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Research Article

ATL 1 – A high yielding, non lodging, drought tolerant and nutritionally superior tenai variety

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Abstract
A high yielding drought tolerant fertilizer responsive non lodging *tenai* variety ATL 1 was developed at Centre for Excellence in Millets, TNAU, Athiyandhal. It is a derivative of a cross between PS 4 x Ise 198. Under rainfed condition, this culture has recorded an average grain yield of 2117 kg/ha and straw yield of 2785 kg/ha, which was 9.6 and 14.8 per cent increase in terms of grain and straw yield, respectively over the check variety, CO (Te) 7. It is a short duration culture and matures in 80-85 days. This culture is characterized by a strong and sturdy culm with long and compact panicles. The plant has 5-7 productive tillers and non-shattering grains. It is endowed with special attributes like easy threshability, synchronized maturity, non-lodging growth habit and is drought tolerant. The grains are bold and attractive brownish yellow in colour. The grains are nutritious with preferred grain qualities for cooking and value addition. It was also observed to possess tolerance to blast and rust diseases under field and control conditions. Considering the above features, the variety ATL 1 was released for cultivation in the districts of Dharmapuri, Tiruvannamalai, Vellore, Salem, Namakkal, Villupuram, Virudhunagar and Krishnagiri under rainfed system.

Key words
Tenai, ATL 1, drought tolerant variety

INTRODUCTION

India is a predominantly an agrarian country. As on March, 2020, it has been estimated that about 58 percentage of population is dependent on agriculture (https://www.ibef.org/industry/agriculture-india.aspx) for their livelihood and it contributes greatly to GDP of the country. Indian agriculture is principally rainfed with about of 86 M.ha under rainfed agriculture (Cherukumalli Srinivasa Rao *et al*., 2015). It is estimated that about 90 per cent of the rainfed area in India is occupied by small millets (Cherukumalli Srinivasa Rao *et al*., 2015). These crops are resilient to climatic vagaries and best suited for rainfed agriculture owing to their shorter duration, C4 mode of photosynthesis and capacity to yield even in poor soil under low rainfall and poor management conditions (Himasree *et al*., 2017). Small millet grains are low in their glycemic index and are endowed with several health benefits like dietary fibre, protein and minerals, because of which they are called “Miracle grains/ *Adbhut Anaj* and nutria-cereals” (Anbukkani *et al*., 2017). They play a major role in fulfilling the nutritional security of farmers of dry land and hill agriculture and also meet the fodder requirement of their livestock.

Among the small millets, *Tenai* (*Seteria italica*) has been an important crop since pre historic periods in China and India. Its grains have been discovered in Neolithic relics (circa 8,000 years ago) in different places of China, along the Yellow river and the Yangtze river (Li and Wu 1996; Nasu *et al.,* 2007) and in Europe (Naciri and Belliard 1987). In Tamil Nadu, it is widely cultivated as a rainfed crop, in the hilly regions of Salem, Namakkal, Erode, Tiruvannamalai, Tiruppatur, Dindigul and Madurai districts. Though majority of farmers cultivate land races like *karunthenai*, *sadaithenai* and *mosuthenai* , the improved

variety CO (Te) 7 is also being cultivated in a sizable area. It has been a long felt need of the tenai farmers of the state to have a variety which is input responsive, non lodging, drought tolerant and has long and compact non shattering panicle with bold grains. To fulfil the above requirements research work aimed at developing a non lodging, fertiliser responsive and high yielding tenai variety was initiated and a new variety ATL 1 tenai was released in the year 2020 for cultivation in hilly and tribal areas in Dharmapuri, Tiruvannamalai, Vellore, Salem, Namakkal, Villupuram, Virudhunagar and Krishnagiri districts of Tamil Nadu.

