Received: 30 Apr 2022 | Revised: 21 Sep 2022 | Accepted: 25 Sep 2022

Electronic Journal of Plant Breeding

Research Article

TRY 4: A high yielding, mid early, sodicity tolerant rice variety suited to Tamil Nadu

S. Geetha[1], A. P. Kirubakaran Soundaraj[2], PL. Viswanathan[1], S. K. Ganesh[2], T. Thirumurugan[3], P. Jeyaprakash[2]*, A.Subramanian[1], S. Chitra[4], S. Avudaithai[5], S. Nithila[6], K.Geetha[6], T. Sherene Jenita Rajammal[7], T. Senguttuvan[8], S. Sheeba Joyce Roseleen[9], P. T. Sharavanan[7], T. Evera[2] and P.Masilamani[2]

[1]Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore
[2]Department of Plant Breeding and Genetics, ADAC&RI, Trichy
[3]Sugarcane Research Station, Cuddalore
[4]Department of Plant Breeding and Genetics, AC&RI, Madurai
[5]Department of Agronomy, ADAC&RI, Trichy
[6]KVK, Sirugamani
[7]Department of Fruit Sciences, HC&RI (W), Trichy
[8]AC&RI, Kudumiyanmalai
[9]Sugarcane Research Station, Sirugamani
[10]Department of Plant Protection, AC&RI, Vazhavachanur
***E-Mail:** jeyaprakash.p@tnau.ac.in

Abstract
Sodicity tolerant rice culture TR 05031, a derivative of the cross ADT 39 x CO 45 was released as Rice TRY 4 during the year 2021 as a mid early duration variety with 127 days duration with high yield, high milling (68.1 %) and head rice recovery (57.2 %). Twelve years of testing across 181 locations in Tamil Nadu revealed that the culture is high yielding (5730 kg/ha with 22.00 per cent increased grain yield over TKM 13 and 16.50 per cent over ADT 39) in salt affected soils. EDAX under SEM studies confirmed that, there was a lesser transport of sodium ions and higher transport of potassium ions from root to shoot in this culture, TR05031. Besides, TR05 031 maintain more tracheids / unit leaf area and accumulate salts to the outer epidermal layer through specialized trichomes, providing resistance to salinity. The culture TR05031 is resistant to major diseases *viz*., blast and brown spot and has field resistance to major pests *viz*., leaffolder, stem borer and gall midge. TR05031 with high yield, better pest and disease resistance and good cooking quality is suitable for cultivation during late *samba/thaladi* in salt affected patches of Tamil Nadu. The culture was released as TRY 4 during 2021 and notified by Government of India for seed production.

Keywords: Rice, TRY 4, variety, mid early, sodicity tolerance

INTRODUCTION

Rice is the staple food of about 2/3rd of world population. One of the most devastating abiotic stresses in rice is salinity and the salt-affected soils account for about 20 per cent of the total paddy cultivating area (Zhou *et al*., 2016). India is the second largest rice producing country in the world with a production of 116.4 million tonnes and productivity of 2638 kg /ha as reported during 2019-20 occupying an area of 44.15 million hectares (www.indiastat.com). However, the production of rice is hampered by several biotic and abiotic factors. One of the better ways to sustain crop production in such problem soil environment is identification of development genotypes with innate salt tolerance potential.

In Tamil Nadu, rice is cultivated in major seasons namely, *Kuruvai, Samba, Thaladi and Navarai.* Delay in monsoon or insufficient rainfall period during *samba / thaladi / late thaladi* seasons coupled with preceeding *kuruvai* crop with scarce rains increases salinity / sodicity in soil. Under such situations, the choice of varieties is very much limited in the state. At present in the late *samba / thaladi* season, farmers are cultivating mid early duration rice varieties *viz.,* TKM 13 or ADT 39 which is not suited to saline / sodic tracts. But these are cultivated under compulsion resulting in reduced yield under such situations. Hence, there is an urgent need among farmers for a fine grain variety with mid early duration and good cooking quality suiting to salt affected soils.

To fulfill this need, plant breeding efforts were taken at Anbil Dharmalingam Agricultural College and Research Institute, Trichy to develop a high yielding mid early rice variety with salinity/ sodicity tolerance. As a result, a promising culture, TR 05031 a derivative of ADT 39 x CO 45 was developed.

MATERIALS AND METHODS

A rice culture TR 05031 was evolved in Department of Plant Breeding and Genetics, Anbil Dharmalingam Agricultural College and Research Institute, Trichy and released for cultivation in Tamil Nadu as TRY 4. It is a derivative of the cross ADT 39 x CO 45. Promising single plants from the segregants of the cross were selected up to F_4 generation. After attainment of homozygosity, the culture was named as TR05031 and evaluated in yield trials. Previously there were no rice varieties in this group; hence this culture was tested with a medium duration variety TRY 3 suited for salt affected soils in station trials from 2007 to 2010. From the year 2013-14 to 2014-15, the culture was evaluated in multilocation trials conducted in six locations. Further, evaluated in Adaptive Research Trial in 80 locations across Tamil Nadu from 2013-14 to 2017-18 with check TRY 3. Simultaneously from 2018 to 2021, the culture was evaluated in on farm testing (87 locations) in salt affected soils in rice growing districts of the state along with the check varieties according to the local farmers' choices namely, TRY 3, TKM 13, ADT 39 and BPT 5204. Large scale demonstrations (one acre) were also conducted with this culture in five locations. The culture TR05031 was evaluated as IET 21730 under All India Coordinated Crop Improvement Program during 2013 and 2014. Altogether, the culture was test verified in 181 across Tamil Nadu in salt affected soils. The reaction of the culture against major pest and diseases of rice, milling quality of rice, cooking quality of grain, anatomical and physiological features relating to sodicity was also evaluated by following appropriate methods.

Table 1.Overall mean yield performance of TR05031 in different trials

S. No.	Name of the Trials	Locations	Grain yield (kg/ha)				
			TR05031	TRY 3	TKM 13	ADT 39	BPT 5204
1.	On-Station trial (2007 - 2010)	3	5267 (126)	4823 (137)	-	-	-
2.	Multi location trials (2013-14 and 2014-15)	6	5089 (127)	5567 (131)	-	-	-
3.	Adaptive Research Trials (2013-14 to 2017-18)	80	5857 (128)	5525 (135)	-	-	-
4.	OFT (2015 -21)	87	5694 (126)	5120 (140)	4693 (130)	4920 (128)	5050 (138)
5.	Large scale demonstrations (2014 to 2019)	5	5390 (127)	5200 (140)		-	-
6.	National trial (*Kharif*,2013 & 2014)*- IET 21730	17	3542 (Alkalinity)	3333 (CSR 36)	-	-	-
			3304 (Inland salinity)	3899 (CSR 23)	-	-	-
			2986 (Coastal Salinity)	2702 (CST7-1)	-	-	-
7.	Number of trials	181		140	34	9	10
	Overall weighted mean yield		**5761 (127)**	**5373 (137)**	**4693 (130)**	**4920 (128)**	**5050 (138)**
	Per cent increase over the checks			**7.0**	**22.00**	**16.50**	**14.07**

**Not included in the mean,* Duration given in paranthesis

RESULTS AND DISCUSSION

Observation of yield trials consecutively over three years proved that the culture was found to be superior in yield. The station trials conducted at Anbil Dharmalingam Agricultural College and Research Institute showed that the culture TR 05031 recorded an average grain yield of 5267 kg/ha with 9.0 per cent increase over the check variety TRY 3 (**Table 1 & 2**).Besides, there was an advantage of 11 days earliness in the culture when compared to TRY 3. Similar trend was observed in MLT over six locations, TR05031 recorded an yield of 5089 kg/ha improved per day productivity than TRY 3 (**Table 1 & 3**).Under adaptive research trial conducted in 80 locations through five years, the culture TR05031 recorded an average yield of 5857 kg/ha which was six per cent increase over the check, TRY 3 (**Table 1, 4a & 4b).** The culture was evaluated in salt affected soils in on-farm testing in 87 locations, registered relatively a higher grain yield (5694 kg/ha) when compared to the different checks namely, TRY 3 (5120 kg/ha), TKM 13 (4693 kg/ha), ADT 36 (4920 kg/ha) and BPT 5204 (5050 kg/ha) (**Table 5**).

