TKM 15 -A High yielding, short duration rice variety suitable for direct sown water limited areas of Tamil Nadu

ABSTRACT

TKM 15 is a short duration, drought tolerant rice varietyreleased from Rice Research Station, Tirur (TNAU)for direct sown rainfed and semidry areas of TamilNadu *viz.,*Kancheepuram, Chengalpattu, Tiruvallur, Pudukottai, Ramanathapuram, Virudhunagar, Sivagangai and Thoothukudi districts. Itmatures in 118 days and has the ability to withstand ~~early stage~~early-stage water stress, good germination percentage under direct sowing, early vigour and high drought recovery.This variety hasmanifested the grain yield of 3995 kg/ha and 4217 kg/ha under rainfed and semidry conditions respectively which was 10.42 per cent and 17.89 per cent increase over the check variety Anna (R) 4 in rainfed and semidry conditions. TKM 15 has erect, high tillering and non-lodging plant habit, with dense droopy compact panicle (25 cm) having ~~more~~a greater number of grains per panicle (253 no.). It is moderately resistant to major diseases such as blast, sheath rot, sheath blight, brown spot and RTD and field tolerant to major pests like leaf folder, stem borer and gall midge which are its added advantage.It has good hulling (80%) percentage, milling (68%) percentage and Head RiceRecovery of 62.9 %. Rice is white, medium slender with 1000 grain weight of 15.0 g. Cooked rice is non sticky with good taste. The feedback from the farmers was that,TKM 15 tolerates water stress and recovers quickly with the receipt of rainfall, has more tillers, densely packed panicle with medium slender grains, gives higher yield under rainfed and semidry environments and also free from pests and diseases under field condition.

KEY WORDS: TKM 15,Rice, Rainfed,Semidry, direct sowing, drought tolerant.

INTRODUCTION

Rice is the staple food for more than one-third of the world's population [Sahebi *et al.*, 2018] and to achieve self-sufficiency in rice production, high yielding rice variety with a high degree of resistance to both biotic and abiotic stresses is a prerequisite [Chukwu *et al*, 2019].

In Tamil Nadu, Rice plays a vital role in ensuring food security and is cultivated in an area of 20.36 lakh hectares in which, about 36 % of the paddy area is cultivated in the delta districts such as Tiruvarur (1.95lakh ha), Thanjavur (2.14 lakh ha), Nagapattinam (0.74 lakh ha),Mayiladuthurai (1.06) and Cuddalore (1.36 lakh ha). Tiruvannamalai (1.71 lakh ha) has the next highest area followed by Ramanathapuram 1.34 lakh ha, Villupuram (1.02 lakh ha),~~,~~Thiruvallur(1.01 lakh ha),Pudukottai (0.92 lakh ha) and Sivagangai (0.78 lakh ha) and these districts are characterised more by dryland agriculture (~~Sesasons~~Seasons and Crops Report, 2021). Around 45 per cent of the total cultivable area in Tamil Nadu (13 per cent of the total rice grown area) is rainfed which is prone to frequent droughts that are triggered by monsoon failures and has affected water storage in all the water bodies.

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Drought is one of the major abiotic stresses that affect rice production in rainfed areas. Recent trends in climate change will further increase the intensity and frequency of drought in the coming years.Current global warming trends are expected to lead to a greater intensity, frequency and severity of

droughts (Diffenbaugh *et al*., 2015, Prudhomme *et al*., 2014). Any detrimental impacts of climate would have major consequences for food security from local to global levels. Drought scenario of Tamil Nadu for the last 10 years reveals that Tamil Nadu experienced recurrent droughts during the years 2012,2013,2014,2016 and 2018and the state has been reeling under droughtfor three consecutive years 2012, 2013 and 2014,. In 2016, worst drought hit in 140 years, was considered as a disaster by the farmers of Tamil Nadu and the state had been declared drought-hit. In 2018, about 24 of 32 districts were affected by hydrological drought of which 19 districts have reported a fall in groundwater levels. The consecutive failure of the North East monsoon resulted in a water crisis in Tamil Nadu.

