content of promising two line hybrids ranged from 21.2 per cent (TGMS 74S x Kairali) to 26.2 per cent (TGMS 74S x Aiswarya) and the mean amylase content was 24.04 per cent. Highest amylose content was observed in the pollinator parent Aiswarya (27.5 per cent) and the TGMS 91S recorded the minimum value of 21.5 per cent average being 24.56.

7) Alkali spreading value

The two line hybrid TGMS 74S x Kairali was found to be have a mean alkali spreading value of 5.0 where as the lowest value of 1.9 was recorded by the hybrid TGMS 81S x Matta Triveni. The average alkali spreading value for hybrids was 3.51. Among the parents, TGMS 74S and Kanchana (4.3) recorded a maximum alkali spreading value and Matta Triveni (1.0) recorded the minimum alkali spreading value with a mean value of 3.17

8) Volume expansion ratio

The two line rice hybrid TGMS 82S x Prathyasa reported the highest volume expansion ratio (2.50) and the lowest by 2.00 (TGMS 81S x Aiswarya) with a mean value of 2.20. Volume expansion ratio of the parents ranged from 2.11 (Makom) to 2.50 (Prathyasa) and mean was 2.19.

9) Elongation ratio

The mean kernel elongation ratio exhibited a range of 1.13 (TGMS 91S x Makom) to 1.32 (TGMS 74S x Kairali) with a mean value of 1.25.

Maximum kernel elongation ratio was recorded by Matta Triveni (1.32) and Samyuktha (1.15) showed the minimum value average being 1.24.

10) Abdominal white and Endosperm type

Abdominal white is absent in all two line rice hybrids and endosperm type showed intermediate type.

11) Sensory quality characters

Sensory quality characters all two line rice hybrids exhibited red streaks after cooking and well separated , moderately soft and desirable taste.

4.4.1 Molecular characterization of hybrids and parents

Fingerprinting of rice hybrids and identification of their genetic relationship were carried out using SSR markers covering all twelve regions of chromosomes.

4.4.2 Marker analysis for polymorphism

The details of marker analysis of hybrids and parents are presented in **Table 77**. All the 10 rice hybrid combinations and their parents were successfully amplified with the 20 microsatellite primer pairs. Out of 20 markers, 15 markers were found to be polymorphic revealing a total of 38 alleles with an average of 1.90 alleles per locus in the rice genotypes examined. The number of alleles per locus ranged from 2 to 3 and the Polymorphism information content (PIC) value ranged from 0.291 (RM2) to 0.648 (RM132) with an average of 0.448

4.5.2 Cluster analysis and Dendrogram construction

A dendrogram **(Fig. 9)** was generated by UPGMA analysis to show the genetic similarity and diversity among the genotypes. Cluster analysis was performed on similarity coefficient matrices calculated from SSR markers to generate a dendrogram of 10 hybrid combinations along with parents. The similarity ranged from 0.44 to 0.79.

Table 77. PIC values and allelic variation of SSR markers

Sl.No.	SSR Marker	Number of alleles	PIC value
1	RM 128	2	0.468
2	RM492	2	0.346
3	RM 168	3	0.549
4	RM119	2	0.388
5	RM 440	2	0.495
6	RM3351	2	0.493
7	RM50	2	0.648
8	RM2	2	0.291
9	RM11	3	0.623
10	RM 149	2	0.320
11	RM257	2	0.500
12	RM216	2	0.445
13	RM 206	2	0.320
14	RM 132	3	0.499
15	RM174	2	0.346

Discussion

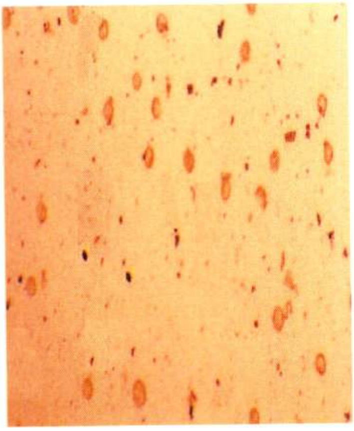
5. DISCUSSION

Farming always depend upon human induced modifications of the natural world and heterosis , meaning ' to alter' in Greek, is a prime example of technology in the service of agriculture. The green revolution undoubtedly established the technical feasibility of maintaining rice production will ahead of population growth in many developing countries. Recent observations, however , have shown a fall in gains and a sign of stress in intensively cultivated irrigated lands. In order to meet the ever growing demand, about 10 million tonnes of more rice per year has to be produced. New technology frontiers need to be explored to increase rice production in support of food security. Environment friendly and socio economically acceptable technologies need to be developed to optimize the efficient use of water, fertilizer and other inputs and to enhance productivity. Hybrid rice technology offers scope for increasing the yield potential of rice beyond the level of high yielding varieties.

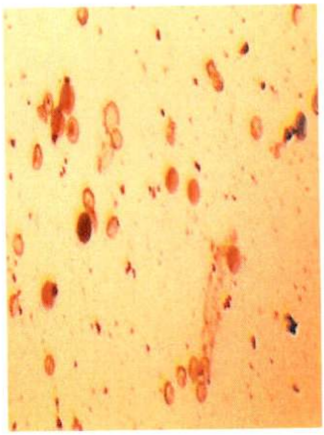
Till date, CMS system has been the most effective for developing rice hybrids in China and elsewhere. However , the inherent limitations associated with CMS system limit the wide spread adoption of this technology (Salgotra *et al.*, 2012) .Discovery of EGMS in rice has resulted in two line hybrid breeding system which is simple and more efficient than the three line breeding system. It has the advantage of exploiting freely available fertility restorers in the production of hybrids and it does not need maintainer lines. It's simple seed producers, low cost and increased vigour are worth mentioning After the discovery of the first PGMS line Nongken in 1973 several elite PGMS and TGMS lines have been developed in China and two line hybrids have been released for cultivation.

In tropical countries like India , where day length differences are marginal , TGMS system is considered more useful than PGMS system as there is adequate variation in temperature over seasons . After the first reported TGMS lines Annong

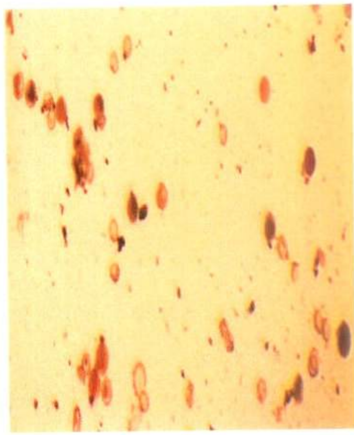
Plate 1. TGMS lines taken for evaluation



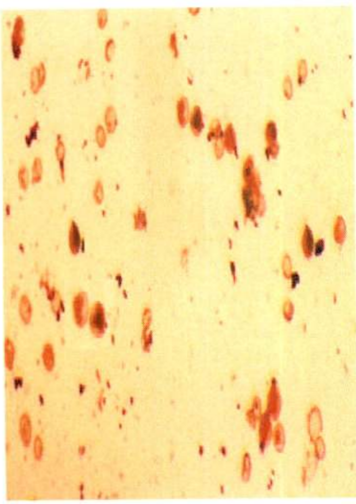
Complete sterile



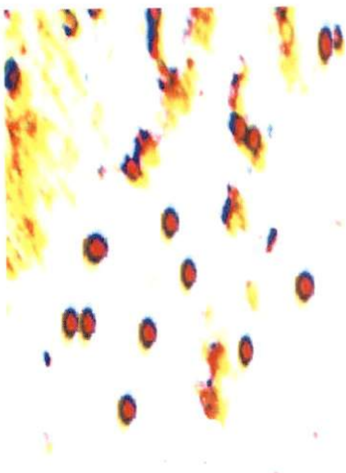
Partial sterile



Partial sterile



Partial sterile



complete fertile

Plate 2. Variation in pollen sterility/fertility status.

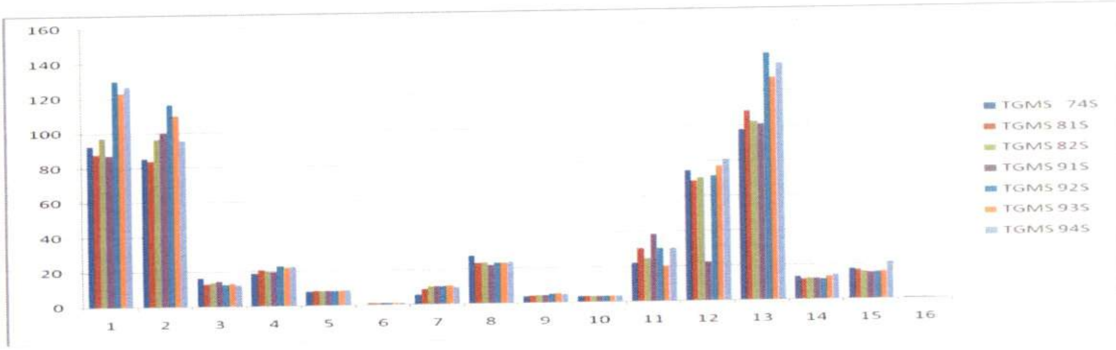
1S, Norin PL12 and IR 32364 from China , Japan and IRRI respectively several TGMS lines have been developed from spontaneous mutants induced mutants and by hybridization.

The preliminary step in exploitation of two line system hybrid rice on a large scale is the identification of TGMS lines with stable fertility transformation behavior. The lines with complete pollen sterility under high temperature condition are considered as promising TGMS lines for commercial exploitation .

5.1.1.1 Morphological characterization of TGMS lines

Rice spikelets consist of a branched pistil, six stamens and two empty glumes , the lemma and palea which protect the floral organs within them (Takeoka *et al.*, 1993) Morphological characterization is the primary factor to know about the genetic variation (or) diversity and to maintain the genetic purity without misappropriation of varieties (Higgins *et al.*, 1988)

In this present study seven TGMS lines were morphologically characterized based on IBPGR –IRRI descriptors for rice (IBPGR-IRRI, 1980). Significant differences were observed between the genotypes for all the characters studied. In this present study the plant characters days to 50% flowering ranged from 87.00 (TGMS 91S) to 120.67 (TGMS 92S). Three TGMS lines TGMS 74S , TGMS 81S and TGMS 91S were of early duration TGMS 82S was of medium duration and TGMS 92S ,TGMS 93S and TGMS 94S were of long duration. In the present study suggested that among the seven TGMS lines under evaluation only four lines coinciding with the crop duration of pollinator parents. Plant height ranged from 83.67 (TGMS 81S) to 116.00 (TGMS 92S). Tillering ability of all seven TGMS lines showed medium tillering ability, number of productive tillers ranged from 12.00 (TGMS 94S) to 16.00 (TGMS 74S).



X – Characters

Y - Mean values

1) Days to 50% flowering
2) Plant height (cm)
3) Number of productive tillers plant^{-1}
4) Panicle length (cm)
5) Grain length (mm)
6) Grain breadth (mm)
7) L/B ratio of grain
8) 1000 grain weight (g)
9) Duration of anthesis in a panicle (days)
10) Duration of spikelet opening (hrs)
11) Angle of glume opening
12) Stigma exertion per centage
13) Total number of spikelets panicle^{-1}
14) Single plant grain yield (g)
15) Single plant straw yield (g)
16) Harvest index

Fig 1. Mean performance of TGMS lines at COH Vellanikkara

For the earhead characters length of panicle ranged from 18.70 (TGMS 74S) to 22.77(TGMS 92S). The long duration TGMS lines showed medium length of panicle. All seven TGMS lines showed shorter length of grain and very narrow grain width ranges from 7.88 (TGMS 74S) to 8.41(TGMS 94S) and 0.80 (TGMS 92S , TGMS 93S) to 1.44 (TGMS 74S). L/B ratio of grain ranged from 5.47 (TGMS 74S) to 10.36 (TGMS 93S) coming under slender type of classification. TGMS 74S showed higher grain weight (27.20 g) all others coming under medium category of grain weight (21.83 to 23.50) total number of spikelets panicle $^{-1}$ ranged from 97.67 (TGMS 74S) to 141.33 (TGMS 92S). Except TGMS 74S all other showed more than 100 spikelets per panicle.**(Fig.1)**

For the floral traits all seven TGMS lines took more than 3 hrs duration for spikelet opening and more than 3 days for complete anthesis in a panicle. Two characters *viz* angle of glume opening and duration of glume opening were inter dependent on each other for effecting hybridization. Parmer *et al.* (1979) reported that large collection of rice cultivars reported that variation for angle of glume opening was due to both genetic and environmental effect .This study indicated that the widest glume opening of 38.33^0 was recorded in TGMS 91S and the lowest in TGMS 93S (20^0). Thiyagarajan *et al.* (2010) reported the range of 15^0 to 25^0 and Ramakrishna *et al.* (2006) reported the range of 23.43 to 30.20 ^{0} .Salgotra *et al.* (2012) reported the range of 21.3^0 to 23.7^0. Duration of glume opening was the highest in TGMS 92S (3.31 hrs) wide opening of glums for longer duration in the male sterile plants enables the stigma to intercept with ease the airborne pollen grains . Stigma exertion per centage ranged from 21.88 (TGMS 91S) to 80.84 per cent (TGMS 94S).Similar higher per centage of stigma exertion (80.32) was reported in COTGMS 08 by Thiyagarajan *et al.* (2010). Ramakrishna *et al.* (2006) reported the stigma exertion range of 25 ^{0}(DRR 5S) to 70 ^{0}(UPRI 95-167S).

Economic characters single plant grain yield ranged from in the fertile period ranged from 11.32 (TGMS 81S) to 13.78 (TGMS 94S). single plant straw yield ranged from 14.73(TGMS 92S) to 20.91(TGMS 94S). Harvest index ranged from 0.39 (TGMS 94S) to 0.45 (TGMS 93S)

5.1.1.2 Sterility/fertility behaviour.

The two-line system simplifies the production of hybrid, since only pair of pure fertile and sterile lines are required. It can also eliminate the potential negative effects associated with the CMS. Furthermore, the nuclear genes responsible for sterility are relatively easy to be transferred to diverse genetic background. However, owing to the limitation of the temperature and/or photoperiod requirement, an EGMS line can only be used in a relatively narrow zone, and suitable sterile lines must be developed for a target production environment (He *et al.,* 2006). Therefore characterization of TGMS lines with respect to their fertility / sterility alteration behaviour will provide clear cut idea of utilization of that particular line for predicting appropriate timings for hybridization programme (at sterile phase) as well as seed multiplication (at fertile phase).

Based on sterility /fertility behaviour the entire study period of 2010 March to 2011 March can be grouped as two distinct periods *viz* pollen sterile and pollen fertile . In the present study the pollen sterile months indicated April, May when 100 per cent sterility was observed . July and August can be considered as pollen fertile months. other months exhibited un stable expression of sterility /fertility and hence could not be grouped under pollen sterile or pollen fertile months. Sterility/fertility behaviour of pollen grains over months during the study period is shown in **Fig.3.**

In the present study the sterile period was longest in TGMS 82S (87 days) followed by TGMS 81S (83 days). Since all these lines were completely sterile for more than 30 consecutive days during sterile phase hybrid seed production utilizing these lines can be taken up at COH Vellanikkara by raising the lines in such a way that following coincides with the sterile phase.

All the lines reverted in to fertile from July 2nd week to September I st week . In the present study all lines exhibited 100 per cent pollen fertility during the periods .Since all these were completely fertile for more than 30 consecutive days during fertile phase multiplication of TGMS lines with purity standard will be easier for these lines. Lu *et al.* (1998) suggested that for successful utilization of TGMS lines the sterile and fertile phase should be atleast for 30 consecutive days. Similar findings was reported by Latha *et al.* (2004) in TS6 completely sterile for 78 consecutive days and reverted to fertile for continuously 69 days in the same Coimbatore location.

5.1.1.3 Influence of weather factors on fertility alteration

Relative influence of primary weather factors such as maximum and mean temperature and secondary weather factors such as relative humidity, rainfall and sunshine hours on pollen sterility/fertility alteration behavior will vary among different lines due to different source of male sterility genes and genetic backgrounds (Wu *et al.,* 1991; Zhang and Lu, 1991). Present investigation revealed that the influence of maximum and mean temperature on pollen sterility for all TGMS lines.

Correlation studies between pollen sterility and different weather factors showed the influence of primary as well as secondary weather factors on fertility alteration.

In the present study all seven TGMS lines exhibited relative influence of maximum and mean temperature on pollen sterility with positively significant values. The significant influence of maximum temperature on pollen sterility was reported by Zhang and Lu (1991) and Chandirakala (2005). Except TGMS 74S, other six lines had significant influence of minimum temperature on pollen sterility. This is in accordance with the findings of Sun *et al.* (1989) and Liu *et al.* (1997).

In the present study none of the seven TGMS lines had no influence by secondary factors such as relative humidity, rainfall , on fertility alteration. This is in accordance with Zhang and Lu (1991) and Liu *et al.* (1997). Except TGMS 92S and TGMS 94S all other TGMS lines had no influence on sunshine hours.

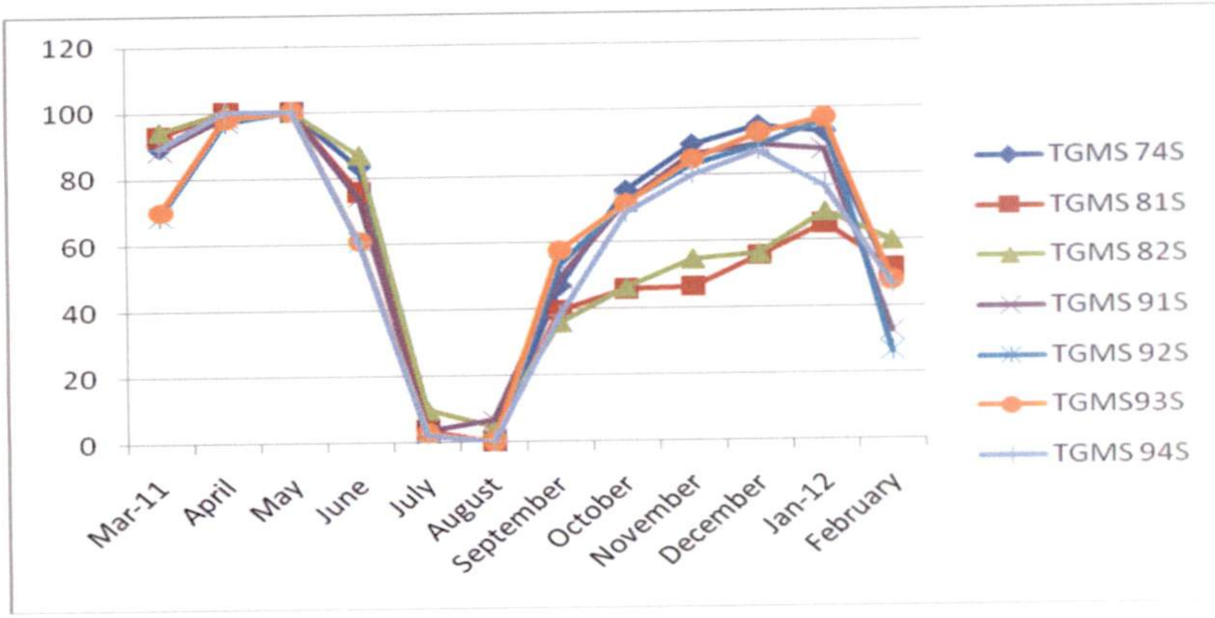
5.1.1.4 CST and CFT in TGMS lines

The foremost step to start two line breeding is characterization of TGMS lines and determination of fertility behaviour of particular line to find out critical sterility temperature (CST) and critical fertility temperature (CFT). Because TGMS lines are sterile in certain temperature regime there is need to determine CST and CFT. Hence the determination of CST and CFT will provide a broad way to decide suitable season and locations for TGMS seed multiplication and hybrid seed production.