Any technology is proven when tested in large scale demonstrations and hence, large scale demonstrations in one acre plot was conducted over six years from

Table 2. On-station trials at ADAC&RI, Trichy*

S. No	Trials	Grain yield (kg/ha)		Days to maturity	
		TR 05031	TRY 3	TR 05031	TRY 3
1	Preliminary Yield Trial 2007-08	4000	3333	125	140
2	Comparative Yield Trial 2008-09	5300	5885	127	135
3	Advanced Yield Trial 2009-10	6500	5250	125	135
	Mean (3)	**5267**	**4823**	**126**	**137**
	% increase over the check		**9.2**	**11 days early**	

* pH- 8.7 ; EC -0.43 dSm-1; ESP- 18.8 %

Table 3. Multilocation MLT – saline /alkaline (2013-2014 and 2014-15)

S.No.	Year and Number of location	Grain yield (kg/ha)		Days to maturity	
		TR 05031	TRY 3	TR 05031	TRY 3
1.	2013 -14 (4)	5304	5038	128	132
2.	2014-15 (3)	4873	6096	125	131
	Mean (7)	**5089**	**5567**	**127**	**131**

Table 4a. Performance of TR 05031 in Adaptive Research Trial during 2013-14, 2014-15, 2016-17 and 2017-18 *

S. No.	Districts/ year/ number of locations	Mean grain yield (kg/ha)		Days to maturity	
		TR 05031	TRY3	TR 05031	TRY3
1	Trichy (19) (2013-14 to 2017-18)	6069	6286	128	136
2	Ramanathapuram(7)(2013-14)	5527	5538	129	135
3	Tiruvallur (3) (2013-14)	5214	5338	125	137
4	Thoothukudi (2)(2016 to 2018	8205	5977	128	140
5	Madurai (10)(2013-14 to 2014-15)	6796	6995	128	132
6	Tirunelveli (7)(2013-14)	6526	5829	126	134
7	Krishnagiri (14)(2013-14 to 2014-15)	4961	4889	130	132
8	Dharmapuri (7)(2013 -14)	6204	5846	131	134
9	Kanchipuram (4)(2013-14)	6407	6713	129	141
10	Cuddalore (8)(2013-14)	5621	5585	127	127
	Overall increase	**5857**	**5525**	**128**	**135**
% increase over check		**6**			

* All the ARTs were conducted in saline situations where soil pH > 8 and EC > 3.0 $dS^{-1}m$

Table 4b. Overall mean performance in Adaptive Research Trials

S. No.	Trial type	Locations	Yield (kg/ha)		Duration (days)	
			TR 05031	TRY 3	TR 05031	TRY 3
1.	ART 2013-14	51	5850	5783	129	134
2.	ART 2014-15	21	6315	6552	129	130
3	ART2016-17	4	5688	4831	126	137
4	ART2017-18	4	5573	4935	127	139
	Mean	**80**	**5857**	**5525**	**128**	**135**
% increase over check				**6**		

Table 5. Performance of TR 05031 in On-farm trials during 2016-2020

S.No.	District/Year	Grain yield (kg/ha)				
		TR 05031	BPT 5204	TRY 3	TKM 13	ADT 39
	2016-17					
1	Nagapattinam (3)	5483	4350	4620	-	-
2	Trichy (6)	5450	5890	6417		
	2017-18					
3	Nagapattinam (1)	5430	-	5340	-	-
	2018-19					
4	Nagapattinam (1)	5670	-	5400	-	-
	2019-20					
5	Trichy (6)	5925	-	5421	-	-
6	Nagapattinam (8)	5773	5310	4863	-	-
7	Kanchipuram (3)	5667	5208	-	-	-
8	Tiruvarur (5)	5990	-	4830	-	-
	2020 Kuruvai					
9	Tiruvarur (9)	5586	-	-	4731	-
10	Nagapattinam (10)	5418	-	-	4688	-
11	Trichy (4)	5794	-	-	4865	-
	2020 Late samba					
12	Cuddalore (2)	5645	-	-	4485	-
13	Trichy (8)	5986	-	-		4995
14	Tiruvarur (9)	6031	-	4720	4560	-
	2020 thaladi					-
15	Trichy (9)	5544	-	4687		-
16	Salem (3)	4153	-	-	4437	-
	Mean grain yield (kg/ha)	**5694**	**5050**	**5120**	**4693**	**4920**
	Mean days to maturity	**126**	**138**	**140**	**130**	**128**
	Number of trials	**87**	**10**	**42**	**34**	**9**
	% increase over checks		**12.7**	**11.21**	**21.32**	**15.73**

Table 6. Performance of TR 05031 in large scale demonstration

S. No.	Location	Grain yield (kg/ha)		Days to maturity	
		TR 05031	TRY 3	TR 05031	TRY 3
1.	ADAC&RI, Trichy (2014-15)	4500	4700	125	138
2.	ADAC&RI, Trichy (2015-16)	5300	5100	129	145
3.	ADAC&RI, Trichy(2016-17)	6200	5900	125	137
4.	ADAC&RI, Trichy (2017-18)	5700	5300	130	140
5.	ADAC&RI, Trichy (2018-19	5250	5000	125	138
	Mean (5)	**5390**	**5200**	**127**	**140**
	% increase over check		**3.6**		

2014 to 2019, TR 05031 recorded an average yield of 5390 kg per ha as against 5200 kg/ha in TRY 3 (**Table 6**). Simultaneously, the culture was also evaluated under All India Coordinated Trials christened as IET 21730 in soils with different salt levels. Under alkaline conditions, the national check CSR 36 recorded 3333 kg/ha, while IET 21730 has recorded an average yield of 3542 kg/ha. In coastal saline conditions, the national check CST 7-1 registered 2702 kg/ha, whereas the culture recorded a high yield (2986 kg/ha) (**Table 7a &7b**).

The overall mean yield of TR 05031 across 181 trials was found to be 5761 kg/ha, which was seven per cent increase over the check TRY 3, 22.0 per cent over TKM 13, 16.50 per cent over ADT 39 and 14.07 per cent over BPT 5204 (**Table 1**). TKM 13 is the recently released rice variety for the state with similar duration, while ADT 39 is the predominant variety in this group. BPT 5204 is a popular rice variety with medium duration and farmer's choice of check variety. Performance analysis of the culture across the districts in the state revealed that it recorded higher grain yield in seven districts namely Trichy (20.36 per cent over TKM 13), Tiruvarur (21.36 per cent over TRY 3 and 25.40 per cent over TKM 13), Nagapattinam (13.8 per cent over TRY 3 and 18.64 per cent over TKM 13), Cuddalore (25.41 per cent than TKM 13), Thoothukudi (37.27 per cent over TRY 3),Tirunelveli (11.9 per cent over TRY 3), Krishnagiri (1.5 per cent over TRY 3) and Dharmapuri (6.12 per cent over TRY 3). At Ramanathapuram and Krishnagiri districts, it recorded on par yield with TRY 3 (**Table 8**).