Ramnad, Sivagangai and Thiruvallur districts form 51.58, 11.50 and 10.09 percent respectively of the total rainfed and semidry rice areas in the state of Tamil Nadu. Apart from these districts, direct seeded rice is being practised in districts like Kancheepuram, Villupuram, Thoothukudi, Pudukottai and Virudhunagar. Farmers in these areas cultivate either land races or high yielding varieties bred for irrigated environment. Land races were not providing any significant yield gains to the farmers and farmers realized heavy yield loss while cultivating high yielding varieties bred for irrigated environment during drought years. When high yielding irrigated varieties are grown in rainfed ecosystem, significant loss in rice production is recorded during the frequent drought spell because the aforesaid high-yielding varieties succumb to frequent droughts (Hao *et al*., 2018).

Due to narrow choice of rice varieties for drought prone environment, farmers face difficulty in increasing rice production in these areas. High yielding rice varieties endowed with virtues and values of drought tolerance and with stable yield performance is the need of the hour. Hence, evolving drought tolerant varieties which can withstand drought with minimal yield loss is crucial.Farmers are in urgent need of direct seeded rice varieties suitable for rainfed and semidry cultivation with high yield potential and preferable grain quality similar to the fine grain irrigated rice varieties. Therefore, attempts were made to develop a short duration, high yielding drought tolerant rice variety suitable for rainfed and semidry cultivation. As a result, drought tolerant, short duration, high yielding rice variety with medium slender grain evolved at Rice Research Station, Tirurwas released as TKM 15 during 2022 by State Variety Release Committee of Tamil Nadu and notified by the Central Ministry of Agriculture and Farmers welfare during August, 2022.

MATERIALS AND METHODS

Hybridization was made betweenTKM (R) 12 and IET 21620 during *Sornavari*, 2010 at Rice Research Station, Tirur with an objective of evolving short duration, drought tolerant rice variety suitable for rainfed and semidry cultivation with medium slender grain type. Breeding method followed is hybridization and selection and homozygous line was fixed as TM 12077 in F_5 generation during *Samba*, 2012. The detailed breeding programme is depicted in Fig. 1. Performance of TM 12077 was tested in different yield trials at Rice Research Station, Tirur during 2013 to 2015 under rainfed and semidry conditions and in Multi Location Trials under different environmental conditions such as dry, semidry and aerobic conditions for two years during 2016 to 2018 in ten locations. Based on the performance, this

culture was promoted to Adaptive Research Trials and was tested in seven districts of Tamil Nadu *viz*., Tiruvallur, Kancheepuram, Villupuram, Viruthunagar, Thoothukudi, Sivakangai, and Ramnadapuram and five KrishiVigyanKendras*viz*., Tiruvallur, Aruppukottai, Tindivanam, Sivagangai and Ramanathapuram during 2018-19 and 2019-20. Performance was also assessed in~~thirty two~~thirty-two farmer's holdings as On Farm Trials (OFT) during 2019 to 2021 and in five Large Scale Demonstrations in 2021-22. TM 12077 was also evaluated in All India Coordinated Rice Improvement Programme (AICRIP) trials during *kharif,* 2017 under Initial Varietal Trial (IVT)- Early Direct Sowing.Physical, cooking and biochemical quality parameterswere analysed at Tamil Nadu Rice Research Institute, Aduthurai. Reaction to pests and diseases was studied at Coimbatore, Aduthurai, Madurai and Thirupathisaram. Laboratory studies on drought tolerance in seedling stage as well as physiological parameters were done at Agricultural College and Research Institute, Echangkottai.

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RESULTS AND DISCUSSION

To achieve self-sufficiency in rice production, rice varieties having high yield along with high degree of resistance to both biotic and abiotic stresses is a prerequisite (Chukwu*et al,* 2019). Drought is one of the major abiotic stresses that affect rice production in rainfed areas. Recent trends in climate change will further increase the intensity and frequency of drought. The increase in drought severity and lack of drought tolerant high-yielding varieties for rainfed environment are the important factors responsible for low production ofrice in rainfedecosystem. Breeding rice varieties with tolerance to drought stress offers an economically viable and sustainable option to improve rice productivity (Pandey and Shukla, 2015). Farmers of drought prone areas require varieties that provide higher yield in years of good rainfall and sustainable good yield in years with drought. The development of improved varieties with combined tolerance of drought stress at multiple growth stages will help farmers in rainfed rice growing regions and maintain stable yields across increasingly unpredictable climatic conditions (Padmini *et al*., 2017).