MATERIALS AND METHODS

In order to develop a high yielding drought tolerant and nutritionally rich *tenai* variety, hybridisation was carried out between PS 4 and Ise 198. Among the different stabilised lines evaluated in station trials during *kharif* 2012, *kharif* 2013, *kharif* 2014 and *Rabi* 2014-15, the culture TNSi 331 was observed to be superior. It was further evaluated under multi location trial (MLT) along with check CO (Te) 7 during 2016 and 2017 in seven locations *viz.,* Aruppukottai, Athiyandal, Bhavanisagar, Coimbatore, Paiyur, Vaigai Dam (2016 only) and Kovilpatti (2017 only). Based on the performance in MLT, the culture was promoted for evaluation in ART along with the commercial check CO (Te) 7 in 142 locations, during 2018 and 2019, spread over 10 districts of Tamil Nadu. The culture was also evaluated in on-farm testing in 68 locations from 2016 to 2019 in Tiruvannamalai and Vellore districts, along with commercial check CO (Te) 7. Simultaneously during the above period, the culture was also evaluated with CO (Te) 7 in large scale demonstration plots at CEM, Athiyandal. Apart from yield, the culture was also evaluated for its disease tolerance capacity and nutritional and cooking qualities during 2019.

RESULT AND DISCUSSION

The performance of *tenai* pre-release culture TNSi 331 in different trials is presented in **Table 1**. In station trials conducted during the period 2012 to 2015, it was found to record an average grain yield of 2813 kg / ha, which was 22.77 per cent increase over the check CO (Te) 7 (2292 kg/ha) (**Table 2**). It was also observed to record straw yield of 4530 kg/ha, while the check yielded 3945 kg/ha. A total of 12 MLTs were conducted to evaluate the performance of the pre release culture. It was observed to record 28.41 per cent increased grain yield as compared to the check in MLTs (**Table 3**). In ARTs conducted by Department of Agriculture in 74 locations, the pre-release culture was observed to record an average grain yield of 1915 kg per ha, while the check recorded 1801 kg/ ha. In ARTs conducted by KVKs during 2018-2019 in 68 locations, TNSi 331 was observed to record 8.43 per cent increased yield (2038 kg/ha) as compared to the check (1880 kg/ha) (**Table 4**). Similar superior performance of the pre release culture was also noticed in OFTs

Table 1. Overall performance of *Tenai* culture TNSi 331

Name of the trials	Number of trials	Grain yield (kg/ha)		% increase over CO (Te) 7	Straw yield (kg/ha)		% increase over CO (Te) 7
		TNSi 331	CO (Te) 7		TNSi 331	CO (Te) 7	
Station trials (2012-2015)	4	2813	2292	22.77	4530	3945	14.82
MLT (2016 –2017)	12	2192	1707	28.41	3079	2142	43.74
ART (2018-2019)	74	1915	1801	6.33	2580	2358	9.39
ART - KVK (2018 -2019)	68	2038	1880	8.43	2420	2091	15.71
On Farm Trials (2016-2019)	68	2271	2084	8.96	3056	2688	13.72
Large scale demonstrations (2016-2019)	7	3009	2523	19.28	4109	3372	21.85
Mean (233 trials)		**2117**	**1932**	**9.60**	**2785**	**2426**	**14.83**

Table 2. Performance of *Tenai* culture TNSi 331 in station trials (2012-2015)

Year	Grain Yield (kg/ha)		Straw Yield (kg/ha)	
	TNSi 331	CO (Te) 7	TNSi 331	CO (Te) 7
Kharif, 2012	2788	2316	4010	3884
Kharif, 2013	2804	2417	4320	3904
Kharif, 2014	2745	2323	4650	4015
Rabi, 2014-15	2916	2110	5140	3978
Mean (4 Trials)	2813	2292	4530	3945
% increase over	-	22.77	-	14.82