Table 7a. Performance of TR 05031 (IET 21730) in National Trials, ALSTVT during *Kharif* 2011

Locations with soil stress conditions (Alkalinity)	**Kanpur**	**Lucknow**	**Karaikal**		**Mean**
Soil pH	9.6	9.6-9.7	7.01-9.32		
Soil Ece (dSm^{-1})	0.94	-	0.95-2.32		
IET 21730 - Grain yield	2967	3073	1875		2638
CSR 23 (Inland salinity check)- Grain yield	2900	3083	1719		2567
JAYA (yield check)- Grain yield	2650	3169	1458		2425
CSR 36 (Alkaline check)- Grain yield	1667	2156	1927		1916
Locations considered as normal under alkalinity	Masodha	Nawagam	Trichy	Annamalai nagar	
2Soil pH	9.6	7.8	8.08	-	
Soil Ece (dSm^{-1})	2.41	0.81	4.01	-	
IET 21730- Grain yield	4326	6024	6521	3565	5109
CSR 23 (Inland salinity check)- Grain yield	4278	6431	3250	2211	4042
JAYA(yield check) - Grain yield	4370	5389	2427	2066	4066
CSR 36 (Alkaline check) Grain yield	4519	5933	2156	2380	3747
Locations with soil stress (Inland Salinity)	Gangavati	Karnal			
Soil pH	6.5-7.5	8.2			
Soil Ece (dSm^{-1})	8.05	10			
IET 21730 - Grain yield	3118	2422			2770
CSR 23 (Inland salinity check)- Grain yield	3849	3011			3430
JAYA(yield check)- Grain yield	3079	2789			2934
CSR 36 (Alkaline check) - Grain yield	3750	2167			
Coastal saline Tolerant variety Trail, kharif,2011	Cuttack	Canning	Goa	Machilipatinam	
Soil pH	6.93	7.23	5.26-5.54	7.35	
Soil Ece (dSm^{-1})	8.38	8.95	2.68-5.95	14.2	
21730- Grain yield	1340	2767	963	2753	2286
CST 7-1 (CS Check)- Grain yield	1330	3062	995	3420	2604
Locations considered as normal	Chinsura	Panvel	Navsari	Port Blair	
Soil pH	6.5	7.8	8.93	5.5	
Soil Ece (dSm^{-1})	0.96-3.0	-	1.79	2.5-4.5	
21730- Grain yield	**3259**	**5185**	2612		3685
CST 7-1 (CS Check) -Grain yield	1976	3546	**2877**		2799

Table 7 b. Performance of TR 05031 (IET 21730) in National Trials during *Kharif* 2012

Locations with soil stress conditions (Alkalinity)	
Annamalai Nagar	
Ph	8.32
Soil Ece (dSm^{-1})	-
IET 21730 - grain yield (kg/ha)	2480
CSR 23 (Inland salinity check)- grain yield (kg/ha)	903
Jaya (yield check)- grain yield (kg/ha)	1010
CSR 36 (Alkaline check)-grain yield (kg/ha)	1503
Locations considered as normal under alkalinity	
Ludhiana	
IET 21730- grain yield (kg/ha)	3941
CSR 23 (Inland salinity check)- grain yield (kg/ha)	6710
JAYA(yield check)- grain yield (kg/ha)	6752
CSR 36 (Alkaline check)- grain yield (kg/ha)	6165
Locations with soil stress (Inland Salinity	
Gangavati	
Soil Ph	8.21
Soil Ece (dSm^{-1})	9.84
IET 21730 - grain yield (kg/ha)	3838
CSR 23 (Inland salinity check)- grain yield (kg/ha)	4369
JAYA(yield check)- grain yield (kg/ha)	1094
CSR 36 (Alkaline check)- grain yield (kg/ha)	3889

Table 8. District wise consolidated performance of TR 05031 in MLT/ ART/ OFT

S. No.	Districts(Number of locations)	Grain yield (kg/ha)			Duration (days)		
		TR 05031	TRY 3	TKM 13	TR 05031	TRY 3	TKM 13
1	Trichy (52)	5856	5816	4865	127	138	131
2	Ramanathapuram (7)	5527	5383	-	123	133	-
3	Tiruvallur (3)	5214	5338	-	125	135	-
4	Thuthukudi (2)	8205	5977	-	128	140	-
5	Madurai (10)	6796	6995	-	128	132	-
6	Tirunelveli (6)	6526	5829	-	126	134	-
7	Krishnagiri (14)	4961	4889	-	130	132	-
8	Dharmapuri (7)	6204	5846	-	131	134	-
9	Kanchipuram (7)	6089	6713	-	129	141	-
10	Cuddalore (10)	5625	5585	4485	128	127	134
XI	Nagapattinam (23)	5561	4884	4687	126	138	125
XII	Tiruvarur(23)	5848	4793	4663	126	140	129
XIII	Salem (3)	5153		4777	124		136

Table 9 a. Reaction of TR 05031 to major diseases

Diseases	Year	Centre	TR 05031	TRY 3
Blast	2010-11	MDU*	5	5
	2010-11	CBE*	5	5
	2011-12	CBE*	5	5
BLB	2011-12	CBE*	7	5
Brown spot	2010-11	MDU*	5	5

* Artificial screening

Host plant resistance has long been used as a viable alternative to chemical control methods (Soundararajan et al., 2004).The culture is moderately resistant to blast and brown spot under artificial and field conditions. (**Table 9 a & b**).The culture is resistant to stem borer and leaffolder besides moderate resistance to gall midge under field conditions (**Table 10 a & b**).

Normally for sodic soils, a blanket recommendation of 187:50:50 kg NPK /ha (25 % high N) is recommended. However, the culture has responded to an additional 20 % N which recorded the highest yield of 6579 kg/ha with a spacing of 20 x 10 cm and fertilizer level of 234: 50:50 kg NPK /ha under sodic conditions (**Table 11a &b**)

The entry TR 05031 found to be moderately tolerant to sainity (EC = 8dSm-1) when screened under glass house conditions **(float method)** using salt impose nutrient medium. (**Table 12 a**). Roll towel method screening enabled to study the response to salinity / sodicity. The response to germination at different levels of $NaHCO_3$ and NaCl under lab condition recorded higher germination at relatively higher level of sodicity (82 % at 25 mM $NaHCO_3$ and 56 % at 50 mM concentration). The response to NaCl is also relatively higher at higher concentration (**Table 12 b & c**).

Increased potassium and proline (323 µg g^{-1}) in leaves of TR05031 leads to maintain water potential under stress. There by it retains enzyme activity like Nitrate reductase (35 µg NO_2 g^{-1} h^{-1}) and higher soluble protein content (24.2 mg g^{-1}) so as to maintain more photosynthetic activity (**Table 12 d**).