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TM 12077, a derivative of TKM (R) 12 / IET 21620is a short duration rice culture (118 days) having erect, high tillering and non-lodging plant habit. This culture was specially bred for direct sowingenvironments under rainfed and semidry situations. In station trialsconducted at Rice Research Station,Tirur, it recorded a mean grain yield of 3718 kg/ha under rainfed and 4418 kg / ha under semidry conditionswhich is 15.22 % and 18.19 % higher than the check variety Anna (R) 4 under rainfed(3227 kg/ha) and semidry conditions (3738 kg/ha) respectively. In Multi Location Trials conducted in 10 locations during 2016 to 2018,TM 12077 registered 2777 kg/ha under rainfed and 2930 kg / ha under semidry conditions and the yield increase recorded was 31.9 and 22.5 per cent over Anna (R) 4 respectively in rain fed (2105 kg/ha) and semidry (2392 kg/ha) conditions.This culture was also nominated to All India Co-ordinated Rice Improvement Project (AICRIP) Trials and tested in Initial Varietal Trial-Early Direct Sowing (IVT-EDS) as IET 26645 during *Kharif,* 2017 and recorded the yield of 3386 kg /ha in 115 days.Adaptive Research Trials were conducted in 62 locations covering seven districts *viz*., Tiruvallur, Kancheepuram, Villupuram, Ramnad, Sivagangai, Viruthunagar and Thoothukudiduring 2018-

2020 and a mean grain yield of 4421 kg/ha was recorded by TM 12077 which was 4.76 % higher than the check variety Anna (R) 4 (4220 kg/ha) (Table 1).

The technologies or varieties developed by the researchers should reach the target end-users. On farm trials are conducted toshowcase the advantages of new varieties to farmers which will help in convincing more farmers to make better choice of varieties. The culture TM 12077was tested in farmer'sholdings, in order to evaluate the performance of this culture in On Farm Trials and ~~Large Scale~~Large-Scale Demonstrations under existing farming situations and to get feedback from farmers and field functionaries.The performance of TM 12077 was assessed in On Farm Trials in 32farmers' holdings during 2019, 2020and 2021 over the check variety Anna(R)4 in Tiruvallur,Sivagangai and Ramnaddistricts and a yield of 4420 kg/ha and 4920 kg/ha under rainfed and semidry respectively was manifested by the test entry whereas Anna (R) 4 recorded the grain yield of 4230 kg/ha and 4250 kg/ha under rainfed and semidry conditions respectively. In the On Farm Trials conductedduring 2020-21 along with the newly released drought tolerant rice variety CO 53, grain yield recorded by TM 12077 and CO 53 was 4213 kg/ha and 3972 kg/ha respectively under rainfed and 4601 kg/ha and 4197 kg/ha respectively under semidry condition.The yield advantage of 6.07 % under rainfed and 9.6 % under semidry environments over CO 53 was realized (**Table 2**).

Large scale demonstrations of TM 12077 conducted at Tiruvallur and Paramakudidistricts showed that a grain yield of 4409 kg in 117 days which was 8.1 % increase over CO 53 (4078 kg/ha)(**Fig. 2)**.The farmers in rainfed regions preferred this culture because ittolerates water stress and recovers quickly with the receipt of rainfall. The farmers were convinced with the high tillering ability, compact panicles, ~~more~~a greater number of grains per panicle, medium slender grain type, non-lodging and field tolerance to major pests and diseases of this culture.

The overall mean performance of TM 12077 against the check variety *viz.,* Anna (R) 4 in different yield trials was 3995 kg/ha and 4217 kg/ha at rainfed and semidry condition respectively which was 10.42 per cent and 17.89 per cent higher than Anna (R) 4 (**Table 1**).

The culture TM 12077 was screened against all the epidemic diseases such as blast, sheath rot, sheath blight, brown spot and rice tungro disease (RTD) during 2016, 2017, 2018 and 2019 under field screening and it was found to be moderately resistant to blast, sheath rot, sheath blight, brown spot and rice tungro disease (RTD) (**Table3**). It was also evaluated for major pests at Coimbatore, Aduthurai and Madurai during 2016 to 2019 and TM 12077 has resistance to stemborer, leaf folder and gall midge (Score 1) under field condition (**Table 4**).