TGMS lines greatly differ in their sensitivity to temperature fluctuation. Only those lines with lower critical sterility point and those, which do not revert back to fertility with slight decrease in temperature, are useful to develop two line hybrids (Wu, 1997). This critical sterility temperature (CST) and critical fertility temperature (CFT) were found to vary in different TGMS lines as the TGMS gene of these lines are transferred into different genetic background.

The lowest mean temperature at which the line becomes sterile from the fertile condition is the critical sterility temperature (CST). The highest mean temperature at which the line becomes fertile from the sterile condition is the critical fertility temperature (CFT). The critical temperature inducing sterility is relatively low (23° C) in temperate zone and 24° C in sub-tropics (Yuan, 1998).

In the present investigation under evaluation of seven TGMS lines the CST ranged from 34.2 (TGMS 74S , TGMS 91S , and TGMS 94S) to 38.6 (TGMS92S). CFT ranged from 23.6 (TGMS 91S) to 25.4 (TGMS 92S, TGMS 93S) .Similar findings also reported by Salgotra *et al.* (2012)



X – Month

Y – Sterility %

Fig 3. Sterlity behaviour of TGMS lines over month at COH Vellanikkara

5.1.1.5 Performance of TGMS lines in higher altitude

Performance of TGMS lines was evaluated in higher altitudes. Compared to their performance in the plain all TGMS lines showed longer duration of cropping pattern. **(Fig.2)** The spikelets opened and closed normally and panicles came out completely from the boot leaf at CRS pampadumpara . These reflect the fertile nature of spikelets and panicles at cooler climatic regions.

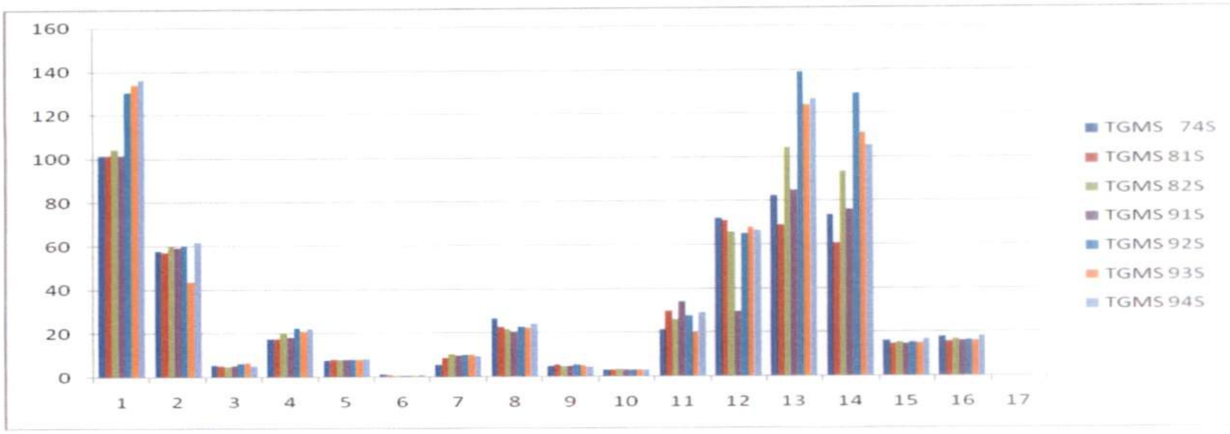
In the present study spikelet fertility from all season showed lines to be fully fertile throughout the study period. The lower temperature experienced at higher altitudes leads to normal pollen mother cell differentiation , meiosis and formation of fertile pollen grain, yellow plumpy and dehiscet anthers. This was in conformity with the findings of Thiyagarajan *et al.* (2010). The present study identified CRS Pampadumpara is a suitable location for TGMS lines multiplication **(Fig.4)**

5.2 Evaluation of pollinators.

5.2.1 Genetic variability

In the process of crop improvement , desirable plants are continuously being selected from genetically variable population. Genetic improvement thus depends on the existence of genetic variability. Therfore an insight into the magnitude of variability present in a crop species is of utmost importance as it is a key factor, which determines the amount of progress expected from selection

All characters exhibited significant difference among the different pollinator parents studied. The range of these traits was also wide, indicating that the genotypes selected for the present study were genetically diverse. Variability among different characters was previously observed by several workers like Mohamad *et al.* (2012) for days to flowering, plant height, panicle length, total number of spikelets panicle^{-1}, number of filled grains panicle^{-1} , 1000 grain weight. Akinwale *et al.* (2011) for days to flowering, plant height, panicle length, 1000 grain weight, grain yield. Aktar *et al.*

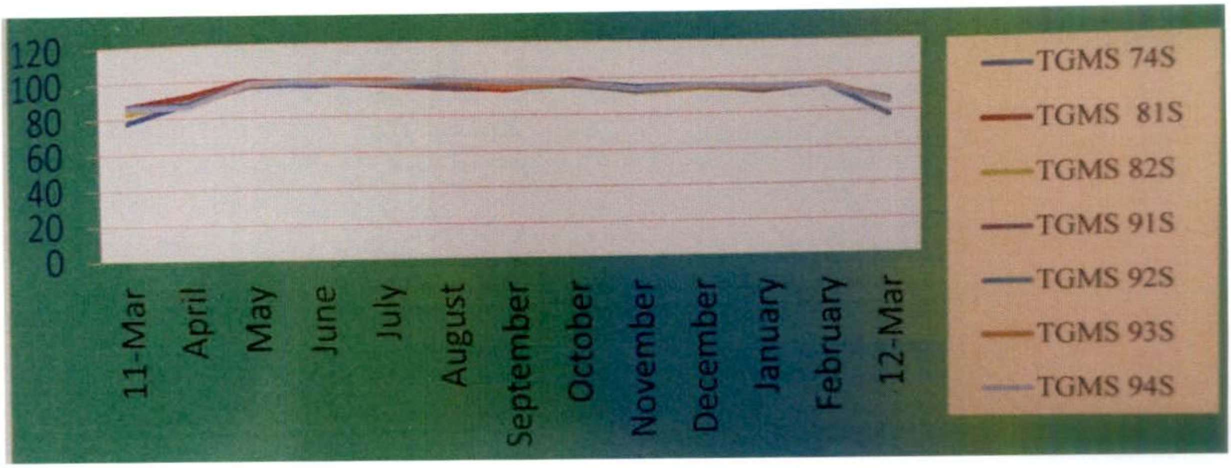


X – Characters

Y – Mean values

1) Days to 50% flowering
2) Plant height (cm)
3) Number of productive tillers plant^{-1}
4) Panicle length (cm)
5) Grain length (mm)
6) Grain breadth (mm)
7) L/B ratio of grain
8) 1000 grain weight (g)
9) Duration of anthesis in a panicle (days)
10) Duration of spikelet opening (hrs)
11) Angle of glume opening
12) Stigma exertion per centage
13) Total number of spikelets panicle^{-1}
14) Number of filled grains panicle^{-1}
15) Single plant grain yield(g)
16) Single plant straw yield(g)
17) Harvest index

Fig 2. Mean performance of TGMS lines at CRS Pampadumpara



X- Month

Y-Fertility %

Fig 4. Fertility behavior of TGMS lines over months at CRS Pampadumpara

(2010) for plant height, and 1000 grain weight. Bagheri *et al.* (2011) for plant height, total number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, grain length, grain width, 1000 grain weight, panicle length. Bhadru *et al.* (2012) for plant height, panicle length, number of productive tillers plant^{-1},number of filled grains panicle^{-1}, single plant grain yield.

5.2.2 Genetic advance and genetic gain

Genetic gain refers to the improvement in genotypic value of new population as compared with the base population and when it is expressed as per centage of mean the new parameter is termed as genetic gain . So to have an effective selection along with heritability, genetic gain measurement is also important.

L/B ratio of grain, single plant straw yield ,single plant grain yield, number of filled grains panicle $^{-1}$,number of productive tillers plant $^{-1}$, plant height , total number of spikelets panicle^{-1}, grain length, days to 50% flowering showed high expected genetic gain. Hence these characters will have a good response to selection and can be improved by selection from the base population. Similar results were also recorded by Yadav *et al.* (2010) for days to 50% flowering, plant height, total number of spikelets panicle^{-1} and single plant grain yield.

The characters 1000 grain weight, panicle length , harvest index recorded moderate value for genetic gain indicating that they are moderate in their usefulness to seletion. similar findings were also reported by Yadav *et al.* (2010) for 1000 grain weight.

Akinwale *et al.* (2011) suggested that estimates of heritability and genetic gain who considered together are more useful than heritability alone. If the heritability is due to additive genetic effect *i.e* the part which is useful to the breeder the expected genetic gain would be high. It is due to non additive effects. The genetic gain would be low. Therefore to have a more reliable conclusion for the present study, the

Plate 3. Field view of pollinator evaluation

characters which have high heritability, genetic gain and high GCV were considered . These includes number of filled grains panicle , grain breadth, L/B ratio of grain, single plant grain yield single plant straw yield. Similar results were reported by Nandeshwar *et al.* (2010) for single plant grain yield.

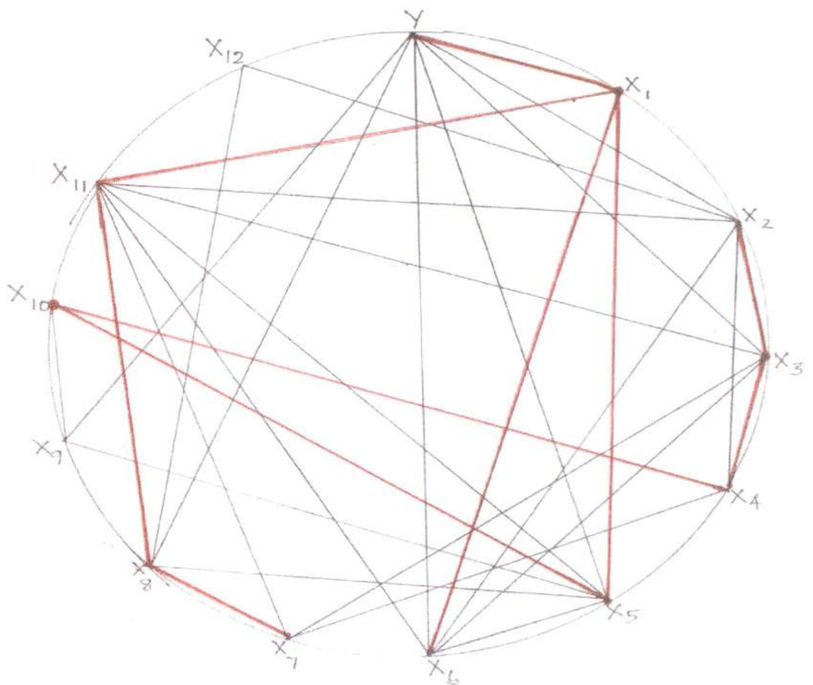
High heritability and high expected genetic gain combined with moderate GCV were observed for days to 50% flowering, plant height, total number of spikelets panicle^{-1}, grain length. The results suggest that above mentioned characters may be under the control of additive genetic effects. Hence the characters are useful for direct selection from phenotypic performance. Nandeshwar *et al.* (2010) reported the similar findings for plant height.

High heritability coupled with low GCV estimate and moderate estimate of expected genetic advance were observed for characters 1000 grain weight. Seyoum *et al*. (2012) reported the same for 1000 grain weight.

5.2.3 Correlation

Correlation coefficient measures the intensity of linear relationship between variables . In genetic studies it is common to find the correlation between two or more characters. Genotypic correlation between two or more characters may result from pleiotropic effects of genes or linkage of genes governing the inheritance of the characters. Phenotypic correlation on the other hand is determined by genotypic and environmental effects. Thus estimation of correlation coefficients among different characters is very important to know the type of relationship existing between the variables.

Yield and other characters of pollinator parents were subjected to correlation analysis. Phenotypic and genotypic correlation among different characters of pollinator parents were obtained (**Fig 5**). Significant correlation at genotypic and



X_1-Days to 50% flowering

X_2-Plant height (cm)

X_3-Number of productive tillers plant^{-1}

X_4-Panicle length (cm)

X_5- Total number of spikelets panicle^{-1}

X_6- Number of filled grains panicle^{-1}

X_7-1000 grain weight (g)

X_8- Grain length (mm)

X_9-Grain breadth (mm)

X_{10}-L/B ratio of grain

X_{11}-Single plant straw yield(g)

X_{12}-Harvest index

Y- Yield

------- Positive Correlation ------- Negative correlation

Fig 5. Genotypic correlation among yield of pollinator parents and different componenet characters

phenotypic levels were observed for the characters *viz* plant height , total number of spikelets panicle $^{-1}$, grain breadth and days to 50% flowering . The results are in conformity with Yadav *et al.* (2010) for total number of spikelets panicle^{-1} and Ekka *et al.* (2011) for plant height and days to flowering . Positive significant correlation at genotypic level was observed for number of productive tillers plant^{-1}, grain length. Plant height was positively and significantly correlated with panicle length and number of filled grains panicle at both level. Similar findings were reported by Mohamed *et al*. (2012).

Among the various characters the highest genotypic association with yield was recorded for total number of spikelets panicle^{-1}, grain breadth, and number of productive tillers plant. This reveals that improvement in grain yield could be achieved by exercising selection simultaneously for increased total number of spikelets panicle $^{-1}$.

5.2.4 Path analysis

The residual effect was found to be -0.219 .The highest positive direct effect was exhibited by single plant straw yield (3.374) on yield . This was followed by harvest index (3.022). The highest negative direct effect was exhibited by number of filled grains panicle^{-1}(-1.487) followed by plant height (-1.420), days to 50% flowering (-0.729), total number of spikelets panicle^{-1} (-0.596). The highest positive indirect effect was observed for number of filled grains panicle^{-1} (2.382) via single plant straw yield followed by total number of spikelets panicle $^{-1}$ (1.548), panicle length (1.280) through single plant straw yield.

The highest negative indirect effect was observed for single plant straw yield (-1.152) via harvest index followed by harvest index (-1.286) via single plant straw yield , number of productive tillers plant^{-1} (-1.260) via harvest index.

5.3 Evaluation of two line hybrids

The analysis of variance revealed highly significant difference among the genotypes for all the characters studied from the two locations suggesting the presence of substantial genetic variability among the genotypes. Variability for component characters of hybrids were previously reported by workers like Hasan *et al.* (2011) for days to flowering, plant height, number of productive tillers plant^{-1}, and panicle length and Sathya and Jebaraj (2013) for days to flowering, plant height, number of productive tillers plant^{-1}, panicle length, number of filled grains panicle^{-1}, single plant grain yield and harvest index. Babu *et al.* (2012) for plant height, panicle length, number of productive tillers plant^{-1}, number of filled grains panicle^{-1},1000 grain weight, single plant grain yield. Subbaiah *et al.* (2011) for days to flowering, plant height, number of productive tillers plant^{-1}, panicle length, single plant grain yield, harvest index. The wide range of variation noticed in all the characters confirmed that the treatments included were appropriate for the study.

Morphological characterization of two line hybrids at COH Vellanikkara and RARS Pattambi revealed for the plant characters TGMS 91S x Kairali showed early flowering compared to TGMS 82S x Aiswarya at two locations. Plant height TGMS 82S x Kairali and TGMS 91S x Kanchana recorded the lowest plant height. TGMS 91S x Samyuktha recorded the maximum plant height at two locations. Tillering ability of all the two line rice hybrids ranged from low to good tillers. Among these TGMS 82S x Prathyasa recorded the highest tillering capacity.

For the earhead characters, TGMS 82S x Kanchana, TGMS 74S x Samyuktha recorded the shortest and longest panicle respectively in COH Vellanikkara. TGMS 74S x Aiswarya, TGMS 81S x Makom , TGMS 81S x Matta Triveni recorded minimum and maximum panicle length. Total number of spikelets

Plate 4. Hybridization block

plant^{-1}, and number of filled grains panicle $^{-1}$. TGMS 82S x Kanchana and TGMS 91S x Samyuktha recorded the minimum and maximum value.

TGMS 81S x Kanchana and TGMS 82S x Prathyasa respectively recorded the minimum and maximum value for grain length and grain breadth. TGMS 91S x Aiswarya and TGMS 81S x Prathyasa recorded the minimum L/B ratio of grain while TGMS 82S x Prathyasa recorded the maximum L/B ratio of grain at two locations.

TGMS 81S x Kairali and TGMS 81S x Matta Triveni respectively recorded the minimum and maximum single plant grain yield and single plant straw yield at COH Vellanikkara and TGMS 91S x Kairali and TGMS 91S x Samyuktha respectively recorded the minimum and maximum plant yield at RARS Pattambi. Harvest index ranged from TGMS 74S x Samyuktha (0.40) to TGMS 82S x Aiswarya (0.50) at COH Vellanikkara and TGMS 91S x Kairali (0.39) to TGMS 91S x Varsha (0.47)

5.3.1 PCV and GCV

The PCV and GCV provide a measure to compare the variability present in the traits. The GCV especially helps to compare the genetic variability in the traits

The characters *viz.*, L/B ratio of grain , single plant grain yield number of filled grains panicle^{-1}, total number of spikelets panicle^{-1}, single plant straw yield and number of productive tillers plant^{-1} recorded high magnitude of PCV and GCV at two locations indicating the existence of large variability and scope of genetic improvement of these traits through selection. Moderate values of PCV and GCV for grain breadth, grain length, plant height, 1000 grain weight indicate their moderate usefulness in crop improvement programme. Low variability for characters namely harvest index , days to 50% flowering reflects little possibility of improving these characters through selection. For all the characters closeness between PCV and GCV was observed suggesting that these characters might be less influenced by environmental factors. Similar findings were reported by Babu *et al.* (2012) for number of filled grains panicle^{-1}, days to flowering and Subbaiah *et al.* (2011) for for total number of spikelets panicle^{-1}, and number of productive tillers panicle^{-1}

5.3.2 Heritability

In the present study except harvest index all other characters exhibited high heritability at COH Vellanikkara. It indicates that the characters are less influenced by the environmental effects and there could be greater correspondence between phenotypic and breeding values. High heritability in various characters of rice hybrids were earlier reported by Babu *et al.* (2012) for days to flowering, plant height, panicle length, 1000 grain weight. Subbaiah *et al.* (2011) for days to flowering, plant height, panicle length, number of productive tillers plant, single plant grain yield, and total number of spikelets panicle^{-1}. Kumar *et al.* (2014) for total number of spikelets panicle^{-1}, number of filled grains panicle^{-1} ,1000 grain weight.