Salt stress response includes alteration in the activity of various important enzymes in plants. Nitrate reductase is one of the known enzyme affected by salt stress. Under stress condition, salt-sensitive rice cultivar (IR64) showed

Table 9 b. Reaction of TR 05031 to major diseases at Trichy during 2020 under field condition

Diseases	Per cent disease index and score		
	TR 05031	TKM 13	ADT 39
Bacterial leaf blight	5.33 (3)	28.89 (7)	15.33(7)
Bacterial leaf streak	4.67 (3)	11.78(7)	9.11(5)
Leaf blast	1.12 (1)	3.78(3)	3.11(3)
Brown spot	0.0	0.0	0.0

Table 10 a. Reaction of TR 05031 to major pests

Pests	Year	Centre	TR 05031	TRY 3	TRY (R) 2
Stem borer (%)	2010-11	MDU (DH)	0.00	11.36	-
	2012-13	TRY (DH)	0.00	5.28	4.32
		TRY (WE)	0.00	1.36	1.90
	2013-14	ADT (DH)	8.60	25.30	7.50
		MDU (DH)	3.64	19.35	5.56
		TRY (DH)	4.30	12.10	3.26
		ADT (WE)	5.40	4.10	7.60
		MDU (WE)	27.78	24.32	16.67
		TRY (WE)	2.54	0.00	2.64
Leaf folder (%)	2012-13	TRY	0.00	4.10	3.50
	2013-14	ADT	4.70	4.20	2.01
		TRY	1.56	5.70	7.14
BPH (Number/ hill)	2010-11	MDU	4.19	3.32	-
	2013-14	ADT	0.70	0.20	-
		CBE	7.00	7.00	-
		MDU	5.00	9.00	-
Gall midge Silver shoot (%)	2010-11	MDU	29.73	34.09	-
	2012-13	TRY	0.00	0.00	0.00
	2013-14	ADT	0.90	3.70	4.50
		MDU	4.76	6.45	5.56

Table 10 b. Reaction of TR05031 to major pests during 2020

Pest	Location	TR05031	TKM 13	ADT 39
Leaffolder (%)	ADAC&RI, Trichy	1.36	9.03	8.53
	OFT at Needamangalam	3.26	7.25	-
	OFT at Tirumangalam village, Lalgudi	1.54	-	-
Stem borer				
Dead heart (%)	ADAC&RI, Trichy	5.33	9.53	7.65
White ear (%)		1.86	5.72	3.65
Dead heart (%)	OFT at Needamangalam	4.66	8.23	-
White ear (%)		1.73	3.14	-
Dead heart (%)	OFT at Tirumangalam village, Lalgudi	0.00	-	
White ear (%)		0.00	-	
Gall midge silver shoot (%)	ADAC&RI, Trichy	0.33	3.56	4.53
	OFT at Needamangalam	0.00	1.23	-
	OFT at Tirumangalam village, Lalgudi	0.00	-	-

Table11 a .Effect of spacing and fertilizer dose on growth and yield attributes

Treatment	Plant height (cm)		Number of productive tillers / sq. m		Panicle length (cm)		Number of filled grains / panicle		Grain yield (kg / ha)	
	2015	2016	2015	2016	2015	2016	2015	2015	2015	2016
Main plot										
M1 : TRY 1	108.1	106.0	281	270.16	23.9	22.21	222.3	217.6	5200	4639
M2 : TRY 3	123.0	123.0	377	271.5	27.1	26.3	226.2	221.2	6101	5253
M3 : TR 05031	110.1	100.0	328	353.0	25.4	22.7	225.7	219.9	5442	5934
M4 : TR 05043	115.0	104.4	275	306.7	22.8	20.3	209.0	204.2	4838	5000
SED	4.1	0.62	12.0	1.26	0.8	0.21	0.4	0.95	26.0	9
CD (0.05)	10.1	1.96	40.0	4.01	2.4	0.68	1.2	3.02	81.0	29.0
Sub plot										
S1:20 x 10 cm with 187:50:50 kg NPK ha^{-1}	112.4	107.54	324.0	323.5	24.5	21.86	209.5	204.5	5462	5311
S2: 20 x 10 cm with 234:50:50 kg NPK ha^{-1}	115.9	111.65	328.0	314.25	25.5	22.95	228.3	223.3	5692	5492
S3: 20 x 10 cm with 150:50:50 kg NPK ha^{-1}	114.1	111.8	317.0	292.5	24.4	23.45	210.1	205.1	5200	5000
S4: 25 x 25cm with 187:50:50 kg NPK ha^{-1}	114.1	107.7	337.0	322.0	24.8	22.2	232.8	227.3	5394	5195
S5: 25 x 25 cm with 234:50:50 kg NPK ha^{-1}	116.1	110.95	323.0	310.0	24.6	23.0	238.8	234.0	5698	5458
S6: 25 x 25 cm with 150:50:50 kg NPK ha^{-1}	111.8	100.0	262.0	239.8	24.9	23.8	205.4	200.2	4965	4782
SEd	NS	0.63	12.0	1.1	0.8	0.15	0.4	0.94	9.0	29
CD (0.05)		1.32	25.0	2.2	1.7	0.31	0.8	1.96	18.0	61

Table 11 b. Interaction effect of spacing and fertilizer dose on grain yield during 2015 and 2016

Treatments	S2 : Spacing 20x10 cm with Fertilizer dose 234:50:50 kg NPK ha^{-1}		Mean ($kgha^{-1}$)	Per day productivity (kg)	S4 : Spacing 25x25cm with Fertilizer dose 187:50:50 kg NPK ha^{-1} (20 % N Recommended for saline soils)		Mean ($kgha^{-1}$)	Per day productivity (kg)
	2015	**2016**			**2015**	**2016**		
M1-TRY 1	5175	4716	4946(135 days)	36.63	4968	4923	4946(135 days)	36.63
M2- TRY 3	6417	5492	5955(135 days)	44.11	6220	5133	5677(135 days)	42.04
M3- TR05031	5444	6579	6012(125 days)	48.09	5216	5544	5380(125 days)	43.04
M4- TR09043	4812	5182	4997(130 days)	38.43	4398	5182	4790(130 days)	36.84
Mean	5462	5492			5200	5196		
	CD(0.05)	CD(0.05)						

Table 12 a. Evaluation of TR 05031 for salinity tolerance at seedling stage *

Genotypes	Score*
TR 05031	5
TRY 3	5
ADT 39	7

*Modified Standard Evaluation system , IRRI, 2002

Table 12 b. Response of TR05031 to different levels of NaCl

NaCl Concentration (mM)	TR05031					TRY 3				
Treatments	Germination %	Shoot length (cm)	Root length (cm)	Fresh weight (g)	Dry weight (g)	Germination %	Shoot length (cm)	Root length (cm)	Fresh weight (g)	Dry weight (g)
Control	88.0	9.31	10.89	0.59	0.13	83.0	12.11	17.35	0.86	0.18
50	69.3	7.97	13.93	0.60	0.14	53.3	9.40	17.70	0.76	0.19
100	64.0	6.69	10.29	0.45	0.14	48.0	7.75	13.47	0.62	0.20
150	25.3	2.89	5.29	0.39	0.17	21.3	2.11	5.29	0.45	0.24
200	8.0	1.27	2.86	0.33	0.15	5.3	0.72	3.07	0.41	0.19

Table 12 c. Response of TR05031 to different levels of $NaHCO_3$

$NaHCO_3$ Concentration (mM)	TR05031					TRY 3				
Treatments	Germination %	Shoot length (cm)	Root length (cm)	Fresh weight (g)	Dry weight (g)	Germination %	Shoot length (cm)	Root length (cm)	Fresh weight (g)	Dry weight (g)
Control	88.0	9.31	10.89	0.59	0.13	83.0	12.11	17.35	0.86	0.18
25	82.7	9.57	16.15	0.68	0.22	74.7	13.15	18.11	0.88	0.28
50	56.0	7.87	9.70	0.58	0.12	56.0	10.73	8.94	0.84	0.17
75	0.0	2.30	0.58	0.36	0.16	0.0	2.82	0.62	0.47	0.20
100	0.0	1.07	0.12	0.28	0.14	0.0	2.06	0.37	0.42	0.20

Table 12 d . Physiological evaluation of TR 05031 for salt tolerance

Genotypes	Proline (µg g^{-1})	Nitrate Reductase (µg NO_2 g^{-1} h^{-1})	Soluble protein (mg g^{-1})	Chlorophyll Stability Index (%)	Catalase (µg H_2O_2 min^{-1} g^{-1})	Chlorophyll Meter value
TR05031	323	35.0	24.2	76.6	68.5	40.18
TRY3	274	22.3	23.5	74.5	64.52	36.66
IW.Ponni	224	17.5	19.0	70.2	70.12	32.21

Table 12 e. Na/ K ratio of shoot and root tissues for TR05031

Genotypes	Root			Shoot		
	Na µg/g	K µg/g	Na/K	Na µg/g	K µg/g	Na/ K
TR05031	2.28	5.40	0.42	2.34	24	0.09
TRY 3	5.33	7.44	0.72	6.15	19.45	0.32
IWP	7.08	7.51	0.94	5.57	16.09	0.35

a decrease in NR activity under *in vitro* and *in vivo* conditions, whereas tolerant CSR 36 cultivar showed an increase in NR activity (Rohilla and Yadav, 2019).