In rice, grain quality is as important as yield. Consumer preference and market price have been determined by rice grain quality which involves milling quality, physical appearance and cooking quality.TKM 15 variety has medium slender grain type with the kernel length of 5.6mm and L/B ratio of 3.11. It has good hulling (80.0 %), milling (68.0 %) and Head rice recovery (62.9%). Amylose content, gelatinization temperature and gel consistency are considered to be three indicators for cooking and eating quality in rice. TKM 15 has intermediate amylose content (21.60), soft gel consistency and high to

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intermediate gelatinization temperature. Upon cooking, linear elongation ratio of 1.60 and volume expansion of 4.0 ml was recorded(**Table 5**).

Studies on drought tolerance

Unlike some other crops, rice is extremely sensitive to drought conditions during the germination and early seedling growth stage. Drought stress causes trouble of water balance, and damages metabolic process at cell level*viz*., impairment of membrane transport, and decreases ATP production and respiration, leading to poor seed germination (Kadam *et al*., 2017).

Vigorous plant growth at the seedling stage under stress condition has been used as a criterion for selecting the tolerant individuals. Laboratory studies (**Table 6**) were performed to assess the drought tolerance potential of genotypes through changes in germination, shoot and root length of the seedlings under Poly ethylene Glycol (PEG) induced drought stress. Stimulated drought conditions had been achieved *in vitro* through incorporation of osmotic solutes such as PEG in the media which was utilized by several authors to screen various genotypes for drought tolerance (Kacem *et al*., 2017, Hellal *et al*., 2018). In the present study, there was a considerable decrease in the germination potential among all the genotypes with increase in PEG concentration from 0.2MPa to 1.0 MPa. TM 12077 showed higher level of tolerance to PEG induced drought stress showing 28.4 % germination with 2.5cm and 8.23cm shoot and root length respectively at 1.0MPa when compared to Anna (R) 4 which was found to be moderate in drought tolerance with 14.8 % germination at the same level of PEG concentration. TKM 12 showed poor ability to cope up with tolerance reaction to drought even at 0.6MPa and showed considerable reduction in germination (21.4 %) and also shoot (2.3cm) and root length (5.0cm) when compared to Anna (R) 4 and TM 12077. Among the four genotypes that were subjected to drought under field condition and analysed for proline content (mg/g) at 60 % field capacity, TM 12077showed higher accumulation of proline (2.15 mg/g) followed by CO 53 (1.98 mg/g), Anna (R) 4 (1.78 mg/g) and TKM 12 (1.52 mg/g). Higher accumulation of proline is usually associated with drought tolerance and it helps for maintenance of leaf turgor and progress in stomatal conductance (Kumar *et al*., 2016). Hence TM 12077can be considered to have higher drought tolerance potential compared to other prominent drought tolerant rice varieties. Chlorophyll Stability Index (80.23%) and total chlorophyll content (1.50 mg/g) were also found to be higher in TM 12077 indicating its higher potential to withstand adverse situation like drought induced stress.

Root characteristics of the plants are the vital attributes for enhancing production under drought stress. Generally, rice varieties with profound and prolific root system show better adaptability in drought (Mishra *et al*., 2019). Root characters are primary traits of drought tolerance and show the inherent potential of genotypes to withstand drought, varieties bred for dry / semi conditions should possess better root architecture than lowland varieties. Root length (cm) and root volume (cc) were also found to be higher in TM 12077 (17.8 cm and 59 cc respectively) among the four genotypes under managed stress condition. CO 53 showed root length of 15.4 cm and root volume of 47 cc and stood next to TM 12077 with respect to root characters and drought tolerance. Drought resistant entries had recorded higher root

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thickness, root volume and deep root system than the susceptible genotypes (Pushpam *et al.,*2018). This is also in accordance to the findings of Yogameenakshi*etal*. (2003) andSheeba *et al*. (2010).

The rice variety TKM 15 was differentiated from parents and other popular varieties *viz.,* Anna (R) 4 and CO 53 using the molecular marker technology. A total of 10 SSR markers were taken for the study. Among these markers, RM252 and RM 442 had polymorphism between TKM 15 and popular varieties and parental lines (**Fig. 3**).