5.3.3 Genetic advance and genetic gain

High expected genetic gain was observed for the characters *viz*., L/B ratio of grain , single plant grain yield , number of filled grains panicle^{-1}, total number of spikelts panicle^{-1}, single plant straw yield, number of productive tillers plant^{-1} , plant height, 1000 grain weight, grain length, and grain breadth. Days to 50% flowering, panicle length, and harvest index exhibited low expected genetic gain and can be considered as having little value in selection. These results are in conformity with Subbaiah *et al*. (2011) for total number of spikelets panicle^{-1}, single plant grain yield. Babu *et al*. (2012) for number of filled grains panicle^{-1} , panicle length and Kumar *et al*. (2014) for panicle length

Among the different component characters number of productive tillers plant, total number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, L/B ratio of grain, single plant grain yield and single plant straw yield showed high GCV , heritability and expected genetic gain. The results are in conformity with Subbaiah *et al.* (2011) for number of productive tillers plant^{-1}

The characters plant height, 1000 grain weight, grain length and grain breadth had high per cent of heritability , high expected genetic gain and moderate GCV. The results suggested that the characters are under the control of additive genetic effects and selection may be effective.

5.3.4 Correlation

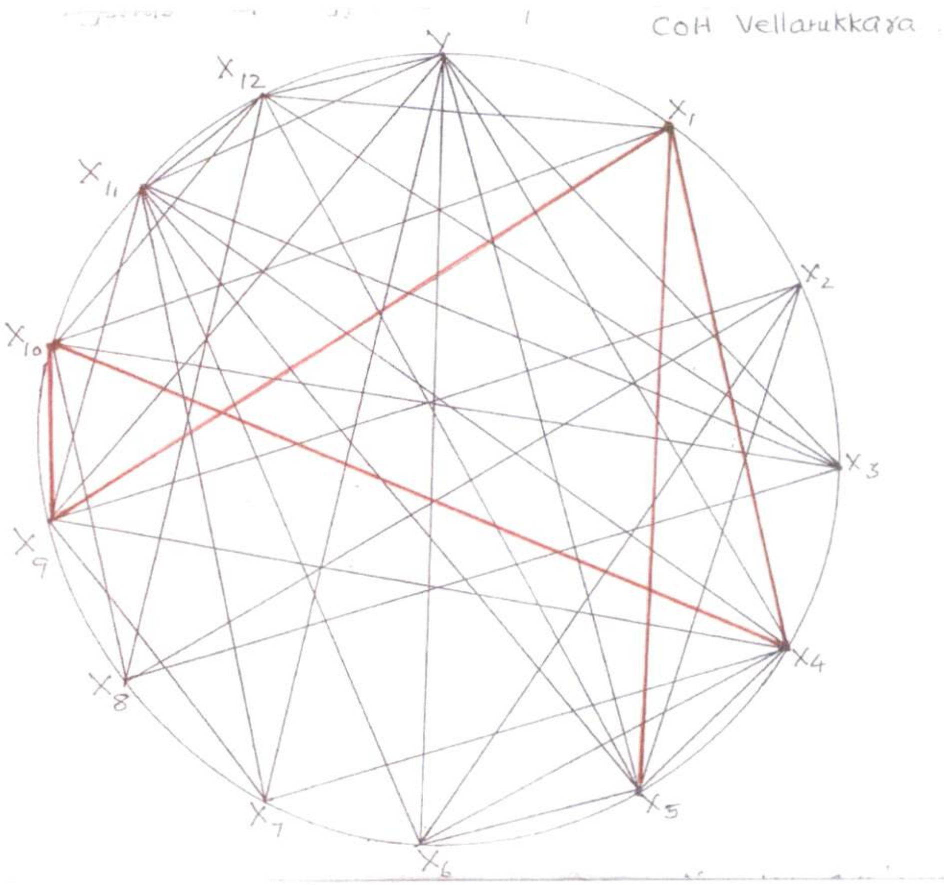
The results of correlation between yield of two line hybrids and component characters are discussed below.

Number of productive tillers plant^{-1}, total number of spikelets panicle^{-1} showed a significant positive correlation with grain yield at both genotypic and phenotypic levels at two locations.

The highest significant positive genotypic correlation with yield was exhibited by total number of spikelets panicle^{-1}. This was followed by number of filled grains panicle^{-1}, number of productive tillers plant^{-1} and panicle length in COH Vellanikkara and single plant straw yield followed by harvest index in RARS Pattambi **(Fig 6 and Fig 7).**

5.3.5 Path analysis

In the present investigation path analysis was performed using eight hybrid rice characters. The low residual effect obtained in the analysis indicates that the characters included in the study are enough to explain the variability in yield.



X_1-Days to 50% flowering

X_2-Plant height (cm)

X_3-Number of productive tillers plant^{-1}

X_4-Panicle length (cm)

X_5- Total number of spikelets panicle^{-1}

X_6- Number of filled grains panicle^{-1}

X_7-1000 grain weight (g)

X_8- Grain length (mm)

X_9-Grain breadth (mm)

X_{10}-L/B ratio of grain

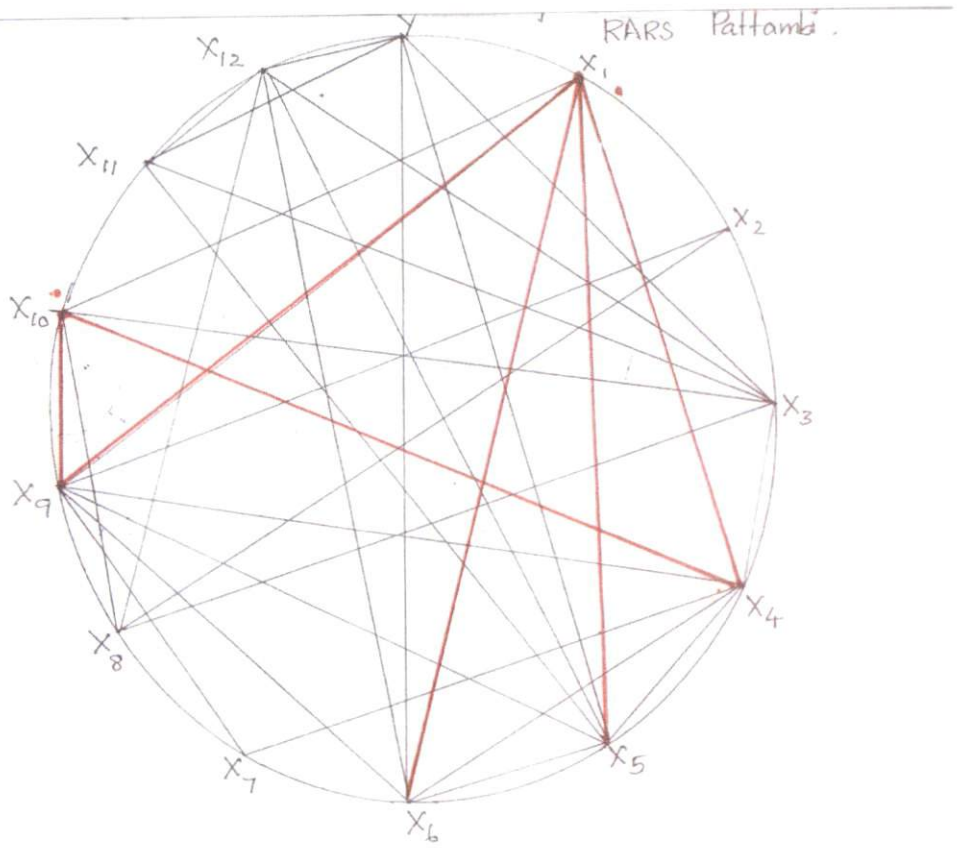
X_{11}-Single plant straw yield (g)

X_{12}-Harvest index

Y- Yield

------- Positive correlation --------Negative correlation

Fig 6. Genotypic correlation among yield of two line rice hybrids and different component characters at COH Vellanikkara.



X_1-Days to 50% flowering

X_2-Plant height (cm)

X_3-Number of productive tillers plant^{-1}

X_4-Panicle length (cm)

X_5- Total number of spikelets panicle^{-1}

X_6- Number of filled grains panicle^{-1}

X_7-1000 grain weight (g)

X_8- Grain length (mm)

X_9-Grain breadth (mm)

X_{10}-L/B ratio of grain

X_{11}-Single plant straw yield (g)

X_{12}-Harvest index

Y- Yield

------- Positive Correlation

-------- Negative correlation

Fig 7. Genotypic correlation among yield of two line rice hybrids and different componenet characters at RARS Pattambi

The highest positive direct effect on yield was observed for number of filled grains panicle^{-1} and single plant straw yield at COH Vellanikkara and RARS Pattambi.

Highest negative direct effect was exhibited by total number of spikelets panicle^{-1} and number of filled grains per panicle at COH Vellanikkara.

Harvest index showed highest positive indirect effect at two locations and highest negative indirect effect was showed by days to 50% flowering and single plant straw yield at COH Vellanikkra and RARS Pattambi.

5.3.6 General combining ability effects of parents

The parents with higher positive significant gca effects for desirable traits are considered as good general combiners. Where as those with negative gca effects for desirable traits are considered to be poor general combiners. But for undesirable traits, the parents with negative significant gca effects are taken as good combiners and these with positive significant gca effects as poor combiners. Earlier it was reported by Faiz *et al.* (2008) that mean performance of the parents was associated with their gca effects.

The gca effects of the five male parents were scored and score chart is presented in **Table 78 and 79**. The positively significant characters were given a score of +1 and negatively significant characters with a score of -1. Only the significant parents were taken into account as the non significant parents are statically not different from zero. The score obtained for each characters was summed up to judge the combining ability status of the parents. Parents were considered as good general combiners if the total score was more than +1, poor combiners if the sum of the score was -1 (or) lesser and medium combiners if the total score equaled zero.

Table 78. Scoring of parents based on general combining ability effects from 4 x 5 line x tester analysis at COH Vallanikkara

Sl.No	Parents	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Remarks
1	Aiswarya	1	1	1	1	1	1	1	1	1	-1	1	1	0	10	H
2	Kanchana	1	-1	-1	0	-1	-1	-1	-1	1	-1	-1	-1	0	-7	L
3	Kairali	-1	-1	1	0	-1	-1	1	1	-1	1	-1	-1	0	-3	L
4	Makom	1	-1	-1	-1	0	-1	-1	-1	-1	0	-1	-1	-1	-9	L
5	Samyuktha	-1	-1	1	0	0	-1	-1	1	1	-1	1	1	0	0	M

Characters

1. **Days to 50% flowering**
2. **Plant height (cm)**
3. **Number of productive tillers plant^{-1}**
4. **Panicle length (cm)**
5. **Total number of spikelets panicle^{-1}**
6. **Number of filled grains panicle^{-1}**
7. **1000 grain weight (g)**
8. **Grain length (mm)**
9. **Grain breadth (mm)**
10. **L/B ratio of grain**
11. **Single plant grain yield (g)**
12. **Single plant straw yield (g)**
13. **Harvest index**

Table 79. Scoring of parents based on general combining ability effects from 4 x 5 line x tester analysis at RARS Pattambi

Sl.No	Parents	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Remarks
1	Aiswarya	0	1	-1	1	1	1	1	1	1	1	1	1	0	9	H
2	Kanchana	1	-1	0	1	0	0	0	-1	-1	1	1	1	0	2	H
3	Kairali	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-13	L
4	Makom	-1	0	1	-1	1	-1	1	1	1	0	1	1	0	4	H
5	Samyuktha	1	1	1	0	-1	-1	1	0	0	-1	1	1	0	1	H

Characters

1. **Days to 50% flowering**
2. **Plant height (cm)**
3. **Number of productive tillers plant^{-1}**
4. **Panicle length (cm)**
5. **Total number of spikelets panicle^{-1}**
6. **Number of filled grains panicle^{-1}**
7. **1000 grain weight (g)**
8. **Grain length (mm)**
9. **Grain breadth (mm)**
10. **L/B ratio of grain**
11. **Single plant grain yield (g)**
12. **Single plant straw yield (g)**
13. **Harvest index**

Based on the scores at two locations Aiswarya, Makom, Kanchana and Samyuktha were good general combiners where as Kairali was the poor combiner. Among the pollinator parents Aiswarya recorded the highest score at low locations.

Score chart data from two locations the good general combiners for different characters were identified. Aiswarya for days to 50% flowering and plant height. Samyuktha for number of productive tillers plant^{-1}, Aiswarya for panicle length, total number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, 1000 grain weight, grain length, and grain breadth.

Aiswarya and Samyuktha for single plant grain yield and single plant straw yield . All pollinators are poor combiners for L/B ratio of grain and harvest index.

Parents were grouped based on *per se* performance and gca effects showed that parallelism between *per se* performance and gca effects does not exist always for most of the studied characters.

But for the evaluation of male parents from two locations Aiswarya (Number of productive tillers plant^{-1}) Makom (single plant straw yield) has high *per se* performance coupled with high gca effects for the characters studied. Hybridization involving these parents would result in more desirable and superior recombinants for economic characters. The table also indicated the parents with high *per se* performance had non significant and negative gca effects. In other words when employed as a parent in crosses the variety may emerge as a poor combiners. This line does not appear to transfer desirable genes for better performance to its progeny. Such behavior could result from intra and or inter allelic interactions of gene concerned with the characters. Though they were not having high *per se* performance and high gca effects they cannot be eliminated since per se performance of parents is the actual value of the characters concerned while gca effects are the predictable component. The superior performance of a variety is not always reflected in its combining ability. Therefore even if the parents are not having desirable gca effects they can be considered for further exploitation if they posses high order of *per se* performance.

5.3.7 Specific combining ability effects:

Superiority of cross combinations could be inferred from their specific combining ability (sca) effects. The hybrids with significant sca effects in a positive direction are considered to be the most promising ones. They are chosen for evaluation in preliminary yield trials. specific combining ability helps in the identification of superior cross combination for commercial exploitation of heterosis. Sca effects give an idea about non additive gene action. Dominance variance is a measure of dominant or non additive gene action . It is associated with heterozygosity and therefore it is not fixable. Dominance variance is the chief cause of heterosis and SCA variance is the measure of dominance variance. The estimates of SCA variance provide an apt diagnosis of the predominant role of intra allelic interaction or non additive gene action.

The sca effect of hybrids for different characters were studied from two locations are scored as was done with gca effects of parents. The score chart are presented in **Table 80 and 81.**

The two line hybrids TGMS 91S x Makom , TGMS 82S x Aiswarya, TGMS 81S x Kairali, TGMS 81S x Kanchana TGMS 91S x Kairali from COH Vellanikkara and TGMS 82S x Samyuktha, TGMS 74S x Samyuktha, TGMS 81S x Aiswarya TGMS 91S x Samyuktha TGMS 74S x Kairali, and TGMS 74S x Makom from RARS Pattambi had high sca effect for various characters studied .

Among the datas from two locations TGMS 91S x Makom showed significant sca effect for five component characters *viz.*, days to 50% flowering, plant height, 1000 grain weight, single plant grain yield, and single plant straw yield.

Table 80. **Scoring of two line hybrids based on specific ability effects from 4 x5 line x tester analysis at COH Vellanikkara**

Cross	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Remarks
1	-1	0	-1	0	1	1	-1	1	0	1	-1	-1	0	-2	L
2	1	-1	1	0	0	-1	-1	0	1	0	-1	-1	0	-2	L
3	1	1	-1	-1	-1	-1	-1	0	-1	1	-1	-1	0	-5	L
4	-1	1	·1	-0	0	0	1	1	1	-1	0	0	0	-3	L
5	1	-1	1	0	1	1	-1	-1	-1	-1	1	1	0	1	H
6	1	-1	-1	-1	-1	-1	-1	1	-1	1	-1	-1	0	-6	L
7	-1	1	-1	1	.0	0	1	0	1	0	1	1	0	4	H
8	-1	-1	1	1	1	1	0	1	1	-1	1	1	0	5	H
9	-1	-1	-1	-1	-1	0	-1	-1	-1	-1	-1	-1	-1	-12	L
10	1	1	1	0	1	-1	1	0	-1	-1	1	1	0	-4	L
11	1	1	1	0	1	1	0	1	-1	1	1	1	1	9	H
12	0	-1	0	-1	0	-1	-1	-1	-1	1	-1	-1	-1	-8	L
13	1	-1	-1	0	-1	-1	1	0	-1	0	-1	-1	0	-5	L
14	-1	1	-1	1	-1	-1	-1	-1	0	-1	1	1	-1	-4	L
15	-1	-1	-1	0	-1	-1	1	1	1	-1	-1	-1	-1	-6	L
16	-1	1	-1	0	-1	-1	1	-1	1	-1	-1	-1	-1	-6	L
17	0	-1	1	0	1	1	1	1	1	-1	1	1	0	6	H
18	-1	1	1	0	1	1	-1	0	0	0	1	1	0	4	H
19	1	1	1	0	1	1	1	1	-1	1	1	1	1	10	H
20	0	1	-1	0	-1	0	-1	0	-1	1	-1	-1	0	-4	L

Cross

1. TGMS 74S x Aiswarya
2. TGMS 74S x Kanchana
3. TGMS 74S x Kairali
4. TGMS 74S x Makom
5. TGMS 74S x Samyuktha
6. TGMS 81S x Aiswarya
7. TGMS 81S x Kanchana
8. TGMS 81S x Kairali
9. TGMS 81S x Makom
10. TGMS 81S x Samyuktha
11. TGMS 82S x Aiswarya
12. TGMS 82S x Kanchana
13. TGMS 82S x Kairali
14. TGMS 82S x Makom
15. TGMS 82S x Samyuktha
16. TGMS 91S x Aiswarya
17. TGMS 91S x Kanchana
18. TGMS 91S x Kairali
19. TGMS 91S x Makom
20. TGMS 91S x Samyuktha

Characters

1. Days to 50% flowering
2. Plant height (cm)
3. Number of productive tillers $plant^{-1}$
4. Panicle length
5. Total number of spikelets $panicle^{-1}$
6. Number of filled grains $panicle^{-1}$
7. 1000 grain weight
8. Grain length (mm)
9. Grain breadth
10. L/B ratio of grain
11. Single plant grain yield (g)
12. Single plant straw yield (g)
13. Harvest index

Table 81. Scoring of two line hybrids based on specific ability effects from 4 x 5 line x tester analysis at RARS Pattambi