Higher catalase activity (68.5 μg H_2O_2 min^{-1} g^{-1}) in TR05031 helps in preventing chlorophyll degradation and recorded more chlorophyll value (**Table 12 d**).

The Na^+ and K^+ content were measured in root and shoot tissues. It was observed that the potassium accumulation in shoot of the culture TR05031 was higher than TRY 3 which leads to partial closure of stomata, thus maintaining the optimal water status (**Table 12 e**).Under salinity Na^+ content was increased due to ion antagonism, altering nutrient uptake and nutrient imbalance. In rice, many researchers found that Na^+- K^+ selectivity of plant root plasma membrane determines the reduced entry of Na^+ and increased uptake of K^+ and low salt transport to expanding leaves is an important mechanism in salinity tolerance. Sodium ion accumulation in rice shoots increased under salinity and that increasing rate was based on transport of salt ions from root to shoot. Difference in the plasma membrane permeability determines the amount of K^+ uptake and Na^+ efflux which determines the level of tolerance and susceptible of rice genotypes under salinity. Higher K^+concentration is essential for plant survival under saline conditions.

Scanning Electron Microscope (SEM) with energy dispersive X-ray spectroscopy (EDAX) was used to evaluate the texture, morphology and elemental composition of fresh fly ash, ash from dumpsite and sediment (Jeyageetha and Kumar, 2016).The elemental composition of green synthesized nanoparticles in *Costus pictus* leaves was determined using EDAX (Ravendran *et al.,* 2021). Hithertoo, EDAX under SEM confirmed that, there was a lesser transport of sodium ions and higher transport of potassium ions from root to shoot in this culture, TR05031 (**Fig. 1&2**). Salt tolerant plants maintain a low cytosolic Na+ / K+ ratio through some strategies viz., extrusion of excess Na+ through roots and compartmentalization in different parts, which in turn decreases Na+ concentration in the cytosol. This osmotic adjustment aids in overcoming adverse salt effects, thus producing a considerable yield (Chakraborty *et al*., 2018).

TR05031 had maximum breadth of 16.5 μm over TRY 3 (14.3 μm) due to presence of matured tracheids and vessels in xylem for good conductivity of water (**Fig. 3**).TR05031 maintain more tracheids /unit leaf area and accumulate salts to the outer epidermal layer through specialized trichomes, providing resistance to salinity (**Fig. 4**).

Market value of rice is primarily determined by its physical qualities. Grain physical properties showed that hulling, milling and head rice recovery of the culture TR 05031is superior and preferred in the market. The rice culture TR05031 has medium slender grain type with good milling (68.1%) and head rice recovery (57.2%) (**Table 13 a**).As per the classification proposed by Bhattacharya *et al.* (1980) based on grain dimension (shape and L/B ratio) and also Houston (1972), rice grain up to the length of 5.5 mm are considered as small rice, between 5.51 mm to 6.6 mm as medium grain and between 6.61 mm to 7.5 mm as long grain rice. Thus the culture TR 05031, which registered a mean grain length of 5.8 mm and L/B ratio of 2.7, is categorized as medium slender grain type.

The culture TR 05031 was evaluated for its cooing quality in terms of kernel length (KLAC) and breadth (KBAC) after cooking, length and breadth elongation ratio and volume expansion. It was observed that the culture possesses favourable KLAC (10 mm) and KBAC (2.8mm) (**Table 13 b**). Water uptake influences the elongation of grain and increase of rice volume upon cooking. The quantity of cooked food is determined by the volume expansion ratio which is relatively high in TR 05031 and highly preferred by stakeholders (**Table 13 b & c**).

Alkali digestion is one of the important indicators of the eating, cooking and processing quality of rice starch (Nishi *et al*., 2001). Examination of the grains of TR 05031 for gel consistency, alkali spreading value, gelatinization temperature and amylose content against the check varieties revealed favourable results. Gel consistency is a good index of cooked rice texture especially among the rice of high amylose content. Rice differs in gel consistency from soft to hard. Gel consistency measures the tendency of cooked rice starch to harden after cooling, varieties with soft gels have higher degree of tenderness when cooked. Rice with soft gel consistency cook tender and remain soft even upon cooling. Rice with soft gel consistency is preferred by most consumers (Juliano, 1979). Analysis of the cooking qualities showed that the culture is found to have soft gel consistency.

Amylose content is an important feature for determining rice cooking and eating qualities (Juliano *et al*., 1993). Higher amylose content (> 25.0%) gives non sticky soft or hard cooked rice. Rice varieties having 20-25% amylose content gives soft and flaky cooked rice (**Table 13 d**). It is also an indicator of volume expansion and water absorption during cooking. Varieties with desirable cooking quality traits like high linear elongation ratio, volume expansion, intermediate amylose content, gelatinization temperature and soft gel consistency would be highly relished by the consumers (Robin *et al*., 2019).

As per the classification proposed by Prathepha *et al.* (2005), TR 05031 was observed to have soft gel consistency, intermediate alkali spreading value, intermediate gelatinization temperature and intermediate amylose content (**Table 13d**), which could bolster