Based on the superior performance of the drought tolerant rice culture, TM 12077 over the check varieties Anna (R) 4 and CO 53, this culture was recommended by Tamil Nadu Agricultural University for State Variety Release Committee and was released as rice variety TKM 15, a variety suitable for direct sowing under rainfed and semidry environments of Tamil Nadu by SVRC during 2022 and notified by the Central Ministry of Agriculture and Farmers welfare during August, 2022.

CONCLUSION

Direct seeded rainfed rice is being cultivated in the districts of Tiruvallur, Kancheepuram, Ramnad, Sivagangai, Villupuram, Virudhunagar and Thoothukudi and maintained as dry or semidry crop depending upon the rainfall received. Already released drought tolerant rice varieties *viz*., Anna (R) 4 released during 2009 by TNAU has difficulty in milling due to long slender grain type. Rice variety CO 53 released during 2019 is having short bold grain mainly suitable for idly making. Farmers are in urgent need of direct seeded rice varieties suitable for rainfed and semidry cultivation with high yield potential and preferable medium slender grain quality and the variety TKM 15 meets the above requirement of farmers in rainfed environments.

Since the majority of the farmers living in drought prone ecologies are socio-economically under privileged, the drought tolerant variety TKM 15, can serve as one of the most viable and deliverable technologies for eradicating poverty from these ecologies.

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Table 1. Overall Mean performance of TM 12077 over the check Anna (R) 4

Name of the Trial	No. of Locations	Grain yield (kg/ha)				% increase over Anna (R) 4	
		Dry		Semidry			
		TM 12077	Anna (R) 4	TM 12077	Anna (R) 4	Dry	Semidry
Station trial (2013- 2015)	6	3718 (117)	3227 (115)	4418 (117)	3738 (110)	15.22	18.19
MLT (2016-2018)	10	2777 (120)	2105 (108)	2930 (122)	2392 (107)	31.92	22.49
ART- DoA& KVK (2018-20)	62	4421 (117)	4220 (115)	-	-	4.76	-
AICRIP – IVT* (2017)	8	3386 (115)	-	-	-	-	-
OFT (2019-20)	5	4420 (117)	4230 (116)	4920 (116)	4250 (115)	4.49	15.76
OFT(2020-21)	25	4213 (118)	3706 (113)	4601(117)	3931(113)	13.68	17.04
Overall Mean	116	3995 (118)	3618 (113)	4217 (120)	3577 (109)	10.42	17.89

*Values in parenthesis denotes the duration (Days)

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Table 2. On Farm Trials conducted during 2020-21 with the recently released drought tolerant rice variety Co 53

Name of the culture	No. of Trials	Grain yield (kg/ha)		Remarks
		Dry	Semidry	
TM 12077	25	4213 (118)	4601 (117)	• Matures in 118 days • Good germination and early vigour • Tolerates ~~early stage~~early-stage stress and recovers quickly on the receipt of rain water. • Non lodging, dense panicle, fine grain type • Resistant to pest and diseases
CO 53	25	3972 (115)	4197 (110)	• Tall plant type prone to lodging • Bold grain type • Tolerates drought
% increase	-	6.07	9.63	

Table 3. Reaction to major diseases of rice

Sl. No.	Culture	Blast			Sheath rot				Sheath blight		
		2016-17	2017-18	2019-20	2016-17	2017-18	2018-19	2019-20	2016-17	2017-18	2019-20 ADT*
1.	TM 12077	3	1	5	5	5	3	3	5	3	5
2.	Anna (R) 4	5	1	3	5	5	7	3	5	5	7

Sl. No.	Culture	BLB*		Brown spot			RTD		
		2018-19 ADT	2019-20 ADT	2016-17 CBE	2017-18 CBE	2018-19 ADT	2016-17 CBE	2017-18 CBE	2019-20 CBE
1.	TM 12077	7	7	3	5	5	5	5	4
2.	Anna (R) 4	9	7	5	5	7	7	3	4