	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Remarks
1	-1	-1	0	-1	-1	-1	1	0	-1	1	1	1	0	2	H
2	0	-1	1	-1	1	1	0	-1	-1	0	1	1	0	1	H
3	1	-1	1	1	1	1	-1	0	0	0	1	1	0	5	H
4	0	1	1	1	1	1	-1	1	1	0	-1	-1	0	4	H
5	-1	-1	-1	1	-1	-1	0	-1	0	-1	-1	-1	0	8	H
6	-1	1	1	0	1	1	1	0	-1	1	1	1	0	6	H
7	0	0	-1	1	1	1	-1	-1	1	-1	1	1	0	2	H
8	-1	1	-1	0	-1	-1	1	1	1	0	-1	-1	0	-2	L
9	1	-1	0	-1	-1	-1	0	1	-1	1	1	1	0	0	M
10	0	1	-1	0	1	-1	1	0	0	0	-1	0	0	0	M
11	1	0	-1	1	1	0	-1	0	1	-1	-1	-1	0	-1	L
12	1	1	0	-1	-1	-1	1	1	-1	1	-1	-1	0	-1	L
13	-1	1	0	0	-1	-0	1	1	1	-1	0	0	0	1	H
14	-1	-1	0	0	1	1	-1	-1	0	-1	1	1	0	-1	L
15	1	-1	1	1	1	1	1	0	-1	1	1	1	1	8	H
16	1	0	-1	1	0	0	0	0	0	0	-1	-1	0	-1	L
17	-1	-1	0	0	1	1	1	1	0	1	0	0	0	3	H
18	-1	-1	0	-1	-1	-1	-1	-1	-1	1	-1	-1	0	-9	L
19	1	1	-1	0	0	-1	1	0	0	0	1	1	0	3	H
20	1	1	1	-1	0	1	-1	0	1	-1	1	1	1	5	H

Cross

1. TGMS 74S x Aiswarya
2. TGMS 74S x Kanchana
3. TGMS 74S x Kairali
4. TGMS 74S x Makom
5. TGMS 74S x Samyuktha
6. TGMS 81S x Aiswarya
7. TGMS 81S x Kanchana
8. TGMS 81S x Kairali
9. TGMS 81S x Makom
10. TGMS 81S x Samyuktha
11. TGMS 82S x Aiswarya
12. TGMS 82S x Kanchana
13. TGMS 82S x Kairali
14. TGMS 82S x Makom
15. TGMS 82S x Samyuktha
16. TGMS 91S x Aiswarya
17. TGMS 91S x Kanchana
18. TGMS 91S x Kairali
19. TGMS 91S x Makom
20. TGMS 91S x Samyuktha

Characters

1. Days to 50% flowering
2. Plant height (cm)
3. Number of productive tillers plant^{-1}
4. Panicle length
5. Total number of spikelets panicle^{-1}
6. Number of filled grains panicle^{-1}
7. 1000 grain weight (g)
8. Grain length (mm)
9. Grain breadth (mm)
10. L/B ratio of grain
11. Single plant grain yield (g)
12. Single plant straw yield (g)
13. Harvest index

TGMS 91S x Kanchana showed significant sca effect for four characters total number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, 1000 grain weight, and grain length. TGMS 81S x Samyuktha showed a significant sca effect for plant height, total number of spikelets panicle^{-1}, 1000 grain weight. TGMS 74S x Makom showed a significant sca effects for plant height, grain length, grain breadth. TGMS 81S x Kanchana showed a significant sca effect for panicle length, grain breadth, single plant grain yield. TGMS 82S x Makom and TGMS 82S x Aiswarya showed significant sca effect for two component traits and TGMS 74S x Kairali, TGMS 91S x Samyuktha, TGMS 74S x Kanchana, TGMS 82S x Kairali, TGMS 82S x Samyuktha, TGMS 81S x Kairali, TGMS 74S x Aiswarya TGMS 81S x Aiswarya , TGMS 82S x Kanchana showed significant character for one character.

5.3.8 Estimation of heterosis

Heterosis is the phenomenon in which F_1 hybrids derived from diverse parents show superiority over their parents in vigour, yield panicle size, number of spikelets panicle^{-1}, number of productive tillers plant^{-1}, etc. Heterosis is expressed in different ways depending on the references use to compare the performance of a hybrid. From practical view point, standard heterosis is the most important because we aim to develop hybrids that are better than existing high yielding varieties growm commercially by the farmers. In the present investigation all the 25 hybrids have been included to assess the heterosis and results are discussed below. The best evolving pollinator parent Samyuktha is considered as a standard check.

The crosses with high standard heterosis for different characters are given in **Table 82 and 83.**

Table 82. Two line hybrids with superior standard heterosis

Sl.No	Characters	COH Vellanikkara	RARS Pattambi
1	Days to 50% flowering	TGMS 91S x Kairali TGMS 81S x Matta Triveni TGMS 82S x Makom TGMS 91S x Matta Triveni TGMS 81S x Samyuktha	TGMS 91S x Kairali TGMS 81S x Matta Triveni TGMS 91S x Kanchana TGMS 81S x Prathyasa TGMS 81S x Aiswarya
2	Plant height	TGMS 74S x Kairali TGMS 82S x Kairali TGMS 91S x Kanchana TGMS 82S x Makom TGMS 81S x Matta Triveni TGMS 81S x Makom	TGMS 91S x Kairali TGMS 82S x Makom TGMS 91S x Kanchana TGMS 81S x Makom TGMS 81S x Prathyasa
3	Number of productive tillers plant^{-1}	TGMS 82S x Prathyasa TGMS 82S x Aiswarya TGMS 81S x Aiswarya TGMS 81S x Makom	TGMS 74S x Samyuktha TGMS 82S x Prathyasa TGMS 81S x Aiswarya TGMS 91S x Samyuktha

Table 82. (Contd...)

		TGMS82S x Makom TGMS91S x Makom	TGMS 74S x Makom
4	Panicle length	TGMS 74S x Samyuktha TGMS 81S x Prathyasa TGMS 91S x Makom TGMS 91S x Aiswarya TGMS 82S x Samyuktha	TGMS 81S x Matta Triveni TGMS 81S x Kanchana TGMA 91S x Aiswarya TGMS 81S x Prathyasa TGMS 91S x Varsha TGMS 91S x Kanchana
5	Total number of spikelets panicle^{-1}	TGMS 91S x Samyuktha TGMS 91S x Kanchana TGMS 74S x Kairali TGMS 74S x Kanchana TGMS 91S x Varsha	TGMS 91S x Samyuktha TGMS 91S x Kanchana TGMS 74S x Kairali TGMS 91S x Makom TGMS 81S x Samyuktha
6	Number of filled grains panicle^{-1}	TGMS 91S x Samyuktha TGMS 91S x Kanchana TGMS 74S x Kanchana TGMS 74S x Kairali TGMS 91S x Kairali	TGMS 91S x Samyuktha TGMS 74S x Kairali TGMS 91S x Varsha TGMS 91S x Kanchana TGMS 81S x Samyuktha

Table 82. (Contd...)

		TGMS 91S x Varsha	
7	1000 grain weight	TGMS 91S x Makom TGMS 81S x Prathyasa TGMS 91S x Varsha	TGMS 81S x Prathyasa TGMS 91S x Makom
8	Grain length	TGMS 82S x Prathyasa TGMS 74S x Makom TGMS 91S x Samyuktha TGMS 74S x Samyuktha TGMS 81S x Matta Triveni	TGMS 82S x Prathyasa TGMS 74S x Makom TGMS 91S x Samyuktha TGMS 74S x Samyuktha TGMS 81S x Matta Triveni TGMS 82S x Samyuktha
9	Grain breadth	TGMS 91S x Samyuktha TGMS 81S x Prathyasa TGMS 81S x Kanchana TGMS 82S x Aiswarya TGMS 91S XAiswarya	TGMS 91S x Samyuktha TGMS 81S x Prathyasa TGMS 81S x Kanchana TGMS 82S x Aiswarya
10	L/B ratio of grain	TGMS 82S x Prathyasa TGMS 81S x Matta Triveni	TGMS 82S x Prathyasa TGMS 82S x Kanchana

Table 82. (Contd...)

		TGMS 82S x Kanchana TGMS 91S x Matta Triveni TGMS 82S x Samyuktha	TGMS 82S x Samyuktha TGMS 74S x Aiswarya TGMS 74S x Kanchana TGMS 81S x Aiswarya
11	Single plant grain yield	TGMS 81S x Matta Triveni TGMS 74S x Kairali TGM,S 91S x Samyuktha TGMS 91S x Makom TGMS 81S x Aiswarya	TGMS 91S x Samyuktha TGMS 81S x Matta Triveni TGMS 74S x Kairali TGMS 82S x prathyasa TGMS 81S x Makom TGMS 91S x Makom
12	Single plant straw yield	TGMS 91S x Varsha TGMS 81S x Matta Triveni TGMS 91S x Samyuktha TGMS 91S x Kanchana TGMS 74S x Kairali	TGMS 81S x Makom TGMS 91S x Samyuktha TGMS 81S x Matta Triveni TGMS 74S x Kairali TGMS 82S x Prathyasa TGMS 91S x Makom

Table 82. (Contd...)

13	Harvest index	-	TGMS 74S x Aiswarya TGMS 74S x Kairali TGMS 81S x Makom TGMS 91S x Samyuktha TGMS 81S x Matta Triveni TGMS 91S x Varsha

Table 83. Two line hybrids with superior *per se* performance and sca effects

Sl.No	Characters	COH Vellanikkara		RARS Pattambi	
		Per se performance	Sca effects	Per se performance	Sca effects
1	Days to 50% flowering	TGMS 91S x Kairali TGMS 82S x Makom TGMS 81S x Samyuktha TGMS 81S x Kanchana	TGMS 81S x Aiswarya TGMS 91S x Makom TGMS 74S x Kairali TGMS 82S x Aiswarya TGMS 74S x Kanchana	TGMS 91S x Kairali TGMS 81S x Matta Triveni TGMS 91S x Kanchana TGMS 91S x Matta Triveni TGMS 91S x Samyuktha	TGMS 74S x Kairali TGMS 91S x Makom TGMS 82S x Aiswarya TGMS 91S x Aiswarya TGMS 82S x Samyuktha
2	Plant height	TGMS 74S x Kairali TGMS 82S x Kairali TGMS91S x Kanchana TGMS 74S x Kanchana TGMS 82S x Makom	TGMS 81S x Samyuktha TGMS 74S x Kairali TGMS 81S x Kairali TGMS 82S x Aiswarya TGMS 82S x Makom	TGMS 91S x Kairali TGMS 91S x Kanchana TGMS 82S Makom TGMS 81S x Prathyasa TGMS 81S Makom	TGMS 74S x Makom TGMS 91S x Makom TGMS 82S x Kanchana TGMS 82S x Kairali TGMS 91S x Samyuktha
3	Number of productive tillers plant^{-1}	TGMS 82S x Prathyasa TGMS 82S x Aiswarya TGMS 81S x Aiswarya TGMS 81S x Matta Triveni TGMS 82S x Makom TGMS 81S x Makom	TGMS 82S x Aiswarya TGMS 91S x Kairali TGMS 91S x Makom TGMS 74S x Samyuktha TGMS 74S x Kanchana TGMS 81S x Samyuktha	TGMS 82S x Prathyasa TGMS 81S x Aiswarya TGMS 91S x Samyuktha TGMS 74S x Makom TGMS 81S x Makom TGMS 82S x Makom TGMS 91S x Kairali TGMS 91S x Makom	TGMS 81S x Aiswarya TGMS 91S x Samyuktha TGMS 91S x Aiswarya TGMS 74S x Kairali TGMS 74S x Makom TGMS 74S x Kanchana
4	Panicle length	TGMS 74S x Samyuktha TGMS 81S x Prathyasa TGMS 91S x Makom TGMS 91S x Aiswarya	TGMS 81S x Kanchana TGMS 82S x Makom	TGMS 81S x Matta Triveni TGMS 81S x Kanchana TGMS 91S x Aiswarya TGMS 81S x Matta Triveni TGMS 74S x Samyuktha TGMS 91S x Varsha	TGMS 81S x Kanchana TGMS 91S x Aiswarya TGMS 74S x Makom TGMS 74S x Samyuktha TGMS 82S x Samyuktha
5	Total number of spikelets panicle^{-1}	TGMS 91S x Samyuktha TGMS 91S x Kanchana TGMS 74S x Kairali TGMS 74S x Kanchana TGMS 91S x Varsha	TGMS 82S x Aiswarya TGMS 81S x Kairali TGMS 74S x Samyuktha TGMS 74S x Aiswarya TGMS 91S x Kairali TGMS 91S x Makom	TGMS 91S x Samyuktha TGMS 91S x Kanchana TGMS 74S x Kairali TGMS 91S x Varsha TGMS 91S x Makom	TGMS 74S x Kairali TGMS 81S x Kanchana 'TGMS 82S x Makom TGMS 82S x Samyuktha TGMS 81S x Aiswarya
6	Number of filled grains panicle	TGMS 91S x Samyuktha TGMS 91S x Kanchana	TGMS 82S x Aiswarya TGMS 81S x Kairali	TGMS 91S x Samyuktha TGMS 74S x Kairali	TGMS 74S x Kairali TGMS 82S x Makom

Table 83. (Contd...)

		TGMS 74S x Kanchana TGMS 74S x Kairali TGMS 91S x Kairali	TGMS 74S x Samyuktha TGMS 74S x Aiswarya TGMS 91S x Kairali	TGMS 91S X Varsha TGMS 91S x Kanchana TGMS 81S x Samyuktha	TGMS 81S x Aiswarya TGMS 81S x Kanchana TGMS 82S x Samyuktha
7	1000 grain weight	TGMS 81S x Prathyasa TGMS 91S x Varsha TGNS 91S x Makom TGMS 91S x Kanchana TGMS 91S x Matta Triveni	TGMS 81S x Samyuktha TGMS 82S x Kairali TGMS 74S x Makom TGMS 91S x Kanchana TGMS 91S x Aiswarya	TGMS 81S xPrathyasa TGMS 91S x Aiswarya TGMS 91S x Kanchana TGMS 91S x Varsha TGMS 74S x Aiswarya	TGMS 91S x Makom TGMS 82S x Kairali TGMS 74S x Aiswarya TGMS 82S x Samyuktha . TGMS 91S x Kanchana
8	Grain length	TGMS 82S x Prathyasa TGMS 74S x Makom TGMS 91S x Samyuktha TGMS 74S x Samyuktha	TGMS 91S x Makom TGMS 81S x Kairali TGMS 81S x Aiswarya TGMS 82S x Aiswarya TGMS 74S x Aiswarya	TGMS 81S x Prathyasa TGMS 74S x Samyuktha TGMS 91S x Samyuktha TGMS 81S x Matta Triveni TGMS 82S x Samyuktha	TGMS 91S x Kanchana TGMA 81S x Kairali TGMS 82S x Kanchana TGMS 74S x Makom TGMS 81S x Makom
9	Grain breadth	TGMS 91S x Samyuktha TGMS 81S x Prathyasa TGMS 81S x Kanchana TGMS 82S x Aiswarya TGMS 91S x Aiswarya	TGMS 82S x Samyuktha TGMS 82S x Samyuktha TGMS 81S x Kairali TGMS 74S x Makom TGMS 74S x Kanchana	TGMS 91S x Samyuktha TGMS 81S x Prathyasa TGMS 81S x Kanchana TGMS 82S x Aiswarya TGMS 91S x Aiswarya	TGMS 91S x Samyuktha TGMS 82S x Aiswarya TGMS 82S x Kairali TGMS 81S x Kanchana TGMS 74S x Makom
10	L/B ratio of grain	TGMS 82S x Prathyasa TGMS 82S x Kanchana TGMS 82S x Samyuktha TGMS 74S x Aiswarya TGMS 74S x Kanchana	TGMS 91S x Makom TGMS 81S x Aiswarya TGMS 91S x Samyuktha TGMS 74S x Kairali TGMS 82S x Aiswarya	TGMS 82S x Prathyasa TGMS 82S x Kanchana TGMS 82S x Samyuktha TGMS 74S x Aiswarya TGMS 74S x Kanchana	TGMS 82S x Kanchana TGMS 81S xAiswarya TGMS 81S x Makom TGMS 82S x Samyuktha TGMS 91S x Kairali
11	Single plant grain yield	TGMS 81S x Matta Triveni TGMS 91S x Samyuktha TGMS 91S x Makom TGMS 74S x Kairali TGMS 91S x Kanchana	TGMS 82S x Aiswarya TGMS 91S x Makom TGMS 81S x Samyuktha TGMS 81S x Kairali TGMS 74S x Samyuktha	TGMS 82S x Aiswarya TGMS 91S x Makom TGMS 81S x Samyuktha TGMS 81S x Kairali TGMS 74S x Samyuktha	TGMS 91S x Samyuktha TGMS 74S x Kairali TGMS 82S x Makom TGMS 91S x Makom TGMS 81S x Kanchana TGMS 74S x Aiswarya
12	Single plant straw yield	TGMS 81S x Matta Triveni TGMS 91S x Samyuktha TGMS 91S x Makom TGMS 91S x Kanchana	TGMS 82S x Aiswarya TGMS 81S x Samyuktha TGMS 91S x Makom TGMS 81S x Kairali	TGMS 91S x Samyuktha TGMS 81S x Matta Triveni TGMS 91S x Makom TGMS 74S x Kairali	TGMS 74S x Kanchana TGMS 91S x Samyuktha TGMS 82S x Makom TGMS 81S x Kanchana

Table 83. (Contd...)

		TGMS 81S x Kanchana	TGMS 74S x Samyuktha	TGMS 82S x Prathyasa	TGMS 74S x Aiswarya
13	Harvest index	TGMS 82S x Aiswarya TGMS 82S x Prathyasa TGMS 81S x Matta Triveni TGMS 91S x Samyuktha TGMS 74S x Kairali TGMS 81S x Aiswarya TGMS 81S x Samyuktha	TGMS 91S x Makom TGMS 82S x Aiswarya	TGMS 91S x Varsha TGMS 81S x Matta Triveni TGMS 91S x Samyuktha TGMNS 81S x Makom TGMS 74S x Kairali TGMS 74S x Aiswarya	TGMS 82S x Samyuktha TGMS 91S x Samyuktha

5.4 Quality analysis

Better understanding of the factors that contribute to the over all grain quality of rice will lay the foundation for developing new breeding and selection strategies for combining high quality,with high yield. It is necessary to meet the growing global demand for high quality rice while offering producuing countries additional opportunities for generating higher export revenues.

Keralities have a dietary preference towards red kernelled rice. All the promising two line hybrids have red kernels. Milling recovery defined the recovery of milled rice from the paddy, Milling recovery of two line rice hybrids reflected less loss of paddy on milling **(Fig.7)**

The cooking quality of rice depends mainly on amylase content and gelatinization temperature. Amylose content determines the stickiness of cooked rice. Intermediate amylase content is preferred by Keralities. Low amylase content show low water absorption, expansion on cooking and the grains become sticky. The variety with high amylase content cooks dry and fluffy but becomes hand on cooking .So intermediate amylase content is preferred. Intermediate amylase content was noted for the TGMS 91S x Samyuktha, TGMS 81S x Matta Triveni, TGMS 91S x Kanchana, TGMS 91S x Makom, TGMS 81S x Makom , TGMS 81S x Kairali and TGMS 81S x Aiswarya.