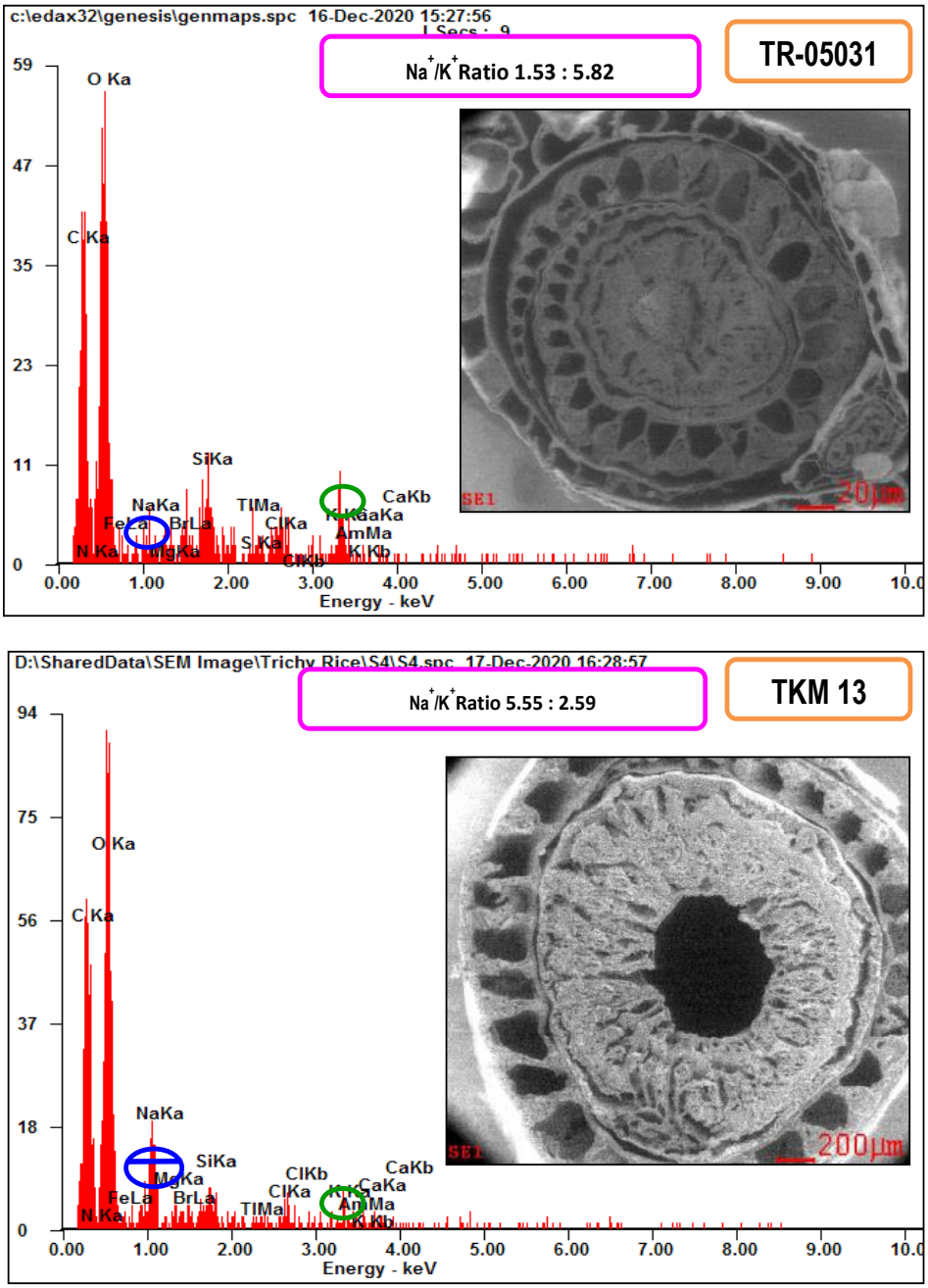

Fig. 1. Effect of salinity on shoot Na^+/K^+ ratio in rice

Table 13 a. Physical quality characteristics

Variety	Hulling (%)	Milling yield (%)	Head rice recovery (%)	Kernel length (mm)	Kernel breadth (mm)	L/B ratio	*Grain type
TR 05031	77.2	68.1	57.2	5.8	2.1	2.7	MS
TRY 3	74.7	64.2	44	5.8	2.4	2.4	MB
ADT 39	59.1	48.9	46.7	5.2	2.0	2.6	MS
BPT 5204	70.2	65.6	57.0	5.4	1.8	3.0	MS