Table 3. Performance of TNSi 331 in MLTs during 2016 and 2017

S.No.	Location	Year	Grain Yield (kg/ha)		Straw Yield (kg/ha)	
			TNSi 331	CO (Te) 7	TNSi 331	CO (Te) 7
1.	Aruppukottai	2016	1937	1948	3124	2338
		2017	2871	1100	3876	1408
2.	Athiyandal	2016	2078	1957	3213	2427
		2017	2803	2371	3728	3059
3.	Bhavanisagar	2016	1852	1185	2463	1541
		2017	3889	2222	5256	2844
4.	Coimbatore	2016	2812	2965	4499	3855
		2017	2222	2552	2977	3114
5.	Paiyur	2016	1807	1333	2530	1762
		2017	1084	963	1388	1156
6.	Vaigai Dam	2016	1100	1080	1485	1210
		2017	-	-	-	-
7	Kovilpatti	2016	-	-	-	-
		2017	1849	797	2404	984
Mean (12 Trials)			2192	1707	3079	2142
% increase over			-	28.41	-	43.74

Table 4. Performance of TNSi 331 in ARTs during 2018 and 2019

Districts	Number of Locations	Grain yield (k/ha)		Straw yield(kg/ha)	
		TNSi 331	CO (Te)7	TNSi 331	CO (Te)7
Dharmapuri	13	1635	1510	2250	1936
Tiruvannamalai	16	2142	1996	2898	2549
Vellore	16	2177	2040	2933	2611
Krishnagiri	16	2210	2068	2973	2638
Villupuram	16	2066	1925	2982	2551
Namakkal	15	2124	2019	2820	2617
Erode	15	1998	1881	2741	2513
Coimbatore	8	2037	1898	2725	2456
Virudhunagar	13	1873	1723	2498	2194
Salem	12	1831	1688	2680	2438
Average	142 (Total No. of trial)	2015	1877	2731**	2435**
Per cent increase			7.32		12.14**

**Straw yield calculated for 133 trials.

Table 5. Performance of TNSi 331 in OFTs during 2016 to 2019

S. No	Districts	Number of Trials	Grain Yield (kg/ha)		Straw Yield (kg/ha)	
			TNSi 331	CO (Te) 7	TNSi 331	CO (Te) 7
1	Tiruvannamalai	40	2273	2083	3063	2675
% increase over				9.14		14.49
2	Vellore	28	2267	2086	3047	2706
% increase over				8.70		12.62
Mean (68 Trials)			2271	2084	3056	2688
% increase over				8.96		13.72

Table 6. Performance of TNSi 331 in large scale demonstration at centre of excellence in millets, Athiyandal.

S. No	Season	Grain Yield (kg/ha)		Straw Yield (kg/ha)	
		TNSi 331	CO (Te) 7	TNSi 331	CO (Te) 7
1	*Kharif* 16	2768	2344	3784	3063
2	*Rabi* 16 - 17	2996	2490	4167	3187
3	*Kharif* 17	3031	2623	4198	3876
4	*Rabi* 17-18	3219	2751	4379	3497
5	*Kharif* 18	2857	2443	3849	3127
6	*Rabi* 18-19	2954	2358	4014	3214
7	*Kharif* 19	3238	2649	4373	3642
Mean (7 Trials)		3009	2523	4109	3372
% increase over			19.28		21.85

Table 7. Reaction of *Tenai* culture TNSi 331 to diseases

S. No	Entry	Blast (Grade)		Rust (Grade)		Brown Spot (Grade)	
		Field	Glass house	Field	Glass house	Field	Glass house
1	TNSi 331	0.67	1.00	1.00	1.00	1.00	0.67
2	CO (Te) 7	1.67	2.33	1.00	1.67	1.00	1.00
3	SiA 3282 (R)	0.69	1.00	1.00	0.67	1.00	0.67
4	SiA 3367 (S)	4.67	6.33	3.67	6.00	1.67	2.00