Gelatinization temperature is the temperature at which starch grains swell irreversibly when boiled in water. It ranges from 56-79^{0}C, depending on the hardness of starch granules. The higher the gelatinization temperature of rice, the more water and time are needed to cook. Gelatinization temperature is assayed as alkali digestion value. Intermediate gelatinization temperature is preferred (70-74^{0}C). The two line hybrids TGMS 91S x Kanchana, TGMS 74S x Kairali, TGMS 91S x Makom, TGMS 82S x Prathyasa, TGMS 81S x Makom, TGMS 81S x Kanchana, TGMS 81S x Aiswarya and TGMS 74S x Aiswarya.

1. TGMS 91S x Samyuktha
2. TGMS 81S x Matta Triveni
3. TGMS 91S x Kanchana
4. TGMS 74S x Kairali
5. TGMS 91S x Makom
6. TGMS 82S x Prathyasa
7. TGMS 81S x Makom
8. TGMS 81S x Kanchana
9. TGMS 81S x Aiswarya
10. TGMS 74S x Aiswarya

Plate 5. Variability of panicles of two line rice hybrids

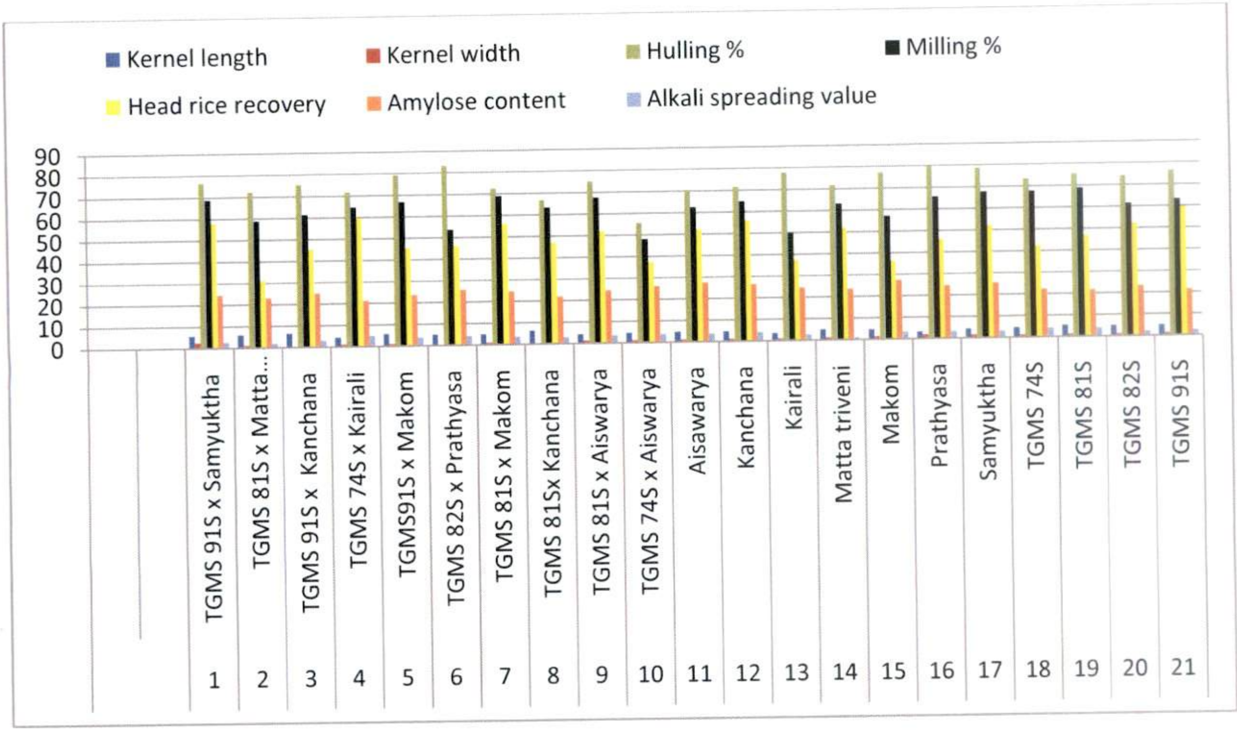


Fig 8. Grain and milling quality characters of promising two line hybrids and parents

Plate 6. Some of the Promising two line rice hybrids

Plate 6. Some of the promising two line hybrids

Plate 6. Some of the promising two line hybrids

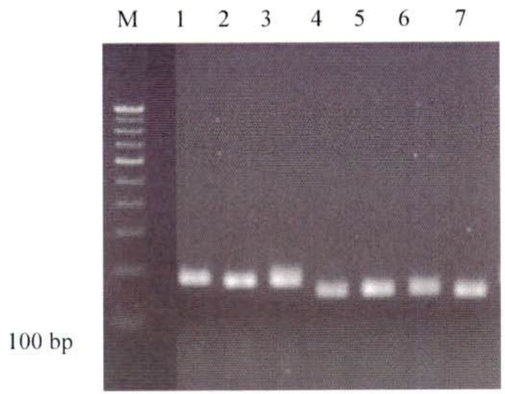
5.5 Molecular analysis

The term polymorphic information content(PIC) was originally introduced in human genetics by Boststein *et al.* (1980). PIC refers to the value of a marker detecting polymorphism within a population depending on the number of detectable allele and their distribution of their frequency. In the present study the number of alleles per locus varied detected by among these markers ranged from 2 to 3 with an average of 1.90. In the present study the average polymorphic information content below 0.50 . Lower PIC values might be the result of use diverse genotypes. Similar to the present study, low PIC values for some other primers were earlier reported by Juneja *et al.* (2006)

The study also further revealed that the primer RM 11 is ascertained more number of alleles with PIC value more than 0.50 which indicates the efficiency of this primer in detecting the most heterogenous accession. Utilisation of microsatellite markers in the analysis of rice genotypes revealed a high level of genetic polymorphism which allowed unique genotyping of the studied hybrids and parents. Hence these markers sufficient for unambiguous identification of hybrid combinations.

Similarity matrix produced by use of NTSYS-pc program (Rohlf, 1999) and it was used to construct dendrograms using Sequential Agglomerative Hierarchical Nesting (SAHN) based on Unweighted Pair Group Method with Arithmetic Means (UPGMA) (Sokel and Michener, 1958) to infer genetic relationships.

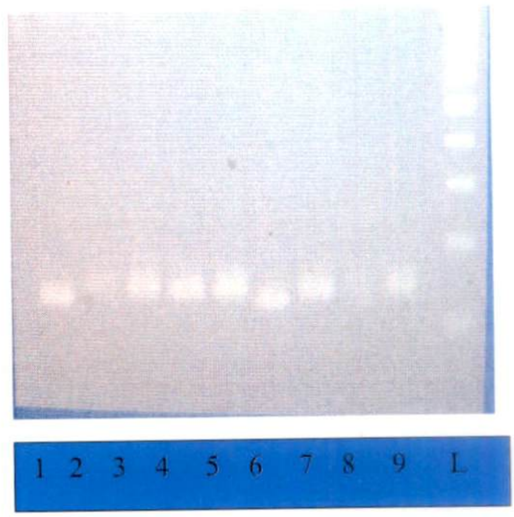
Cluster analysis using NTSYS generated dendrogram **(Fig. 8)** throws light on genetic similarity. Genotypes within the cluster had more similarity and less similarity was observed between genotypes in different cluster. Genetically diverse parents are the prime requirement for heterosis breeding for exploitation of good hybrids with improved yield and yield attributing characters. Present study revealed that the grouping of rice genotypes into ten clusters based on similarity coefficient. Rice genotypes from different clusters possessed alleles responsible for diverse agronomic and yield contributing characters.



1-TGMS 74S
2-TGMS 81S
3-TGMS 82S
4-TGMS 91S
5-TGMS 92S
6-TGMS 93S
7-TGMS 94S

Plate 7. SSR profile rice genotypes with primer RM 11

L- Ladder
1- TGMS 74S
2-TGMS 74S x Aiswarya
3- Aiswarya
4-TGMS 91S
5-TGMS91 S x Samyuktha
6-Samyuktha



L -Ladder
1-TGMS 81S
2-TGMS 81S x MattaTriveni
3- MattaTriveni
4- TGMS 82S
5- TGMS 82S x Prathyasa
6- Prathyasa
7- TGMS 7S
8 - TGMS 74S x Kairali
9- Kairali

Plate 8. SSR Profile of few tow line rice hybrids with primer RM 11

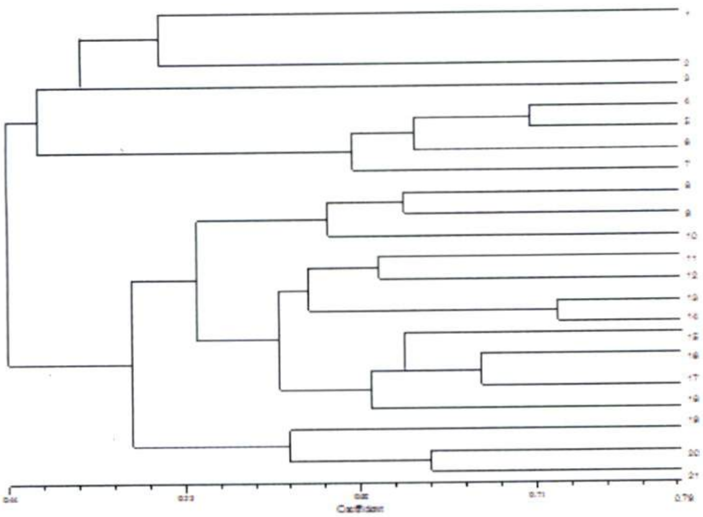


Fig 9.Dendrogram based on SSR marker data

1) TGMS 91S x Samyuktha
2) TGMS 91S x Kanchana
3) TGMS 91S
4) TGMS 91S x Makom
5) TGMS 81S x Makom
6) Makom
7) TGMS 81S
8) TGMS 81S x Kanchana
9) TGMS 81S x Aiswarya
10) TGMS 82S
11) Kanchana
12) Samyuktha
13) TGMS 82S x Prathyasa
14) Prathyasa
15) Aiswarya
16) TGMS 81S x MattaTriveni
17) MattaTriveni
18) Kairali
19) TGMS 74S
20) TGMS 74S x Kairali
21) TGMS 74S x Aiswarya

Summary

6. SUMMARY

The present investigation entitled "Standardisation of two line heterosis breeding in rice for Kerala" was conducted in the Department of Plant Breeding and Genetics , College of Horticulture, Kerala Agricultural University during 2010-2014. Field trails were laid out at experimental fields of College of Horticulture, Vellanikkara and Cardamom Research Station, Pampadumpara and Regional Agricultural Research Station, Pattambi, of Kerala Agricultural University. The salient findings of the study are summarized as follows.

1) Among the seven TGMS lines the lines, TGMS 74S, TGMS 81S , TGMS 82S and TGMS 91S flowering coincide with the cropping duration of pollinator parents.

2) Based on the sterility/fertility behavior of TGMS lines, the entire study period could be classified into two distinct periods *viz,* pollen sterile and pollen fertile months. Pollen sterile months were April and May when 100 per cent sterility was observed . July and August could be considered as pollen fertile months. Those months exhibited unstable expression of sterility/fertility and hence could not be grouped under pollen sterile or pollen fertile months.

3) The sterile period was longest in TGMS 82S (87days) followed by TGMS 81S (83 days). All lines were completely sterile for more than 30 consecutive days during sterile phase.

4) All seven TGMS lines exhibited 100 per cent fertility from July 2nd week to September Ist week.

5) Correlation studies between weather parameters and pollen sterility behavior indicated that maximum temperature and mean temperature had

the highest significant positive correlation with sterility. Except TGMS 74S other six TGMS lines had significant influence of minimum temperature on pollen sterility.

6) All seven TGMS lines were not influenced by environmental factors such as relative humidity and rainfall.

7) CST ranged from 32.9^{0C} (TGMS 81S and TGMS 82S) to 34.2 ^{0C} (TGMS 74S,TGMS 91S,TGMS 92S, TGMS 93S, TGMS 94S). CFT ranged from 22.7^{0C} (TGMS 91S) to 24.2^{0C} (TGMS 81S, TGMS 82S,TGMS 92S, TGMS 93S and TGMS 94S)

8) TGMS lines were fully fertile throughout the year at CRS Pampadumpara.

9) CRS Pampadumpara and College of Horticulture Vellanikkara can be considered as clearly defined fertility, sterility alteration regimes for the TGMS lines. These are the two major desirable locations for the maintenance of TGMS lines and for two line hybrid rice seed production respectively.

10) Significant correlation at genotypic and phenotypic levels were observed in pollinators for the characters *viz.*, plant height, total number of spikelets panicle^{-1}, grain breadth and days to 50% flowering.

11) Path analysis in pollinators showed that highest negative direct effect was exhibited by number of filled grains per panicle followed by plant height, days to 50% flowering, total number of spikelets panicle^{-1} . Highest negative indirect effect was observed for single plant straw yield via harvest index.

12) Evaluation of two line hybrids indicated that TGMS 81S x Kairali and TGMS 81S x Matta Triveni recorded the minimum and maximum single

plant grain yield and single plant straw yield at COH Vellanikkara and TGMS 91S x Kairali and TGMS 91S x Samyuktha recorded the minimum and maximum plant yield at RARS Pattambi

13) Significant positive correlation at genotypic and phenotypic levels were observed in hybrids for the characters *viz,* number of productive tillers plant^{-1}, total number of spikelets panicle^{-1} at two locations .

14) In hybrid evaluation highest positive direct effect on yield was observed for number of filled grains panicle^{-1} and single plant straw yield at COH Vellanikkara and RARS Pattambi . Highest negative direct effect was exhibited by total number of spikelets panicle^{-1} and number of filled grains panicle^{-1} at COH Vellanikkara.

15) Based on the gca effects of pollinator parents, Aiswarya, Makom, Kanchana, Samyuktha and TGMS 81S, TGMS 82S, TGMS 91S were good general combiners, whereas Kairali was the poor combiner. Parallelism between *per se* performance and gca effects did not exist always for most of the characters studied.

16) The two line hybrids TGMS 91S x Makom . TGMS 82S x Aiswarya, TGMS 81S x Kairali, TGMS 81S x Kanchana , TGMS 91S x Kairali , TGMS 81S x Kanchana , TGMS 91S x Kairali from COH Vellanikkara and TGMS 82S x Samyuktha , TGMS 74S x Samyuktha , TGMS 81S x Aiswarya , TGMS 91S x Samyuktha, TGMS 74S x Kairali , TGMS 74S x Makom from RARS Pattambi had high sca effects for various characters studied.

17) Cooking quality analysis revealed intermediate amylose and alkali spreading values for the hybrids TGMS 91S x Makom, TGMS 91S x Kanchana, TGMS 81S x Makom and TGMS 81S x Aiswarya.

18) Molecular assay of hybrids and parents revealed that the number of alleles per locus ranged from 2 to 3.

19) Polymorphic information content which is a reflection of allele diversity ranged from 0.291 (RM 2) to 0.648 (RM 132) with an average of 0.448.

20) RM 11 marker showed more number of alleles with PIC value more than 0.50 indicating the efficiency of this primer in detecting the most heterogenous accession.

21) Three alleles were detected by RM 11, RM 168 and RM132 with a PIC value of 0.623, 0.549 and 0.499 respectively.

References

7. REFERENCES

Aananthi, N. and Jebaraj, S. 2006. Heterosis in two line rice hybrids. Indian J. Agric. Res. 40(3): 178-183.

Abraham, M.J., Zaman, F.U., Natarajan, U.S., Mahendru, A. and Mohammad, F. 1998. Developing Pusa 5 A, a stable *indica* CMS line with high outcrossing potential. IRRN 23(2): 15-16.

Akagi, H., Yokozeki, Y., Inagaki, A. and Fujimura, T. 1997. Highly polymorphic microsatellites of rice consist of AT repeats, and a classification of closely related cultivars with these microsatellite loci. Theor. Appl. Genet. 94: 61-67.

Akinwale, M.G., Gregorio, G., Nwilen, F., Akinyele, B.O., Ogunbayo, S.A. and Odiyi, A.C. 2011. Heritability and correlation coefficient analysis for yield and its components in rice (*Oryza sativa* L.). African J. Plant science 5(3): 207-212.

Aktar, A., Hasan, M.J., Begum, H., Kulsum, M.U. and Hossain, M.K.2010. Combining ability analysis in rice (*Oryza sativa* L.). Bangladesh J. Pl. Breed. Genet.23(2): 07-13.

Ali, J., Siddidq, E.A., Zaman, F.U., Abraham, M.J. and Ahemed, I. 1995. Identification and characterization of temperature sensitive genic amle sterile sources in rice (*Oryza sativa* L.). Indian. J. Genet. 55: 243-259.

Ali, S.S., Akhter, M., Sabar, M. and Ali, M. 2008. Evaluation of rice CMS lines from diverse male sterility sources in Pakistan. J. Agric. Res. 3(1): 1-5.

Abarshahr, M., Rabiei, B., Lahigi, H.S. 2011. Genetic variability , correlation and path analysis in rice under optimum and stress irrigation regimes.Notulae scientia biologicae. 3:4

Arumugachamy, S., Giridharan, S., Soundararaj, A.P.M.K., Vivekanandan, P. and Anthoniraj, S. 1995. Physical, milling, chemical and cooking characters in some rice cultivars of Tamil Nadu, India. IRRN. 20(1): 10-12.

Asish K.B., Kalaiyarasi, R. and Thiyagarajan, K. 2007. Genetic parameter studies on quality traits in rice. Madras. Agric. J. 94(1-6): 109-113.

Asish, K.B., Kalaiyarasi, R., Thiyagarajan, K. and Manonmani, S. 2006. Physiochemical and cooking quality characteristics of promising varieties and hybrids in rice. Indian J. Genet. Plant Breed. 66 (2):107-112.

Athwal, D.S. and Virmani, S.S. 1972. Cytoplasmic male sterility and hybrid breeding in rice In: Rice Breeding. International Rice Research Institute, P.O.Box 933, Manila, Philipines

Angustina, U.A., Iwunor, O.P., Ijeoma, O.R.2013. Heritability and character correlation among some rice genotypes for yield and yield components. J. Plant Breed. Genet. 01(02): 73-84.

Azeez, M.H. and Shafi, M. 1966. Quality in rice. Tech .Bull. No.13, Dept. agic.Govt. West Pakistan. P.50.

Azzini, L.E. and Rutger, J.N.1982. Amount of outcrossing on different male steriles of rice. Crop Sci. 22(8-9): 905-907.

Babu , R.V., Shreya, K., Dangi, S.K., Usharani, G. and Nagesh, P.2012. Genetic variability studies for qualitative and quantitative traits in popular rice hybrids of India. Int. J.of scient and res publ 2(6) : 2250-3153

Bagheri, N., Odar, N.B.J.. and Pasha, A. 2011. Path coefficient analysis for yield and yield components in diverse rice (*Oryza sativa* L.) genotypes. Biharean biol. 5(1):32-35

Bai, D.L. and Luo, X.H. 1996. Liangyou Peite a new two line hybrid rice released in China. Int. Rice Res. Newsl. 1: 42-43.

Bai, N.R., Regina, A., Devika, R., Leenakumari, S., Devi, D.S.R. and Joseph, C.A. 1991. Grain quality of some red rice genotypes. IRRN. 16(1): 6-7.