*MS - Medium slender, MB- Medium bold

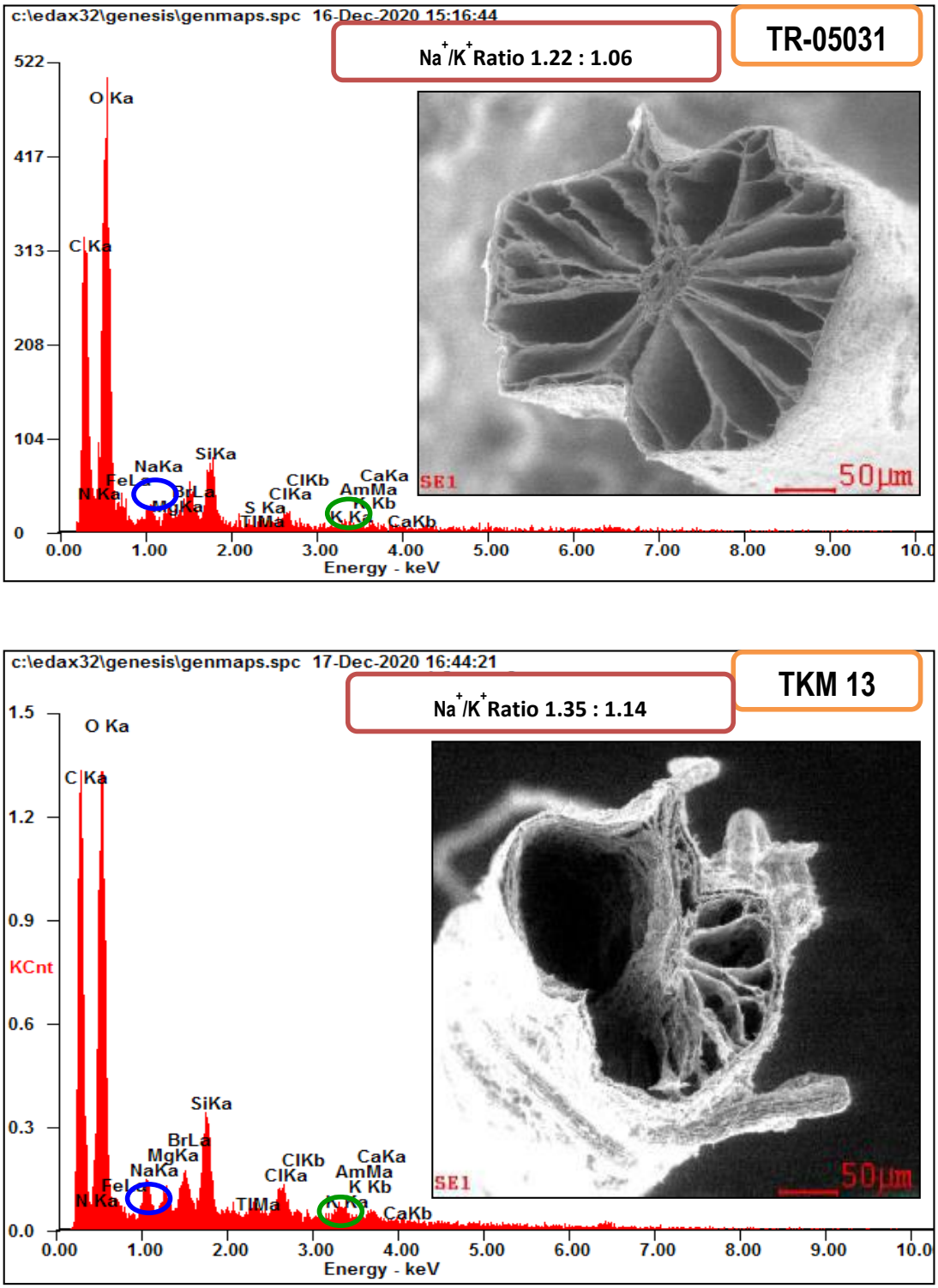

Fig. 2. Effect of salinity on root Na^+/K^+ ratio in rice

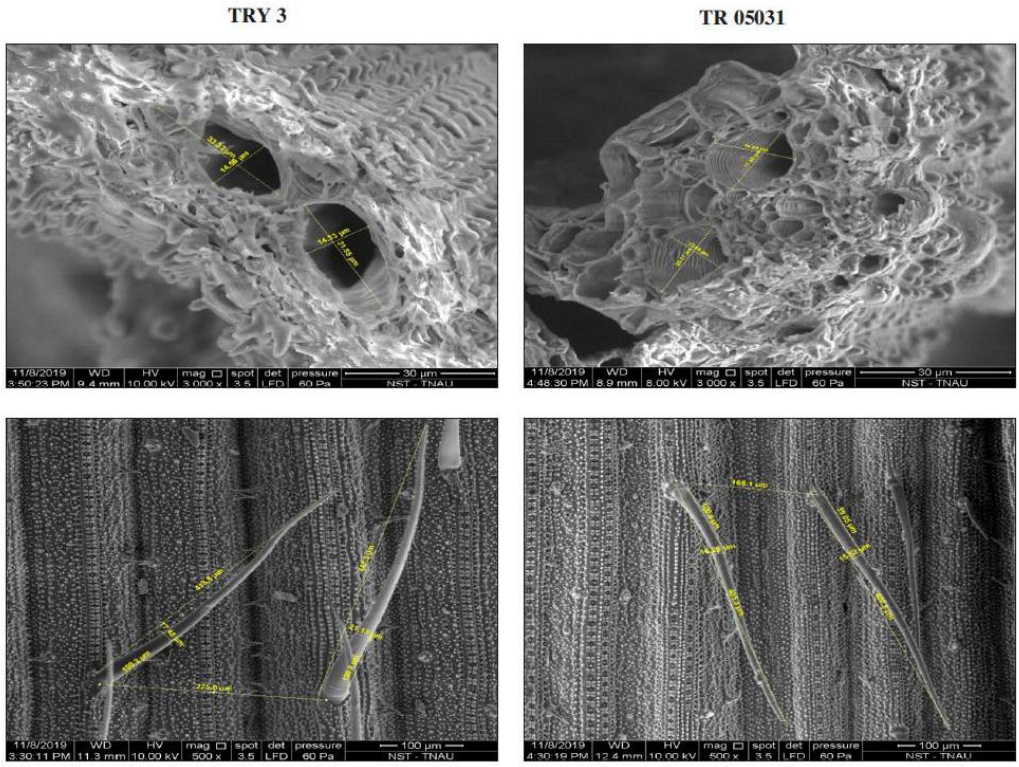

Fig. 3. Leaf Anatomical Characters TR 05031 & TRY 3

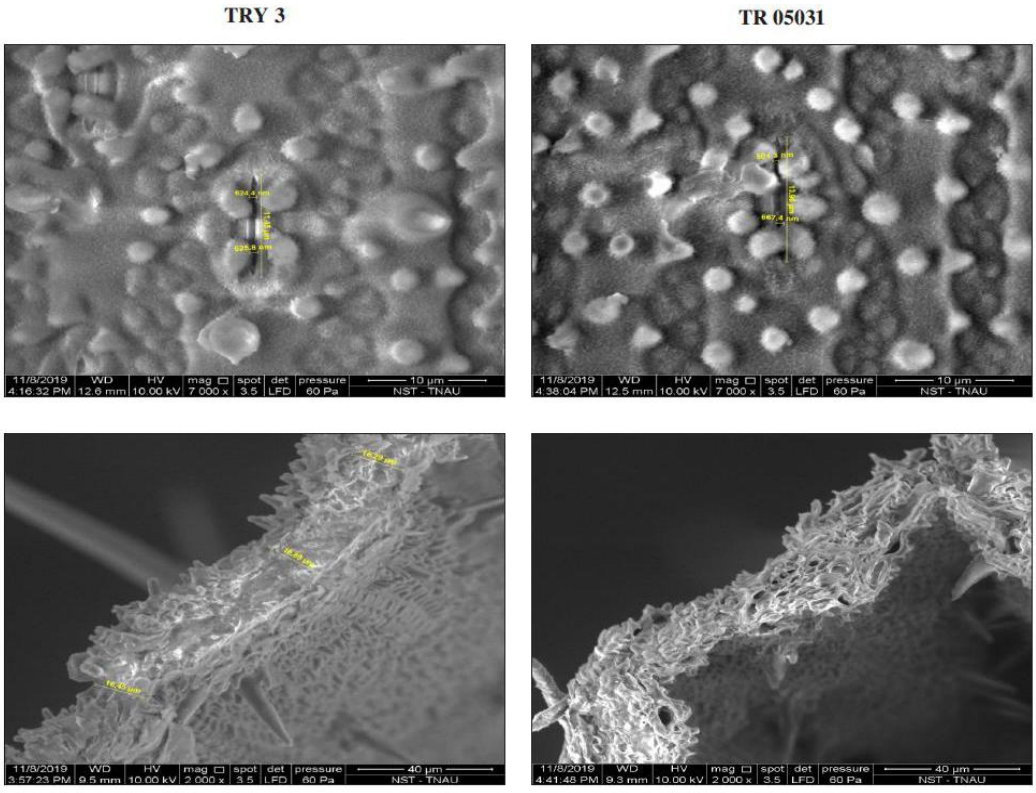

Fig. 4. Leaf Anatomical Characters TR 05031 & TRY 3

Table 13 b. Cooking quality characteristics

Parameters	TR 05031	TRY 3	ADT 39	BPT 5204
Kernel length after cooking (mm)	10	11.2	10.0	10.6
Kernel breadth after cooking (mm)	2.8	3.2	2.9	2.7
Linear elongation ratio	1.72	1.93	1.92	1.96
Breadth wise expansion ratio	1.33	1.33	1.45	1.50
Volume expansion (ml)	4.5	4.2	4.2	3.9

Table 13 c. Cooking quality characteristics for milled rice

S.No.	Traits	TR 05031		TRY 3	
		Milled rice (Raw)	Cooked rice	Milled rice (Raw)	Cooked rice
1	Weight of rice (g)	5	27	5	27
2	Water uptake (g)	-	46	-	46
3	Gruel loss (g)	-	2	-	2
4	Volume of raw rice (ml)	4.6	25	5	27
5	Expansion ratio	-	5.4	-	5.4
6	Length expansion	-	1.68	-	1.05
7	Breadth expansion	-	1.45	-	0.35

Table 13 d. Biochemical and nutritional characteristics

Parameters	TR 05031	TRY 3	BPT 5204	ADT 39
Gel consistency	70 (Soft)	85 (Soft)	100 (Soft)	126 (Soft)
Alkali spreading value	2.0	3.0	3.0	3.0
Gelatinization temperature	Intermediate	Intermediate	Intermediate	Intermediate
Amylose content	Intermediate (20.1)	Intermediate (21.7)	Intermedaite (21.7)	Intermediate (19.7)

Table 13 e. Organoleptic evaluation of cooked rice

Characteristics	TR 05031	TRY 3
Texture	9 (soft)	8 (firm)
Flavour	9 (highly acceptable)	7.5
Appearance	8 (Creamy white)	7 (white)
Tenderness on touching	8	7
Tenderness on chewing	8	7
Taste	9	7
Elongation	8	7
Overall acceptability	8.5	7

Maximum score 10

its consumer preference. The culture also good organoleptic traits (**Table 13 e**). The distinguishing morphological characters of TRY 4 has been furnished (**Table 14**) The variety TRY 4 is notified by the Central Seed Sub Committee, New Delhi (Notification order: F.No./ 3-81/2021-SD.IV) of Ministry of Agriculture and Farmers Welfare , New Delhi, the 24th December, 2021.