Table 4. Reaction to major pests

Sl. No.	Culture	Stem Borer			Leaf folder				
		2016-17	2017-18	2018-19	2019-20	2016-17	2017-18	2018-19	2019-20
1.	TM 12077	1	0	1	1	1	3	1	1
2.	Anna (R) 4	1	0	3	1	1	1	1	0

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Sl. No.	Culture	Gall Midge		BPH*	WBPH*	GLH*
		2018-19		CBE (2017-18)		
		ADT	MDU			
1.	TM 12077	1	1	7	9	7
2.	Anna (R) 4	1	0	5	9	9

Table 5.Quality characteristics of TM 12077

i. Physical quality characteristics

Variety	Hulling (%)	Milling (%)	Head rice recovery (%)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	*Grain Type
TM 12077	80.0	68.0	62.9	5.6	1.9	2.95	MS
Anna(R) 4	78.7	66.2	59.0	6.8	2.1	3.11	LS
CO 53	78.8	69.6	59.6	5.4	2.5	2.20	SB

ii. Cooking quality parameters

Parameters	TM 12077	Anna (R) 4	CO 53
Kernel length after cooking (mm)	9.0	9.2	8.5
Kernel breadth after cooking (mm)	2.7	2.7	3.4
Linear elongation ratio	1.60	1.60	1.59
Breadthwise elongation ratio	1.30	1.40	1.45
Volume expansion ratio	4.0	4.2	3.9

iii. Biochemical characteristics

Parameters	TM 12077	Anna (R) 4	CO 53
Gel consistency	Soft	Soft	Soft
Gelatinization temperature	High to intermediate	High to intermediate	High to intermediate
Amylose content	21.7	22.6	23.50

Table 6. Laboratory studies on drought tolerance under varied PEG levels

Genotypes	Control	0.2 MPa	0.4 MPa	0.6 MPa	1.0 MPa
Germination percentage (%)					
TM 12077	100.0	88.4	84.9	55.4	28.4
TKM (R)12	98.0	80.5	71.4	21.4	0.0
Anna (R) 4	97.0	84.6	79.4	38.9	14.8
Shoot length (cm)					
TM 12077	12.8	10.0	8.0	6.7	2.5
TKM (R)12	11.4	8.5	5.5	2.3	0.0
Anna (R) 4	11.2	10.1	6.7	4.2	1.9
Root length (cm)					
TM 12077	20.45	17.45	15.73	11.00	8.23
TKM (R)12	12.40	10.95	9.85	5.00	0.00

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Anna (R) 4	19.75	17.80	16.25	11.80	8.25
Seedling vigour index					
TM 12077	845.20	320.62	134.78	56.33	2.01
TKM (R)12	658.30	165.90	60.34	16.90	0.26
Anna (R) 4	785.20	190.45	68.22	18.90	0.81

Physiological parameters at water stress (60% FC)

S.No.	Genotypes	TM 12077	Anna (R) 4	TKM (R) 12
1.	Proline content (mg/g)	4.15	3.78	3.52
2.	Chlorophyll Stability index (%)	80.23	70.45	67.89
3.	Total chlorophyll content (mg/g)	1.50	1.29	1.21

Biometrical Characters under Managed stress condition

Genotypes	Days to Maturity	Plant Height (cm)	Tillers per plant	No. of panicles / sqm	Root Length (cm)
TM 12077	117	90.0	14	302	17.8
Anna (R) 4	110	114.4	10	227	12.5
TKM (R) 12	123	115.0	10	226	13.2

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Fig.1: Pedigree of TM 12077 (IET 26645)