Bajracharya, K., Steele, A., Jarvis, D.I. , Sthapit , B.R. and Witcombe, J.R. 2005. Rice landrace diversity in Nepal: Variability of agro-morphological traits and SSR markers in landraces from a high-altitude site. Plant Genet. Resour. 25(2): 120-133.

Bala, A., Muthiah, A.R. and Boopathi, S.N.M.R. 1999. Genetic variability,character association and path coefficient analysis in rainfed rice under alkaline condition. Madras .agric.J. 86(1-3):122-124

Bansal, U.K., Kaur, H. and Saini, R.G. 2006. Donors for quality characteristics in aromatic rice. Crop Improv. 43(2): 197-202.

Bassi, D.S., Zhu, Y.G., Ahmed, M.I., Jachuk, P.J. and Virmani, S.S. 1992. Diversifying the CMS system to improve the sustainability of hybrid rice technology. In: *Advances in Hybrid Rice Technology*. Virmani, S.S., E.A. Siddiq and K. Muralidharan (eds). International Rice Research Institute, P.O. Box 933, Manila, Philippines. pp. 129-145.

Bastia, D., Mishra, T.K. and Das, S.R. 2008. Genetic variability and selection indices for grain yield in upland rice. Oryza. 45(1) :72-75

Behla, R.S., Rang, A. and Bharaj, T.S. 2007. Floral and morphological traits of some A, B and R lines of rice. Crop Improv. 34(1): 24-26.

Bhadru, D., Lokanadha, R.D. and Ramesha, M.S.2012. Correlation and path analysis of yield and yield componenets in hybrid rice (*Oryza sativa* L.) .on line publication.17th oct.

Bisne, R., Sarawgi, A.K. and Verulkar, S.B. 2009. Study of heritability, genetic advance and variability for yield contributing characters in rice. Bangladesh J. Agril. Res. 34(2) :175-179

Blair, M.W. and McCouch, S.R. 1997. Microsatellite and sequence tagged site markers diagnostic for the rice bacterial leaf blight resistance gene *xa-5*. Theor. Appl. Genet. 95(2): 174-184.

Borkakati, R.P. and Virmani, S.S. 1997. Determination of critical stage of fertility alteration in two thermo-sensitive genic male sterile mutants of rice. In: *Proceeding International Symposium on Two-line System of Heterosis Breeding in Crops*, Sep.6-8, 1997, China National Hybrid Rice Research and Development Centre, Changsha, China. pp.188-192.

Botstein, C., White, R.L., Skolnick, M. and Davis, R.W. 1980. Construction of a genetic linkage map in man using restriction fragment length polymorphism. Am. J. Hum. Genet.32:314-331.

Cagampang, B.G., Perez, C.M. and Juliano, B.O. 1973. A gel consistency test for eating quality of rice. J Sci .Food Agric. 24: 1589-1594.

Chakravarthi, B.K. and Naravaneni, R. 2006. SSR marker based DNA fingerprinting and diversity study in rice (*Oryza sativa.* L) African J. Biotech. 5(9): 684-688.

Chandirakala, R. 2005. Genetic analysis and characterization of thermo sensitive genic male sterile lines (TGMS) and their utilization in heterosis breeding of rice (*Oryza sativa* L.), Ph.D. Thesis. Tamil Nadu Agricultural university, Coimbatore.

Chandirakala, R. and Thiyagarajan, K. 2010. Heterotic expression of two line hybrids in rice (*Oryza sativa* L.). Electronic J. Plant Breed. 1(4): 1070-1078.

Chen, L., Sun, C.Q., Li, Z.C. and Wang, X.K. 2000. Study on heterotic ecotype of two line *japonica* hybrid rice in North China. J. China Agric. Univ. 5: 30-40.

Chen, S.H., H.R. Lu and J.B. Yang. 1997. Heterosis, combining ability and correlation of agronomic traits in two-line inter-subspecific hybrid rice. J. Fujian Agricultural Univ., 26: 1-7.

Chen, S.H., Lu, H.R., Yang, J.B., Hu, R.Y. and Zhao, M.F. 1997a. Heterosis, combining ability and correlation of agronomic traits in two line inter specific hybrid rice. J. Fujian Agric. Univ. 269(1): 1-7.

Chen, S.H., Temnykh, S., Xu, Y., Cho,Y.G. and McCouch, S.R. 1997b. Development of a microsatellite framework map providing genome-wide coverage in rice (*Oryza sativa* L.). Theor. Appl. Genet. 95(3): 553–567.

Chen, X.H., Wan, B.H., Lu, Y.P., Peng, H.F., Liang, K.Q. and Zhao, J. 2001. Studies on outcrossing seedy potentialities of photo thermo sensitive genic male sterile rice. J.S.China agric. Univ. (Chinese).22(1):1-4

Cheng, S.S., Sun, Z.X., Min, S.K., Ziong, Z.M., Ying, C.S. and si, H.M. 1990. Studies on response to photoperiod sensitive genic amle sterile rice (PGMSR): In: Observation of fertility in PGMSRs under natural condition at Hangzhou (30°05'N). Chinese J.Rice Sci. 4: 157-162.

Cherian, B. 1998. Characterization and utilization of TGMS lines for heterosis breeding in rice (*Oryza sativa* L.). M.Sc.Thesis, Tamil Nadu Agricultural University, Coimbatore.

Das, P., Santra, C.K., Mukhopadhyay, S.and Dasgupta, B.M.T. 2013. Genetic variability in cytoplasmic male sterile lines in rice (*Oryza sativa* L.). IOSR. JAVS. 3(5):95-100.

Dipti, S.S., Hossain, S.T., Bari, M.N. and Kabir, K.A. 2002. Physicochemical and cooking properties of some fine rice varieties. Pakistan J. Nutri. 1(1): 188-190.

Dipti, S.S., Hossain, S.T., Bari, M.N. and Kabir, K.A. 2003. Grain quality characteristics of some Beruin Rice varieties of Bangaladesh. Pakistan J. Nutri. 2(4): 242-245.

Domini, P., Law, J.R., Koehner, R.M.D., Reeves, J.C. and Cooke, R.J. 2000. Temporal trends in the diversity of UK wheat. Theor. Appl. Genet. 100(7-8): 912-917.

Dong, F.G., Zhu, X. and Ziong, Z.M. 1995. Breeding of PGMS *indica* rice with a morphological marker. Chinese Rice Res. Newsl. 3: 1-2.

Dong, N.V., Subudhi,P.K., Luong, P.N., Quang,V.D., Quy,T.D., Zheng,H.G., Wang, B. and Nguyen, H.T. 2000. Molecular mapping of a rice gene conditioning thermosensitive genic male sterility using AFLP, RFLP and SSR techniques. Theor. Appl. Genet. 100:727–734.

DRR. 1996. Two line heterosis breeding in development and use of hybrid rice technology-Annual report for 1994-95, Directorate of Rice Research, Hyderabad, India.pp.27-30

Du, L.Q., Minh, H.T., Nhan, N.T. and Quy, T.D. 1997. Some characteristics of thermo-sensitive genic lines in rice and results of F_1 seed production. In: Proceedings of International symposium of Two-line system of Heterosis Breeding in Crops. Sep. 6-8, 1997, China National Hybrid Rice Research and Development Centre, Changsha, China. pp. 228-231.

Durai, A.A.2001. Association analysis in hybrid rice Ann.Agric.Res.22(3):420-422.

Edwards, K.J., Barker,H.A., Daly, A., Jones, C. and Karp, A. 1996. Microsatellite libraries enriched for several microsatellite sequences in plants. Biotechniques. 20(6): 758-760.

Ekka , R.E., Sarawgi, A. K. and Kanwar, R.R. 2011. Correlation and path analysis in traditional rice accessions of Chhattisgarh. J. rice research. 4(2): 11-18

Erickson, J.R. 1969. Cytoplasmic male sterility in rice (*Oryza sativa L.*). American Soceity of Agronomy Abstracts 1969:6.

Faiz, F. A., Sabar, M., Awan, T. H., Tjaz, M. & Manzoor, Z. (2008). Heterosis and combining ability analysis in basmati rice hybrids. *J. Anim. PI. Sci.* 16 (1 - 2).

FAO, 2006. Food outlook, Global market analysis. Rome: FAO

Feng, Y.Q., Wang, C.Y. and Li, C.X. 1985. Studies on the utilization of the Hubei-day nuclear male sterile rice. Acta.Agric. sin. 20: 227-234.

Fisher, P.J., Gardner, R.C. and Richardson, T.E. 1996. Single-locus microsatellites isolated using 5-anchored PCR. Nucleic Acids Res. 24: 4369-4371.

Fitzgerald, M.A., Hamilton, N.R.S., Calingacion, M.N., Verhoeven, H.A. and Butardo, V.M. 2008. Is there a second gene for fragrance in rice? Plant Biotechnol. J. 6: 416–423.

Fufa, H., Baenziger, P.S., Beecher, B.S., Dweikat, I., Graybosch, R.A. and Eskridge, K.M. 2005. Comparison of phenotypic and molecular marker based classification of hard red winter wheat cultivars. Euphytica. 145 (2): 133-146.

Fukrei, P.K., Kumar, A., Tyagi, W., Rai, M. and Pattanayak, A. 2011. Genetic variability in yield and its components in upland rice grown in acid soils of north east india. J. of rice res. 4: 1&2.

Ganesan, K.N. 1995. Cytoplasmic differences of CMS lines in heterosis breeding of rice (*Oryza sativa* L.) M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Ganesan, K.N. 2000. Character association in rice hybrids involving CMS lines. J. Ecobiology.12(2):153-156.

Gao, L.Z. 2005. Microsatellite diversity and population genetic structure of an endangered wild rice, *Oryza officinalis* (Poaceae) from China. Mol. Ecol. 14(1): 4287-4297.

Gao, L.Z., Zhang, C.H., Chang, L.P., Jia, J.Z., Qiu, Z.E. and Dong, Y.S. 2005. Microsatellite diversity of *Oryza sativa* L. with emphasis on *indica-japonica* divergence. Genet. Res. 85(1): 1-14.

Gao, Y., Yang, Z.Y., Wei, Y.L., Zhao, Y.C., Gao,R.L., Hua, Z.T. and Pan, Q.M. 1996. The approach of breeding *japonica* photo-thermo sensitive genic male sterile rice adapted to climatic conditions of the north of China. Chinese J.Rice Sci. 10: 54-56.

Garris, A.J., Tai, T.H., Coburn, J., Kresovich, S. and McCouch, S. 2005. Genetic structure and diversity in *Oryza sativa* L. Genetics. 169(2):1631-1638.

Gnanasekaran, M., Vivekanandan, P. and Muthuramu, S. 2006. Combining ability and heterosis for yield and grain quality inn two line rice (*Oryza sativa* L.) hybrids. Indian J. Genet. 66(1): 6-9.

Gong, G.M., Zhou, G.F. and Yin, C.Q. 1993. Analysis on the combining ability of main agronomic traits of *indica* double functional genic male sterile lines. Chinese J. Rice Sci. 7:137-142.

Gupta, P. K. and Varshney, R.K. 2000. The development and use of microsatellite markers for genetic analysis and plant breeding with emphasis on bread wheat. Euphytica. 113(2): 163-185.

Hasan, M.J., Kulsum, U., Rahman, M.H., Ali, M.H. and Julfiquar, W. 2011. Genetic variability of some cytoplasmic male sterile lines (CMS) of rice (*Oryza sativa* L.) genotypes. Bangladesh J.Agril Res. 36(2) :263-270.

He, H., Peng, X., Gong, H., Zhu, C. and Ye, G. 2006. Fertility behaviour of rice (*Oryza sativa)* lines with dominant male sterile gene and inheritance of sterility and fertility restoration. Field crops Res. 98(1): 30-38.

He, Y., Qi, H.X. and Wang, C.Y. 1995. Evaluation of combining ability of two line hybrid in *japonica* rice. J. Huazhong Agric. Univ. 14: 220-225.

Higgins, J., Evans, J.L. and Law, J.R. 1998. A revised classification and description of faba bean (*Vicia faba* L.) cultivars. Plant Varieties Seeds, 1: 27-35.

Hoang, T.M., Lam, Q.D., Tran, D.Q. and Nguyen, T.T. 1997. Development of TGMS lines with diversified source of sterility. In: Proceeding of International symposium on Two-line system of Heterosis Breeding in crops. Sep. 6-8, 1997, China National Hybrid Rice Research and Development centre, Changsha, China, pp. 204-205.

Hoang, T.M., Nghien, T.N., Lam, Q.D., Nguyen, T.T., Vu, T.T., Pham,T.T. and Tran, D.Q. 2000. Development of TGMS lines with diversified source of sterility. In: Proceedings of conference on Rice Research and Development in Vietnam – India cooperation, September 18-20, 2000, Canthocity, Vietnam. pp. 161-166.

Hossain, S., Haque, M.D.. and Rahman, J. 2015. Genetic variability, correlation and path coefficient analysis of morphological traits in some extinct local aman rice (*Oryza sativa* L.). J.Rice Res, 4:1

Huang, X.Q., Borner, A., Roder, M.S. and Ganal, M.W. 2002. Assessing genetic diversity of wheat (*Triticum aestivum* L.) germplasm using microsatellite markers. Theor. Appl. Genet. 105(5): 699-707.

Huang, Z., Ge, B., Xiang, G., Chen,W., Lui, Y. and Ni, K. 1997. Selection and breeding of *indica* dual – purpose genetic male sterile line (DGMSL) 2136s. In: Proceedings of International Symposium on Two-line system of Heterosis Breeding in Crops. Sep. 6-8, 1997. China National Hybrid Rice Research and Development centre, Changsha, China. pp. 184-187.

Hussain, A.A., Maurya, D.M. and Vaish, C.P. 1987. Studies on quality status of indigenous upland rice (*Oryza sativa* L.). Indian J.Genet. 47 (2): 145-152.

Hussain, A.J. 1996. Studies on thermo-sensitive genic male sterile (TGMS) lines in rice (*Oryza sativa* L.). M.Sc Thesis, Tamil Nadu Agricultural University, Coimbatore (Unpublished).

Idris, A.E. and Mohamed, K.A. 2013. Estimation of genetic variability and correlation for grain yield components in rice (*Oryza sativa* .L). Global J. Plant Ecophysiology. 3(1): 1-6

Idris, A. E., Justin, F. J., Dagash, Y. M. I. and Abuali, A. I. 2012. Genetic variability and inter relationship between yield and yield components in some rice genotypes. American J.Experimental Agriculture.2(2): 233-239.

IRRI.1972. Annual Report for 1971. Int. Rice Res. Institute, Los Banos, Philippines, p.238

Jaiswal, H. K., Shrivastava, A. K. and Dey, A. 2007. Variability and association studies in indigenous aromatic rice. *Oryza*. 44(4): 351- 353.

Janaiah, 1998. Hybrid rice for India's food security in THE 21ST Century. In: National Symposium on Rice Research for 21st Century-challenges, priorities and strategies, Cuttack, India on February 5-7, 1998. pp. 15-16.

Janardhanam, V., Nadarajan, N. and Jebaraj, S.2001. Correlation and path analysis in rice (*Oryza sativa* L.). Madras agric. J.88(10-12):719-720.

Jayamani, P. and Rangasamy, M. 1995. Floral characters influencing outcrossing in rice. Oryza. 32(1):9-12.

Jayaramaiah, V.K., Vidyachandra, B. and Shreedhara, D. 2007. Evaluation of new CMS lines for out crossing potential in rice. Oryza. 44(2): 150-153.

Ji, H.C., Kim, Y.I., Lee, H.B., Cho, J.W., Seo, S. and Yamakawa, T. 2007. Genetic diversity of coloured rice lines based on botanical characteristics and simple sequence repeat markers. J. Fac.Agr.Kyushu Univ. 52(2): 287-293.

Jia, J.H., Zhang, D.S., Li, C.Y., Qu , X.P., Wang, S.W., Chamarerk, V., Nguyen, H.T. and Wang, B. 2001. Molecular mapping of the reverse thermo-sensitive genic male-sterile gene (rtms1) in rice. Theor. Appl. Genet. 103:607–612.

Jin, D.M., Wang, W.J., Lan, S.Y., Xu, Z.X. and Yang, S.H. 2001. Heterosis and correlative analysis of yield componenets and panicle characters of rice (*Oryza sativa* L.) hybrid Pei-ai64s/E32. J.Huazhong agric.Univ.(Chinese).20(6):516-521.

Johnson, H.W., Robinson, H.F.and Comstock, R.E. 1955. Estimate of genetic and environmental variability in soybean. Agron. J. 47:314-318.

Jones, J.W. 1926. Hybrid vigour in rice. J. Am. Soc. Agron. 18: 423-428.

Juliano, B.O. 2003. Rice Chemistry and Quality. Intern. Rice Res. Inst. Manila, Philippines.

Juliano, B.O., Bautista, G.M., Lugay, J.C. and Reyes, A.C. 1964. Studies on the physico-chemical properties of rice. J. Agric. Food Chem., 12(1): 131-138.

Juneja, H., Inagaki, Y.A. and Fujimura, T. 2006. Highly polymorphic microsatellites of rice consist of AT repeats and a classification of closely related cultivars with these microsatellite loci. Theor. Appli. Genet. 94:61-67.

Kalaiyarasi, R. and Vaidyanathan, P. 2000. Sterility mechanism in different TGMS and CMS lines in rice. International Rice Research Conference 2000. International Rice Research Institute, Los Banos, Manila, Philippines. March 31- April 3 2000. Pp. 136 -137.

Kalaiyarasi, R. and Vaidyanathan, P. 2002. Cytological screening of differential genetic mechanism for expression of temperature sensitive genic male sterility in rice. International Rice Congress 2002. Beijing, China 16- 20 Sep' 2002. Pp. 217.

Kalaiyarasi, R. and Vaidyanathan, P. 2003. Cytological screening of rice TGMS lines. Plant Breeding. 122: 334-338.

Kalaiyarasi, R., Asish K.B., Thiyagarajan, K. 2006. Evaluation of promising TGMS lines for exploitation of two line heterosis in rice *(Oryza sativa* L.). Indian J.Genet. & Plant Breed. 66 (3) : 225-226

Kalaiyarasi, R., Palanisamy, G.A. and Vaidyanathan, P. 2002. The potentials and scope of utilising TGMS lines in inter – subspecies crosses of rice (*Oryza sativa* L.). J. Genet. & Breed. 56: 137-143.

Kalaiyarasi, R.2000. browsing on inter sub-species hybrids for exploitation of TGMS lines in rice (*Oryza sativa* L.). Ph.D Thesis, Tamil Nadu Agricultural University (Unpublished).

Karad, S.R. and Pol, K.M. 2008. Character association, genetic variability and path coefficient analysis in rice (*Oryza sativa* L.). Int. J. agric. Sci.4(2): 663-666

Karim, D., Sarkar, U., Siddique, M.N.A., Miah, M.A.K. and Hasnat, M.Z.2007.Variability and genetic parameter analysis in aromatic rice. Int. J. Sustain. Crop. 2(5):15-18.

Karim, M.A., Ali, A., Ali., S.S., Ali, L. and Majid, A. 1992. Grain quality of some promising medium-grain. IRRN, 17: 13.