Irrigation water quality worsens day by day coupled with an increase in area of salinity. In Tamil Nadu state, delayed North East monsoon warrants late *samba*/ *thaladi* rice crop to over exploit the ground water making cultivable soils saline/sodic. Occurrences of Insufficient rainfall during the preceding *kuruvai* also increase the soil salinity due to the continuous use of ground water. Arice variety for salt affected situations with mid early

Table 14. Distinguishing morphological characters of TRY 4

S.No.	Characteristics	TRY 4
1	Coleoptile: colour	Green
2	Basal leaf: sheath colour	Green
3	Leaf: intensity of green colour	Medium
4	Leaf : anthocyanin colouration	Absent
5	Leaf: distribution of anthocyanin Colouration	Not applicable
6	Leaf sheath: anthocyanin colouration	Absent
7	Leaf sheath: intensity of anthocyanin colouration	Not applicable
8	Leaf:pubescence of blade surface	Glabrous
9	Leaf: auricles	Present
10	Leaf: anthocyanin colouration of auricles	Absent
11	Leaf: collar	Present
12	Leaf: anthocyanin colouration of collar	Absent
13	Leaf: ligule	Present
14	Leaf: shape of ligule	Split
15	Leaf: colour of ligule	White
16.	Leaf: length of blade (cm)	Long (>45cm)
17.	Leaf: width of blade (cm)	Medium (1-2cm)
18.	Culm: attitude (for floating rice only)	Not applicable
19.	Culm: attitude	Erect
20.	Time of heading (50% of plants with panicles) (days)	Medium (91-110)
21.	Flag leaf: attitude of blade (early observation)	Erect
22	Spikelet:density of pubescence of lemma	
23.	Male sterility	Absent
24.	Lemma: anthocyanin colouration of keel	Absent
25.	Lemma: anthocyanin colouration of area below apex	Absent
26	Lemma: anthocyanincolouration of (cm) apex	Absent
27.	Spikelet: colour of stigma	White
28.	Stem: Thickness (mm)	Medium (0.4-0.55cm)
29.	Stem: length (excluding panicle; excluding floating rice) (cm)	Medium (111-130cm)
30.	Stem: Anthocyanin colouration of nodes	Absent
31.	Stem: intensity of anthocyanin colouration of nodes	Not applicable
32.	Stem: anthocyanin colouration of internodes	Not applicable
33.	Panicle: length of main axis (cm)	Long (22-26)
34.	Flag leaf: attitude of blade (late observation)	Erect
35.	Panicle: curvature of main axis	Semi-straight
36.	Panicle:number per plant	Medium (11-20)
37.	Spikelet:colour of tip of lemma	White
38.	Lemma and Palea: colour	Brown
39.	Panicle: awns	Absent
40.	Panicle:colour of awns (late observation)	Not applicable
41.	Panicle: length of longest awn	Not applicable
42.	Panicle: distribution of awns	Not applicable
43.	Panicle : presence of secondary branching	Present
44.	Panicle: secondary branching	Strong
45.	Panicle: attitude of branches	Semi-erect
46.	Panicle: exertion	Mostly exerted

Table 14. Continued..

S.No.	Characteristics	TRY 4
47.	Time maturity (days)	Medium (121-140)
48.	Leaf: Senescence	Medium
49.	Sterile lemma: colour	Straw
50.	Grain weight of 1000 fully developed grains	16 g Low (15-20g)
51.	Grain length (mm)	7.5 Medium (8.6-10.5)
52.	Grain width(mm)	2.6 Medium (2.6-3.0)
53.	Grain : phenol reaction of lemma	
54.	Decorticated grain : length (mm)	5.8
55.	Decorticated grain : width (mm)	2.1
56.	Decorticated grain : shape (in lateral view)	Medium slender
57.	Decorticated grain : colour	White
58.	Endosperm : present of amylase	--
59.	Endosperm content of amylase	--
60.	Varieties with endosperm of amylase absent only Polished grain : expression of white core	--
61.	Gelatinization temperature through alkali spreading value	--
62.	Decorticated grain : aroma	Absent
63.	Ligule length (cm)	2.5
64.	Flag Leaf Length (cm)	45
65.	Flag leaf width(cm)	1.2
	Other related traits	
1	Early plant vigour	Good
2	Septum	Cream
3	Days to 50% flowering	95-100 days
4	Stigma color	White
5	Apiculus color	Green
6	Filled grains/panicle	~215-226 Nos. (in primary tillers)
7	Average single plant yield	45-60g
8	Panicle type	Compact
9	Threshability	Easy
10	Milled Rice colour	White
11	Abdominal white	Absent

duration is warranted in these situations. As the existing saline resistant varieties in the state are bold and farmers need a fine grain variety for their daily consumption and a remunerative market value. To cater these needs, Tamil Nadu Agricultural University released a rice variety, TRY 4 during the year 2021 from the Department of Plant Breeding and Genetics, ADAC&I, Trichy, which is a boon to farmers of salt affected soils of Tamil Nadu.

REFERENCES

Bhattacharya, K. R., Sowbhagya, C. M. and Indhudhara Swamy, Y. M. 1980. Quality of Indian rice. *Journal of Food Science. and Technology,* **17**: 189–193

Chakraborty, K., Basak, N., Bhaduri, D., Ray, S., Vijayan, J., Chattopadhyay, K. and Sarkar, R. K. 2018. Ionic basis of salt tolerance in plants: nutrient homeostasis and oxidative stress tolerance. *Plant nutrients and abiotic stress tolerance*, 325-362. [Cross Ref]

Houston, D.F. Rice Chemistry and Technology. 1972. The American Association of Cereal Chemistry. St. Paul, MN, USA.

Jeyageetha .J.C. and Kumar, S.P. 2016. Study of SEM/ EDXS and FTIR for Fly Ash to Determine the Chemical Changes of Ash in Marine Environment. *International Journal of Science and Research,* **5** (7): 1688-1693

Juliano, B.O. The chemical basis of rice grain quality. 1979. In Proceedings of the, Workshop on Chemical Aspects of Rice Grain Quality, 69-90.

Juliano, B. O., Perez, C. M. and Perez, F. C. 1993. Screening For stable high head rice yields in rough rice. *Cereal Chem*, **70**(6): 650-655.

Nishi, A., Nakamura, Y., Tanaka, N. and Satoh, H. 2001. Biochemical and genetic analysis of the effects of amylose-extender mutation in rice endosperm. *Plant Physiology* **127**: 459-472. [Cross Ref]

Ravendran, N.C, Sivashankari, L. and Helen Rani. R. 2021. Plant-mediated synthesis of zinc oxide nanoparticles using *Costus pictus* D. leaf extract and its physio-chemical properties. *Journal of Pharmacogn Phytochem,* **10**(6): 274-278. [Cross Ref]

Robin,S., Pushpam, R. Rajeswari, S., Amudha, K., Jeyaprakash, P., Manonmani, S., Raveendran, M., Rabindran, R., Ramanathan, A., Suresh, S., Soundararajan, R.P., Radhamani, S., Ravichandran, V. and Ganesamurthy, K. 2019. CO 52 (IET 25487): A highly remunerative medium duration fine grain rice variety. *Electronic Journal of Plant Breeding*, **10** (3): 1148 – 1160. [Cross Ref]

Rohilla, P. and Yadav, J.P. 2019. Acute salt stress differentially modulates nitrate reductase expression in contrasting salt responsive rice cultivars. *Protoplasma*. **256**(5):1267-1278. [Cross Ref]

Prathepha, P., Daipolmak, V., Samappito, S. and Baimai, V. 2005. An assessment of alkali degradation waxy protein and their relation to amylose content in Thai rice cultivars. *Science Asia,* **31**: 69-75. [Cross Ref]

Soundararajan, R.P., Kadirvel, P., Gunathilagaraj, K. and Maheswaran, M. 2004. Mapping of quantitative trait loci associated with resistance to brown planthopper in rice by means of a double haploid population. *Crop Science*, **44**: 2214-2220. [Cross Ref]

Zhou, Y., Yang, P., Cui, F., Zhang, F., Luo, X. and Xie, J. 2016. Transcriptome analysis of salt stress responsiveness in the seedlings of Dongxiang wild rice (*Oryza rufipogon* Griff.). *PLoS ONE*., **11**:e0146242. [Cross Ref]