Table 8. Nutritional and cooking quality of *Tenai* TNSi 331

S. No.	Particulars	TNSi 331	CO (Te) 7
	Nutritional Quality characters		
1.	Crude protein (%)	13.88	13.62
2.	Crude Fat (%)	4.7	4.0
3.	Crude fibre (%)	36.3	34.0
4.	Ca (%)	0.34	0.35
5.	β-carotene (mg/g)	0.172	0.157
	Sensory evaluation score (5 score)		
1.	Colour & appearance	4.33	3
2.	Flavour	4.67	3
3.	Texture	5.00	3
4.	Taste	4.67	3
5.	Overall acceptability	4.33	3
	Flouring capacity		
1.	Initial weight (g)	500	500
2.	Final weight (g)	478	460
3.	Residues weight (g)	22	40
	Cooking qualities		
1.	Before cooking weight (g)	50	50
2.	After cooking weight (g)	177	170
3.	Before cooking volume (ml)	66	65
4.	After cooking volume (ml)	225	210

conducted in 68 locations during 2016 to 2019 (**Table 5**). In large scale demonstrations, the test entry recorded an average yield of 3009 kg/ha as compared to the check which registered 2523 kg/ha. The culture TNSi 331 was observed to record better straw yield recording 4109 kg / ha, which was 21.85 per cent higher than check (3372 kg/ha) (**Table 6**). Overall, the culture TNSi 331 was observed to record an average grain yield of 2117 kg / ha and straw yield of2785 kg/ha which was 9.6 per cent and 14.83 per cent higher as compared to check CO (Te) 7 (1932 kg and 2426 kg/ha, respectively).

Among the different diseases that play a detrimental role in crop production and productivity of *tenai*, Blast, Rust and Brown Spot are very important. Reaction to the pre release culture TNSi 331 to these diseases under field and glass house condition revealed that incidence of the above diseases was lesser in TNSi 331 (Blast grade – 0.67; Rust grade – 1.0 and brown spot grade -1.00) as compared to commercial check, susceptible and resistant checks (**Table 7**).

Milled rice of the culture TNSi 331 was observed to possess better nutritional properties (Crude protein – 13.88 %, Crude fibre – 36.3 % and β-carotene – 0.172 mg/g) as compared to the check. It also had better colour, appearance and other sensory features *viz.,* flavour, texture, taste as compared to CO (Te)7. It was also observed to possess better flouring capacity and cooking qualities as compared to CO(Te)7 (**Tables 8 and 9**).

Being a rainfed crop, *tenai* straw is used as fodder for cattle by farmers of rainfed agriculture. Hence, the fodder quality of the test entry was studied as compared to the check. It was observed that TNSi 331 recorded a better organic matter (95.4 %), protein (8.8%), crude fibre (33.6 %), potassium (2.8 %), phosphorus (0.34%) and mineral matter (3.88 %) content as compared to CO (Te)7 (**Table 10**).

The proposed culture is characterised by green plants and leaves without pigmentation. Leaves are characterised by white mid rib. The inflorescence in oblong in shape and is

Table 9. Grain quality characteristics of *Tenai* culture TNSi 331

S. No.	Characteristics	TNSi 331	CO (Te) 7
a)	**Nutritional Quality**		
1.	Protein (%)	12.3	12.0
2.	Carbohydrate (%)	61.2	62.6
3.	Fat (%)	4.6	4.7
4.	Crude fibre (%g)	8.2	8.4
5.	Mineral matter (%)	3.5	3.3
6.	Phosphorus (mg/100g)	306	292
7.	Calcium (mg/100g)	34	31
8.	Iron (mg/100g)	5.7	5.3
9.	Bulk density (g/ml)	0.74	0.70
10.	1000 grain weight (g)	3.6	2.9
11.	Threshability (%)	87.2	86.0
12.	Milling (%)	68.1	65.0
b)	**Cooking qualities**		
1.	Water uptake (ml)	955	943
2.	Cooking time (min)	26	24
3.	Initial Volume (ml)	100	100
4.	Cooked volume (ml)	726	705
5	Initial weight (g)	74	70
6.	Cooked weight (g)	758	735
c)	**Sensory evaluation score (1-10)**		
1	Colour & appearance	9.8	9.5
2	Flavour	9.7	9.3
3	Texture	9.9	9.2
4	Taste	**9.8**	9.0