Kavimani, S. 2004. Genetic analysis of thermosensitive genic male sterile (TGMS) lines and its utilization in heterosis breeding of rice (*Oryza sativa* L.). Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore.

Kempthorne, O. 1957. An introduction to genetic statistics. John Wiley and Sons, Inc., New York, pp. 399-472.

Khanna, Y.P., Bijral, J.S., Sharma, T.R., Gupta, B.S., Raina, C.L. and Kanwal, K.S. 1992. Grain Quality of F_1 rice hybrids. IRRN. 17(1):9-10.

Khedikar, V.P., Bharose, A.A., Sharma, D., Khedikar, Y.P. 2003. Studies on genetic parameter in scented rice genotypes. J.Soils Crops. 13(2):338-342.

Khush, G.S., Kumar, I. and Virmani, S.S. 1986. Grain quality of hybrid rice. Paper Presented in the International Symposium on Hybrid Rice, 6-10th October 1986, Changsha, Hunan, China.

Khush, G.S., Poule, C.M. and Dela Cruz, N.M. 1979. Rice grain quality evaluation and improvement at IRRI. In: Chemical Aspect of Rice Grain quality. IRRI, Los Banos, Philippines, pp: 21-31.

Kirubakaran, A.P.M., Thiyagarajan, K., Arumugachamy, S. and Ali, S. 2002. Prospects of two line hybrid rice breeding in Tamil Nadu. IRRN.27(1):21-22

Kishore C, Prasad Y, Haider Z.A, Kumar R, Kumar K (2008). Quantitative analysis of upland rice. Oryza 45 (4): 268 – 272

Kole, P.C. and Hasib K.M. 2003 Interrelationship and path analysis in some mutant and parent hybrids of aromatic rice. J. Nuclear Agric. Biol. 32: 108-114.

Kole, P.C and Hasib, K.M. 2008. Correlation and regression analysis in scented rice. Madras Agricultural Journal: 1 6, 178-182

Ku, S., Yoon, H., Suh, H.S. and Chung, Y.Y. 2003. Male sterility of thermosensitive genic male-sterile rice is associated with premature programmed cell death of the tapetum. Planta. 217: 559-565.

Kulkarni, N., Devi, G.N. and Sarojini, G. 2000. Genotype x environment interactions for quality traits in mutants of Samba Mashuri. Oryza. 37(1): 72-74.

Kumar, A., Rangare, N.R. and Vidyakar, V.2014. Study of genetic variability of Indian and exotic rice germplasm in Allahabad agroclimate.The bioscan 8(4): 1445-1451.

Latha, R. 2001. Genetic and molecular analyses of thermosensitive genic male sterility and its utilization in two line heterosis breeding of rice (*Oryza sativa* L.). Ph.D Thesis, Tamil Nadu Agricultural University, Coimbatore (Unpublished).

Latha, R., Jayamani, P., Annadurai, A., Thiyagarajan, K. and Rangaswamy, M. 1998. Identification of fertility/ sterility phases of TGMS lines in rice. In: *Abst. First National*

Plant Breeding Congress. July 1-3, 1998. Tamil Nadu Agricultural University, Coimbatore.

Latha, R., Thiyagarajan, K. and Senthilvel, S. 2004. Genetics, fertility behaviour and molecular marker analysis of new TGMS line TS 6 in rice. Plant Breed. 123: 235-240.

Latha, R., Thiyagarajan, K. and Senthilvel, S. 2005. Critical temperature and stages of fertility alteration in TGMS lines of rice. 4th *International Crop Science Congress*.pp 1-6

Lee, D. S., Chen, L.J. and Suh, H.S. 2005. Genetic characterization and fine mapping of a novel thermo-sensitive genic male-sterile gene tms6 in rice (*Oryza sativa* L.) Theor. Appl. Genet. 111: 1271–1277.

Lenka, J.D. and Mishra, B. 1973. Path coefficient analysis of yield in rice varieties. Indian J.agic. Sci.43: 376-379.

Li, Z. K., Fu, B.Y., Gao, Y.M., Xu, J.L., Ali, J., Lafritte, H.R., Jiang, Y.Z., Rey, J.D., Vijayakumar, C.H.M. and Maghirang, R. 2005. Genome-wide introgression lines and their use in genetic and molecular dissection of complex phenotypes in rice (*Oryza sativa* L.). Molecular Biology, 59: 33-52.

Liu, A.M., Deng, H.F. and Li, B.H. 1997. Studies on fertility of Annong 810S. In: *Proceeding of International Symposium on Two-line System of Heterosis Breeding in Crops*.Sep.6-8, 1997, China National Hybrid Rice Research and development Centre, Changsha, China.pp.188-192.

Lopez, M.T. and Virmani, S.S. 2000. Development of TGMS lines for developing two-line rice hybrids for the Tropics, Euphytica, 114: 211–215.

Lopez, M.T., Toojinda, T., Vanavichit, A. and Tragoonrung, S. 2003. Microsatellite Markers Flanking the *tms2* Gene Facilitated Tropical TGMS Rice Line Development. Crop Sci. 43: 2267–2271.

Lu, X.G., Virmani, S.S. and Rencui, Y. 1998. Advances in Two line hybrid rice breeding.pp. 89-98. In: S. S.Virmani, E. A. Siddiq and K.Muralidharan (eds.). Advances in Hybrid Rice Technology. International Rice Research Institute, Manila, Philippines.

Lu, X.G., Zhang, Z.U., Maruyama, K. and Virmani, S.S. 1994. Current status of two line hybrid rice breeding. In: *Hybrid rice technology - New Development and future prospects*. S.S. Virmani. (eds). International Rice Research Institute, Manila, Philippines. pp. 37-49.

Luo, X.H., Qiu, Z.H., and Li, R.H. 1994. Breeding of Pei-Liang-You-Tequing, a new two line hybrid rice combination. Hybrid Rice. 5: 7-9.

Lush, K.A. 1940. Inter relationship between yield and some selected agronomic characters in rice. African Crop Sci.J.6(3): 323-328.

Madhavan, J. and M. Subramanian. 1999. Studies on floral biology and anthesis in certain A, B and R lines of rice. Vistas Rice Res., 1:39-151

Maruyama, K., H. Araki and E. Amao. 1990. Enhancement of outcrossing habits of rice plant of mutation breeding. Gamma Field Symposia, 29: 11-25.

Maruyama, K., Araki, H. and Kato, H. 1991. Thermosensitive genic male sterility induced by irradiation. In: Rice Genetics-II IRRI, Manila, Philippines, pp. 227-232.

McCouch, S. R., Chen, X., Panaud,O., Temnykh,S., Xu,Y., Cho,Y.G. and Blair, M. 1997. Microsatellite marker development mapping and applications in rice genetics and breeding. Plant Mol. Biol. 35(1): 89-99.

McCouch, S.R., Teytelman, L., Xu, Y., Lobos, K.B., Clare, K., Walton, M., Fu, B., Maghirang, R., Li, Z. and Xing, Y. 2002. Development and mapping of 2240 new SSR markers for rice (*Oryza sativa* L.). DNA Res. 9(1): 199-207.

Mishra, L.K. and Verma, R.K. 2002. Genetic variability for quality and yield traits in non-segregating populations of rice (*Oryza sativa* L.). Plant Archives, 2: 251-256.

Mohamed, K.A., Idris, A.E., Mohammed , H.I. and Osman, K.A. 2012. RankingRice (*Oryza sativa* L.) Genotypes Using Multi-Criteria Decision Making, Correlation and Path Coefficient Analysis British Biotechnology Journal. 2(4): 211-228.

Mou, T.M., Li, C.H., Yang, G.C. and Lu, X.G. 1998. Breeding and characterizing *indica* PGMS and TGMS lines in China. In: *Advances in hybrid rice technology.* Proceedings of third

International Symposium on Hybrid rice, 14-16 November 1996, Hydrabad, India. Pp. 77-88.

Mou, T.M., Yang, G.C., Li, C. and Xu, J. 2004. Development of TGMS lines and two line hybrids through a shuttle breeding programme between IRRI and China. IRRN 29.2.

Nandeshwar, B.C., Pal, S., Senapati, B.K. and De, D.K. 2010. Genetic variability and character association among biometrical traits in F_2 generation of some rice crosses. Electronic J.of Plant Breed. 1(4): 758-763.

Nayak, A. R. 2008. Genetic variability and correlation study in segregating generation of two crosses in scented rice. *Agric. Sci. Digest.* 28(4):280-282

Ni, J., P.M. Colowit and D.J. Mackill. 2002. Evaluation of genetic diversity in rice subspecies using microsatellite markers. Crop Sci. 42(6-7): 601-607.

Olufowote, J.O., Xu, Y., Chen, X., Park,W.D., Beachel, H.M., Dilday, R.H., Goto, M. and McCouch, S.R. 1997. Comparative evaluation of within-cultivar variation of rice (*Oryza sativa L.*) using microsatellite and RFLP markers. Genome. 40(3): 370-378.

Onate, L.U. and Del Mundo, H.M. 1966. Eating quality of some varieties of low land rice. Philipp.agric.47:208

Pandey, M.P., Rongbai, L., Singh, J.P., Main, S.K., Singh, H. and Singh, S. 1998. The identification and nature of genic male sterile source, UPRI95-140 TGMS in rice. Cereal Res. Com. 26: 265-269.

Panse, V.G. and Sukhatme, P.V. 1964. Statistical Methods for Agricultural Research Workers, 2nd Ed. ICAR, New Delhi.

Panwar L.L. 2005. Line x Tester analysis of combining ability in rice (*Oryza sativa* L.). Indian J. Genet. 65(1): 51-52.

Parida, S. K., Rajkumar, K.A., Dalal, V., Singh, N.K. and Mohapatra, T. 2006. Unigene derived microsatellite markers for the cereal genome. Theor. Appl. Genet. 112(7): 807-817.

Parikh, M., Motiramani, N.K., Rastogi, N.K. and Sharma, B. 2012. Agro morphological characterization and assessment of variability in aromatic rice germplasm. Bangladesh J. Agril Res. 37(1) :1-8

Parmar, K.S., Siddiq, E.A. and Swaminathan, M.S. 1979. Variation in components of flowering behaviour of rice. Indian J. Genet. 39(5): 542-550.

Patil, D.V. 2000. Heterosis and doubled haploid exploration in two line hybrid rice (*Oryza sativa* L.). Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore (unpublished).

Peng, S., Bouman, B., Visperas, M.R., Castaneda, A., Nie, L. and Park, H.K. 2006. Comparison between aerobic and flooded rice in the tropics: Agronomic performance in an eight-season experiment. Field crops research. 96 (2-3): 252-259.

Philpot, K., Martin, M. and Butardo, V. 2006. Environmental factors that affect the ability of amylose to contribute to retrogradation in gels made from rice flour. J.Agric. Food Chem. 54: 5182–5190.

Prathyusha, A., Mohan Reddy, D., Sreenivasulu, Y., Sudhakar, P. and Reddy, K.R. 2009 Molecular characterization and diversity analysis of traditional and elite cultivars of rice using simple sequence repeat (SSR) markers Oryza. 46(4): 275-278.

Radhidevi, R.P. 2000. Genetic and molecular studies in three line and two line hybrids of rice (*Oryza sativa* L.). M.Sc.(Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Radhidevi, R.P., Nagarajan, P., Shanmugasundaram, P., Chandra Babu, R., S. Jayanthi, S. and Subramani, S. 2002. Combining ability analysis in three line and two line rice hybrids. Plant Archives. 2: 99-102.

Ramakrishnan, S.H., Anandakumar, C.R., Saravanan , S. and Malini, N. 2006. Association Analysis of some Yield traits in Rice (*Oryza sativa* L.). J. App. Sci. Res., 2(7): 402-404.

Ramakrishna, S., Mallikarjuna Swamy, B.P., Mishra, B., Vikrathamath, B.C. and Illyas Ahmed, M. 2006.Characterization of Thermosensitivity, Morphologhy And Floral Biology in Rice (*Oryza sativa L.).* Asian.J.Plant Sci.5(3): 421-428

Ramiah, K. 1933. Inheritance of flowering duration in rice. Indian J. Agric. Sci. 3: 377-410.

Rangaswamy, M., Latha, R., Jayamani, P., Annadurai, A. and Thiyagarajan, K. 1998. Combining ability studies in two line hybrids. In: Abstract. First National Plant Breeding congress, July 1-3, 1998. Tamil Nadu Agricultural University, Coimbatore. pp. 16.

Rashid, M., Cheema, A.A. and Ashraf, M. 2007. Line x Tester analysis in basmati rice. Pak. J. Bot. 39(6): 2035-2042.

Reddy, O.U.K., Siddiq, E.A., Sarma, N.P., Hussain, A.J., Nimmakayala, P., Ramasamy, P., Pammi, S. and Reddy, A.S. 2000. Genetic analysis of temperature-sensitive male sterility in rice. Theor. Appl. Genet. 100: 794-801.

Reddy, O.U.K., Siddiq, E.A., Ali, J., Hussain, A.J. and Ahmed, M.I. 1998. Genetics of thermo-sensitive genic male sterile lines in rice. IRRN. 23: 10.

Reddy, O.U.K., E.A. Siddiq and J. Ali. 1996. Fertility a hering conditions of promising temperature sensitive genic male sterile lines in rice. In: Proceedings of III International Symposium on Hybrid Rice, November, 14-16, 1996, Hyderabad, India. pp. 91.

Roder, M.S., Korzun, V., Wendehake, K., Plaschke, J., Tixier, M., Lorey, P. and Ganal, M.W. 1998. A microsatellite map of wheat. Genetics. 149: 2007-2023.

Rohlf, F.J. 1999. NTSYS-PC Numerical taxonomy and multivariate analysis system. V.2.1, Exeter Software, Setauket, N.Y.

Rongbai, L., Pandey, M.P. and Sharma, P. 2005. Inheritance of thermo sensitive genic male sterility in rice (*Oryza sativa* L.). Curr. Sci. 88 (11): 1809-1815.

Sadhasivam.V. 2004. Characterization of rice (*Oryza sativa L.)* thermosensitive genic male sterile (TGMS) lines and studies on their combining ability. M.Sc thesis,Tamil Nadu Agricultural University, Coimbatore (Unpublished).

Saini, N., Jain, N., Jain, S. and Jain, R.K. 2004. Assessment of genetic diversity within and among Basmati and non-Basmati rice varieties using AFLP, ISSR and SSR markers. Euphytica. 140(2): 133-146.

Salgotra, R.K., Gupta, B.B. and Ahmed, M.I. 2012. Characterization of thermosensitive genic male sterility (TGMS) rice genotypes(*Oryza sativa* L.) at different altitudes. Aust J. of crop sci. 6(6):957-962.

Sampoornam, R. 1998. Heterosis and combining ability studies on two line hybrids in rice (*Oryza sativa* L.). M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Sampoornan, R. and Thiyagarajan, K. 1998. Studies on heterosis for grain yield and its components in two line hybrid rice. In: Abstract. First National Plant Breeding Congress, July, 1-3, 1998, Tamil Nadu Agricultural University, Coimbatore. pp.190.

Satheesh, K.P., Saravanan, K. and Sabesan, T. 2010. Combining ability for yield & yield contributing characters in rice (*Oryza sativa* L.) Electronic J. of Plant Breed. 1(5): 1290-1293.

Satheeshkumar, P. and Saravanan, K. 2012. Genetic variability, correlation and path analysis in rice (*Oryza sativa* L.). International Journal of current research. 4(9): 082-085

Sathya, R. and Jebaraj, S.2013. Studies on choice of parents and gene action in rice hybrids involving yield and physiological traits under aerobic condition. Plant Gene and Trait. 4(19) :104-108

Satish, C.B., Dayakar, R.T., Ansari, N.A. and Sudheer, S.K.2009. Correlation and path analysis for yield and yield components in rice (*Oryza sativa* L.). Agricultural science digest, 29(1): 45-47.

Sawant, D.S., Shetye, V.N. and Desai, S.S. 2006. Studies on relative stability of cytoplasmic male sterile lines and their floral traits influencing out-crossing in rice (*Oryza sativa* L.). Intl. J. of Plant Sci. 1(2): 150-153.

Seetharam, K., Thirumeni, S. and Paramasivam. K. 2009. Variability studies in rice (*Oryza sativa* L.) for salt tolerance . IUP J.of genet and evolution 2(3): 17-25

Seetharamaiah, K.V., Kulkarni, R.S. and Mahadevappa, M. 2001. Variability and genetic parameters of floral and morphological traits influencing outcrossing in Rice (*Oryza sativa* L.). Andhra Agric. J. 48(2): 181-184.

Seyoum, M., Alamerew, S. and Bantte, K. 2012. Genetic Variability, Heritability, Correlation Coefficient and Path Analysis for Yield and Yield Related Traits in Upland Rice (*Oryza sativa* L.). *J. Plant Sci. 7: 13-22.*

Shen, Y., Gao, M. and Cai, Q. 1994. A novel environment induced genic male sterile (EGMS) mutant in *indica* rice. Euphytica. 76: 89-96.

Shikari, A.B., Hussain, S.Z., Parray, G.A., Rather, A.G. and Shafiq, A. 2008. Physico-chemical and cooking properties of non-basmati temperate rice (*Oryza sativa* L.). Crop Improv.35(2): 109-114.

Shinjyo, C. 1969. Cytoplasmic genetic male sterility in cultivated rice. (*Oryza sativa*.L).II. The inheritance of male sterility. Jpn. J. of genet. 44: 149-156.

Shobha Rani, N., Subba Rao, L.V., Pandey, M.K., Sudharshan, I. and Prasad, G.S.V. 2008. Grain quality variation for physicochemical, milling and cooking properties in Indian rices (*O. saiva* L.). Indian J. Crop Sci. 3(1): 133-136.

Sidharthan, B., Thiyagarajan, K. and Manonmani, S. 2007. Cytoplasmic male sterile lines for hybrid rice production. J. Applied Sci. Res. 3(10): 935-937.

Singh V. K., Upadhyay, P., Sinha, P., Mall, A.K., Jaiswal, S.K., Singh, A., Ellur, R.K., Biradar, S., Sundaram, R.M., Singh, I. Ahmed, I., Mishra, B., Singh, A.K. and C. Kole, C. 2011. Determination of genetic relationships among elite thermosensitive genic male sterile lines (TGMS) of rice (*Oryza sativa* L.) employing morphological and simple sequence repeat (SSR) markers. J. Genet., 90. 11–19.

Singh, R. and Singh, B. 1998. Genetic Variability in floral traits of 10 cytosterile lines of rice (*Oryza sativa* L.). IRRN. 23: 4.

Singh, Y., Pani, D.R., Pradhan,S.K. and Singh, U.S. 2008. Divergence analysis for quality traits in some indigenous Basmati rice genotypes. Oryza. 45(4): 263-267.

Sivasubramanian, S. and Madhava Menon, P. 1973.Genotypic and phenotypic variability in rice. Madras Agric. J. 60: 1093-1096.

Snedecor, G.W. and W.G.Cochran, W.G. 1967. Statistical Methods. VI edition, Iowa state university press, Iowa, USA.