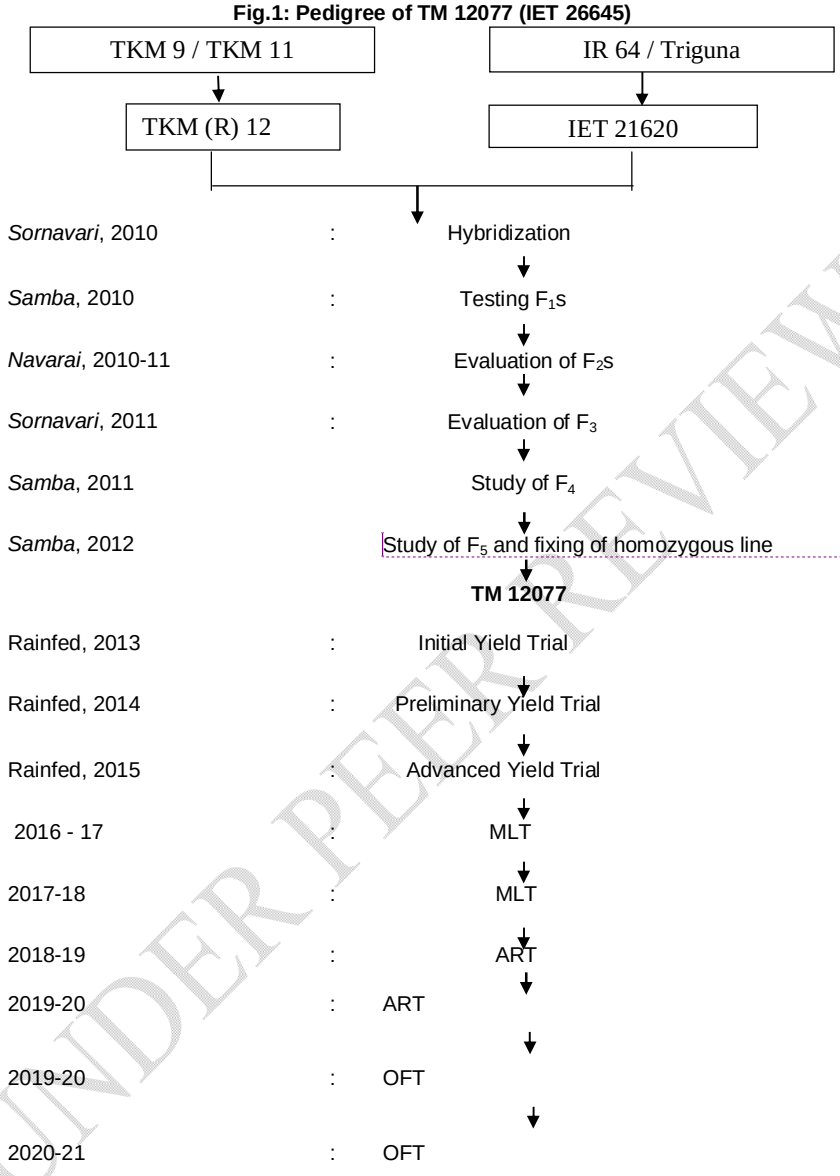

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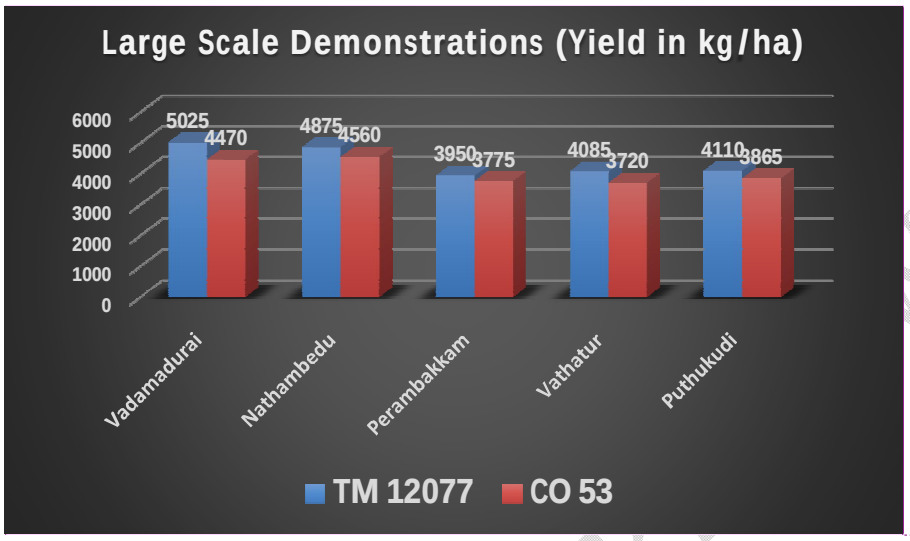
Fig 2. Large Scale Demonstrations of TM 12077



Comment [R10]: review the overlapping of numbers in the figure

Fig 3. Molecular marker studies using Microsatellite markers