Table 10. Fodder quality characteristics of *Tenai* culture TNSi 331

S.No.	Characteristics**	TNSi 331	CO (Te) 7
1.	Organic matter (%)	95.4	92.8
2.	Crude protein (%)	8.8	8.3
3.	Acid Detergent Insoluble Crude Protein (ADICP)	2.2	2.1
4.	Ether Extract (EE)	0.8	0.8
5.	Neutral Detergent Fibre (NDF)	13.7	14.6
6.	Acid Detergent Fibre (ADF)	5.3	6.9
7.	Crude fibre (%)	33.6	30.0
8.	Potassium (%)	2.8	2.3
9.	Phosphorus (%)	0.34	0.32
10.	Miner matter (%)	3.88	3.71

** (%DM)

Table 11. Descriptors of *Tenai* culture TNSi 331

S. No.	Character	TNSi 331		CO (Te) 7	
		Range	Mean	Range	Mean
1.	Days to 50% flowering (day)	48-53	50	53-58	55
2.	Plant height (cm)	110-120	115	115-130	120
3.	Number of basal tillers	5-8	6	6-9	7
4.	Flag leaf length (cm)	32.0-42.5	37.8	30.5- 40.6	35.9
5.	Flag leaf width (cm)	1.3-2.9	2.4	0.8- 2.4	1.6
6.	Peduncle length (cm)	15.6-26.2	21.3	13.5-21.2	18.5
7.	Ear length (cm)	28.3-32.8	28.5	25.6-33.9	29
8.	Panicle exertion	Full exertion		Full exertion	
9.	Days to maturity (day)	80-85	83	85 - 90	88
10.	Grain yield per plant (g)	12.2-19.5	14.5	10.0-16.0	12.0
11.	Fodder yield per plant (g)	15.9-23.3	19.3	14.2-20.1	15.6
12.	Thousand grain weight (g)	3.1-3.9	3.6	2.8-3.0	3.2
13.	Plant pigmentation at flowering	Green		Green to purple	
14.	Leaf colour	Green		Green to purple	
15.	Blade pubescence	Intermediate		Intermediate	
16.	Sheath pubescence	Glabrous		Glabrous	
17.	Degree of lodging at maturity	Non lodging		Non lodging	
18.	Senescence	Green at maturity		Yellow at maturity	
19.	Midrib colour	White		Green	
20.	Inflorescence lobes	Medium		Short primaries	
21.	Inflorescence bristles	Short		Very short	
22.	Lobe compactness	Compact		Intermediate	
23.	Inflorescence shape	Oblong		Cylindrical	
24.	Inflorescence compactness	Compact		Compact	
25.	Fruit colour	Brownish Yellow		Yellow	
26.	Grain shape	Elliptical		Oval	
27.	Apical sterility in panicle	Absent		Present	

Plate. 1. Field view of ATL -1

characterised by lobes which are medium in length, short bristles and compact lobes. The panicles do not have apical sterility and the grains are elliptical with brownish yellow colour. The plants possess stay green feature and hence plants remain green at senescence. The detailed descriptor is presented in **Table 11 and Plate 1.**

In view of the consistent superior performance of the culture TNSi 331 as compared to the check CO(Te)7 for grain and straw yield, drought tolerance potential and preferable grain quality traits coupled with the nutritional superiority, it was recommended for release as ATL 1 in 37th Crop Scientists Meet – Millets held at TNAU during 2019 and was released by state variety release committee during 2020. This would fulfil the long felt needs of the farmers of dry lands, hilly and tribal areas in Dharmapuri, Tiruvannamalai, Vellore, Salem, Namakkal, Villupuram, Virudhunagar and Krishnagiri districts of Tamil Nadu where *Tenai* is predominantly grown under rainfed condition.

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