Sokal, R.R. and C.D.Michener. 1958. A statistical method of evaluating systematic relationships. Univ. Kan. Sci. Bull., 38: 1409-1438.

Sood, B.G. 1983. Genetic analysis of kernel elongation in rice. Indian J. Genet., 43(1): 40-43.

Spargue, G.F. and Tatum, L.A. 1942. General versus specific combining ability in single crosses of corn. J. Am. Soc. Agron. 34: 923-932.

Subbaiah, V.P., Sekhar, R.M., Reddy, K.H.P. and Reddy, N.P.E. 2011. Variability and genetic parameters for grain yield and its components and kernel quality attriburtes in CMS based rice hybrids (*Oryza sativa* L.) Int J. of appl biol and pharmacol tech. 2: 3:34-36

Subudhi, P.K., Borkakati, R.P., Virmani, S.S. and Huang, N. 1997. Molecular mapping of a thermosensitive genetic male sterility gene in rice using bulk segregant analysis. Genome. 40: 188-194.

Suganthi, A. and Nacchair, F. 2015. Quality parameters of different varieties of paddy rice grown in Vadakkanchery Kerala. IJAPBC, 4(2) : 2237 -4688.

Sun, C., Wu, C., Jiang, T., Chen, L., Li, Z. and Wang, X. 2000. Studies on the relationship between heterosis and genetic differentiation in hybrid rice. In: International Rice Research Conference, Mar .31- Apr. 3 2000, International Rice Research Institute, Manila, Phillipines. p.143

Sun, Z.X., Cheng, Z.H. and Si, H.M. 1993. Determination of critical temperature and panicle development stage for fertility change of thermo sensitive genic male sterile rice 5460S. Euphytica. 67.

Sun, Z.X., Xiong, Z.M., Min, S.K. and Si, S.M. 1989. Identification of temperature sensitive male sterile rice. Chinese J.Rice Sci. 3:49-55.

Sundar, S. 2003. Exploitation and characterization of thermosensitve genic male sterile (TGMS) lines for heterosis breeding in rice (*Oryza sativa* L.). Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore (Unpublished).

Sunita, J., Rajinder, J. and Mccouch, K. 2004. Genetic analysis of Indian aromatic and quality rice (*Oryza sativa* L.) germ plasm using panels of fluorescently-labeled microsatellite markers. Theor. Appl. Genet. 109 (5): 965-977.

Surek, H. and Besar, N. 2003. Correlation and path coefficient analysis for some yield related traits in rice (*Oryza sativa*.L) under Thrace conditions. Turkish J.agric.Forestry. 27(2):77-83.

Tai, G.C.C. 1979. An internal estimation of expected response to selection. Theor. Appl. Genet. 54: 273-275.

Takeoka, Y., Shimizu, M. and Wada, T. 1993. Panicles. In Matsuo T, Hoshikawa K, eds, Science of the Rice Plant, Vol 1. Food and Agriculture Policy Research Center, Tokyo: 295–338.

Tan, Y.F., Li, J.X., Yu, S.B., Xing, Y.Z., Xu, C.G. and Zhang, Q. 1999. The three important traits for cooking and eating quality of rice grains are controlled by a single locus in an elite rice hybrid, Shanyou 63. Theor. Appl. Genet. 99: 642–648.

Tan, Z.C., Li, Y.Y., Chen, L.B. and Zhou, G.Q. 1990. Studies on ecological adaptability of dual purpose line Annong 1S. Hybrid Rice. 3: 35-38.

Tang, W.B., He, Q., Xiao, Y.H., Deng, H.B. and Chen, L.Y.2004. Heterosis analysis of the combinations with dual purpose genic male sterile rice C815S. J. Hunan agric .Univ.(Chinese). 30(6): 499-502.

Temnykh, S., DeClerck, G., Lukashova, A., Lipovich, L., Cartinhour, S. and McCouch, S.R. 2001. Computational and experimental analysis of microsatellites in rice (*Oryza sativa*

L.). Frequency, length variation, transposons associations and genetic marker potential. Genome Res. 11(10-12): 1441-1452.

Thiyagarajan, K., Latha., R. Jayamani., P. Annadurai, A. and Rangaswamy, M. 1998. Heterosis in two line rice hybrids. In: Abstract: First national plant breeding congress. July 1-3, 1998. TNAU, Coimbatore.

Thiyagarajan, K., Manonmani, S., Malarvizhi, D., Robin, S., Pushpam, R. and Mohana Sundaram, K. 2010. Development of new TGMS lines with good floral traits in rice. Electronic J. Plant Breed. 1(4): 568-57 1.

Tuwar, A.K., Singh, S.K., Sharma, A. and Bhati, P.K. 2013. Appraisal of genetic variability for yield and its component characters in rice (*Oryza sativa* L.) . Bio life. 1(3): 84-89.

Udupa, S.M., Robertson, L.D., Weigand, F., Baum, M. and Kahl, G. 1999. Allelic variation at (TAA) n microsatellite loci in a world collection of chickpea (*Cicer arietinum* L.) germplasm. Mol. Genet. 261(4): 354-363.

Vanaja, T. and Babu, L.C. 2006. Variability in grain quality attributes of high yielding rice varieties(*Oryza sativa* L.) of diverse origin. J. of Trop Agric. 44(1-2): 61-63

Vanisree, S., Swapna, L., Raju, D., Raju, Sand Sreedhar, M. 2013. Genetic varaiability and selection criteria in rice. J.of biol and scient opinion.1(4).

Varshney, R.K., Thiel, T., Stein, N., Langridge, P. and Graner, A. 2002. *In silico* analysis on frequency and distribution of microsatellites in ESTs of some cereal species. Cellular and Molecular Biology Letters, 7(4): 537-546.

Verma, O.P. and Srivastava, H.K.2004. Productive association of quantitative traits in diverse ecotypes of rice (Oryza sativa L.). J.Sustainable Agric. 25(2): 75-91.

Verma, O.P., Singh Santoshi, U., Dwivedi, J.L. and Singh, P.P. 2000. Genetic variability, heritability and genetic advance for quantitative traits in rice. Oryza. 37(1): 38-40.

Viraktamath, B.C. and Virmani, S.S. 2001. Expression of thermosensitive genic male sterility in rice under varying temperature situations. Euphytica. 122: 137-143.

Viraktamath, B.C., Lopez, M.T. and Virmani, S.S. 1998. Characterizing thermo-sensitive genic male sterile lines of rice. Intl. Rice. Res. Notes. 23: 6.

Virmani, S.S. 1996. Hybrid rice. Adv. Agron. 57: 377-462.

Virmani, S.S., R.C. Chaudary and G.S. Khush. 1981. Current outlook on Hybrid rice. Oryza, 18 : 67-84.

Waghmode, B.D., Kadam, S.R. and Dongale, J.H. 2007. New cytoplasmic male sterile lines developed in Maharashtra State, India. IRRN. 32 (1): 14-15.

Wan, B.H. and Deng, Y. 1990. Observations on the fertility changes in the Hubei photoperiod-sensitive genic male sterile rice Nongken 58S. J.South China Agric.Univ. 11: 1-6.

Wang, B., Xu, W.W., Wang, J.Z., Wu, W., Zheng, H.G., Yang, Z.Y., Ray, J.D. and Nguyen, H.T. 1995. Tagging and mapping the thermosensitive genic male-sterile gene in rice (*Oryza sativa* L.) with molecular markers. Theor. Appl. Genet. 91: 1111-1114.

Wang, F., Peng, H.P., Li, S.G., Wu,Y., Cai, Z., Tang, C.S. and He, J. 1997. Multiplication techniques for TGMS line with cold water irrigation.Chinese J.Rice Sci.11:1-5.

Wang, H., Zhang, P., Ma, Z.R., Zhang, M.Y., Sun,G.H. and Ling, D.H. 2004. Development of a genetic marker linked to a new thermo-sensitive male sterile gene in rice (*Oryza sativa* L.). Euphytica. 140: 217-222.

Wang, X.M., Wang, M.Z., Mei, G.Z., Wu, H.Y., Duan, W.J. and Wang, W.S. 1990. Photoperiod conditioned male sterile and its inheritance in rice. In: Rice genetics II, IRRI, Los Banos, Phillippines.pp.217-229.

Wang, Y.G., Xing, Q.H., Deng, Q.Y., Liang, F.S., Yuan, L.P., Weng, M.L., Wang, B. 2003. Fine mapping of the rice thermo-sensitive genic male sterile gene tms5. Theor Appl Genet. 107: 917-921.

Wang, Z., Weber, J.L., Zhong, G. and Tanksley, S.D. 1994. Survey of plant short tandem repeats. Theor. Appl. Genet. 88(1): 1-6.

Weising, K., Winter, P., Huttel, B. and Kahl, G. 1998. Microsatellite markers for molecular breeding. J. Crop Production. 1(1): 113-143.

Wright, S. 1923. The theory of path coefficients. Genetics. 8: 239-355.

Wu, X.J. 1997. Genetic strategies to minimize the risk in exploiting heterosis in rice by means of thermosensitive genic male sterility system. In: *Proc. Int. Symp. on Two- Line System of Heterosis Breeding in Crops*. Sep. 6-8, 1997, China National Hybrid Rice Research and Development Centre, Changsha, China. pp. 121-131.

Wu, X.J. and Yin, H.Q. 1992. Genetics and stability of thermo-sensitive genic male sterile rice. Chinese J. Rice Sci. 6: 63-69.

Wu, X.J., Yin, H.Q. and Yin, H. 1991. Preliminary study of temperature effect on Annong S1 and W6154S. Crop Res. 5: 4-6.

Xiao, J., Li, J., Yuan, L., McCouch, S.R. and Tanksley, S.D. 1996. Genetic diversity and its relationship to hybrid performance and heterosis in rice as revealed by PCR-based markers. Theor. Appl. Genet. 92(5): 637-643.

Xul, W., Virmani, S.S., Hernandez, J.E., Sebastian, L.S. and Li, Z.K. 2000. Molecular divergence of maintainer and restorer lines of tropical rice hybrids. Molecular breed. 2(2): 126-129.

Yadav, P.N., M.P. Chauhan and R.S. Singh, 2010. Genetic variability, heritability and expected genetic advance for certain qualitative characters in rice. New Agric. 13: 84-94.

Yamaguchi, Y., Ikeda, R., Hirasawa, H., Minami, M. and Ujihara, A. 1997. Linkage analysis of Thermosensitive genic male sterility gene, *tms-2* in rice (*Oryza sativa* L.). Breed. Sci. 47: 371-373.

Yang, J.C. 1990. The pollen fertility change of a rice temperature sensitive genic male sterile line 5460TS under natural conditions in Fuzhou. J. Fujian Agric.Coll. 19: 245-251.

Yang, Q., Liang, C., Zhuang, W., Li, J., Deng, H., Deng, Q. and Wang, W. 2007a. Characterization and identification of the candidate gene of rice thermo-sensitive genic male sterile gene *tms5* by mapping. Planta. 225: 321–330.

Yang, Y.C., Liang, N.Y. and Chen, Q.H. 1990. Thermosensitive genic male sterile rice R59TS. Sci. Agric. Sin. 23: 90.

Yi, M.M., Nwea, K.T., Vanavichit, A., Chai, W. and Toojinda, T. 2009. Marker assisted backcross breeding to improve cooking quality traits in Myanmar rice cultivar Field Crops Res. 113: 178–186.

Yu, S. B., Zhong, D.B., Sanchez, A., Xu, J.L., Domingo, J., Khush, G.S. and Li, Z.K. 2000. An integrated molecular linkage map and genomic regions with clustered QTLs detected in the LTRI populations. In. Abstracts. International Rice Genetics Symposium. IRRI. Philippines: 116.

Yuan L. P. 1998. Hybrid rice breeding in china. In: S.S.Viramani, E.A. Siddiq, and K. Muralidharan (Eds). Advances in hybrid rice technology. Proc. of the 3rd International Symposium on Hybrid Rice. 14-16 *Nov.* 1996 (Hyderabad, India). Int. Rice Res. Institute, Manila, Philippines, pp : 27-33.

Yuan, L. P. 1990. Progress of two-line system hybrid rice breeding. Sci. Agr. Sin. 3: 1-6.

Yuan, L.P., Yang, Z.Y. and Yang, J.B. 1994: Hybrid rice research in China. Hybrid rice technology: New developments and future prospects, 143—147. Int. Rice Res. Inst. Manila.

Yussouf, M.S., Iqbal, J.M. and Haq, M.A. 2010. Combining ability analysis for yield and related traits in basmati rice (*Oryza sativa* L.). Pak. J. Bot. 42(1): 627-637.

Zeng, H.L., Lu, K.Y., He, D.H., Pan, X.Z., Zhangduan, R. and Zeng, Z. 2000. Evaluation on the fertility of some *indica* rice hybrids under high temperature conditions. J. Huazhong Agric.Univ. 19: 1- 4.

Zhang, X.G. and Lu, X.G. 1991. Fertility response to photoperiod and temperature of five *indica* environment sensitive genic male sterile lines of rice. In: *Agricultural Biotechnology.* Yuu, C.B and Z.L.Chen (Eds). China Science and Technology, Press, Beijing, China, pp. 678-679.

Zhang, Z., Deng, Y., Tan, J., Hu, S., Yu, J. and Xue, Q. 2007. A genome wide microsatellite polymorphism database for the indica and japonica rice. DNA research. 14: 37-45.

Zhang, Z., Zeng, H., Yang, J., Yuan, S. and Zhang, D. 1994. Conditions inducing fertility alteration and ecological adaptation of photoperiod-sensitive genic male sterile rice. Field Crops Res. 38: 11-20.

Zhang, Z.G. and Lu, X.G. 1992. Reflections of identification of light and temperature properties of fertility transformation of PGMR. Hybrid Rice. 6: 29-32.

Zhang, Z.G., Zeng, H.L. and Yuan, S,C. 1992. Restudies on the model of photo-thermo reaction of fertility alteration in photosensitive genic male sterile rice. J.Huazhong Agric. Univ. 11: 1-6.

Zhao, X. and Kochert, G. 1993. Phylogenetic distribution and genetic mapping of a (GGG) n microsatellite from rice (*Oryza sativa* L.). Plant Mol. Biol. 21(5): 607-614.

Zhu, X.D., Dong, F.G., Zhen, D.L., Zhang, X.H. and Yan, X.Q. 1995. Studies on heterosis of hybrid rice combined with *indica* photoperiod temperature sensitive genic male sterile line M_2S with marker. Acta. Agric. Zhejiangensis. 7: 323-325.

Zou, J.H., Pan, X.B., Chen, Z.X., Xu, J.Y., Lu, J.F., Zhai, W.X. and Zhu, L.H. 2000. Mapping quantitative trait loci controlling sheath blight resistance into rice cultivars (*Oryza sativa* L.). Theor. Appl. Genet. 101(6): 569-573.

Abstract

STANDARDISATION OF TWO LINE HETEROSIS BREEDING IN RICE (*Oryza sativa* L.) FOR KERALA

By

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ABSTRACT OF THESIS

Submitted in partial fulfilment of the requirement

for the degree of

Doctor of Philosophy in Plant Breeding & Genetics

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ABSTRACT

The present investigation entitled **"Standardisation of two line heterosis breeding in rice(*Oryza sativa* L.) for Kerala"** was conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University during 2010-2013.The objectives of the study were to identify the promising TGMS lines of rice, for the production of two line hybrids suited to Kerala and to standardize the two line heterosis breeding programme.

The experimental materials consisted of TGMS lines collected from Tamil Nadu Agricultural University and high yielding varieties of rice from different research stations of Kerala.

The primary investigation was carried out at College of Horticulture, Vellanikkara to study the sterility/fertility behavior of TGMS lines .It was found that April and May seasons can be considered as the ideal period of exploiting 100 per cent sterility in rice for the hybrid seed production.Experiments at CRS Pampadumpara was the suitable location for TGMS line seed multiplication. The present study concluded that CST(Critical Sterility Temperature) ranged from 34.2 to 38.6^{0}Cand CFT (Critical Fertility Temperature) ranged from 23.6 to 25.4^{0}C.

Natural pollination with suitable pollinator parents proved to be a viable method for the production of two line hybrid seeds.Aiswarya, Makom, Kanchana and Samyuktha were good general combiners whereas Kairali was a poor combiner . *Per se* performance and gca effects were not correlated for most of the characters evaluated.

The two line hybrids TGMS 91S x Makom, TGMS82S x Aiswarya , TGMS 81S x Kairali, TGMS 81S x Kanchana, TGMS 91S x Kairali exhibited superior SCA effects for various characters in COH Vellanikkara . TGMS 82S x Samyuktha , TGMS 74S x Samyuktha, TGMS 81S x Aiswarya, TGMS 91S x Samyuktha, TGMS 74S x Kairali, TGMS 74S x Makom showed superior SCA effects for the characters studied at RARS Pattambi.

Molecular analysis revealed that the number of alleles per locus ranged from 2 to 3. Polymorphic information content ranged from 0.291 (RM2) to 0.648 (RM132) with an average of 0.448. RM11 markers showed more number of alleles with PIC value more than 0.50 indicate the efficiency of this primer in detecting the most heterogenous accession.

Cooking quality analysis of promising hybrids revealed intermediate amylose content and intermediate alkali spreading value for TGMS 91S x Makom , TGMS 91S x Kanchana, TGMS 81S x Makom and TGMS 81S x Aiswarya.

TGMS 81S x MattaTriveni recorded highest grain and straw yield at COH Vellanikkara. TGMS 91S x Samyuktha was the best performer at RARS Pattambi

Annexure

APPENDIX 1

ABBREVIATIONS

Bp	Base pair
CFT	Critical Fertility Temperature
CMS	Cytoplasmic male sterility
COH	College of Horticulture
CRS	Cardomom Research Station
CST	Critical Sterility Temperature
^0C	Degree Celsius
DMART	Duncan's Multiple Range Test
DNA	Deoxyribo Nucleic Acid
dNTPs	Deoxyribo Nucleotyide triphosphate
EDTA	Di-sodium Ethylene Diammine Triacetate
FAO	Food and agricultural organisation
GC	Gel consistency
GCA	General combining ability
GCV	Genotypic coefficient of variation
GA%	Genetic advance as percentage of mean
HI	Harvest index
H2	Heritability
IRRI	International Rice Research Institute
KAU	Kerala Agricultural University
MS	Male sterile
MSL	Mean sea level
PCR	Polymerase Chain Reaction
PCV	Phenotypic coefficient of Variation
PGMS	Photoperiod Sensitive Genic Male Sterility
PIC	Polymorphic Information Content
PMC	Pollen Mother Cell
POP	Package of Practices
RAPD	Random Amplified Polymorphic DNA
RARS	Regional Agricultural Research Station
RBD	Randomized Block Design
RFLP	Restriction Fragment Length Polymorphism
SCA	Specific Combining Ability
SCAR	Sequence Characterized amplified region
SSR	Simple Sequence Repeat
TGMS	Thermo Sensitive Genic Male Sterility
TBE	Tris Borate EDTA
viz	Namely
w/v	Weight/Volume
v/v	Volume/Volume
µl	Microlitre