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 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, Tiruppur, 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 fulfill 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 |
|--------------------|------------------|--------------------|--------------------------|-------------------|--------------------------|
| 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 | 2516 | 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 |

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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           |
| 1.    | Aruppukottai | 2016 | 1937                | 1948                |
|       |            | 2017 | 2871                | 1100                |
|       |            | 2016 | 2078                | 1957                |
| 2.    | Athiyandal | 2017 | 2803                | 2371                |
| 3.    | Bhavanisagar | 2016 | 1852                | 1185                |
|       |            | 2017 | 3889                | 2222                |
| 4.    | Coimbatore | 2016 | 2812                | 2965                |
|       |            | 2017 | 2222                | 2552                |
| 5.    | Paiyur     | 2016 | 1807                | 1333                |
|       |            | 2017 | 1084                | 963                 |
| 6.    | Vaigai Dam | 2016 | 1100                | 1080                |
|       |            | 2017 | -                   | -                   |
| 7.    | Kovilpatti | 2016 | -                   | -                   |
|       |            | 2017 | 1849                | 797                 |

Mean (12 Trials) 2015

Grain yield 2192
Straw yield 1707

% increase over 3079

% increase over 2142

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               |
| Tiruvannamalai    | 16                  | 2142               | 1996               |
| Vellore           | 16                  | 2177               | 2040               |
| Krishnagiri       | 16                  | 2210               | 2068               |
| Villupuram        | 16                  | 2066               | 1925               |
| Namakkal          | 15                  | 2124               | 2019               |
| Erode             | 15                  | 1998               | 1881               |
| Coimbatore        | 8                   | 2037               | 1898               |
| Virudhunagar      | 13                  | 1873               | 1723               |
| Salem             | 12                  | 1831               | 1688               |
| Average           | 142 (Total No. of trial) | 2015             | 1877               |

Per cent increase 7.32

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               |
|       | % increase over|                  | 9.14               | 14.49              |
| 2     | Vellore        | 28               | 2267               | 2086               |
|       | % increase over|                  | 8.70               | 12.62              |
| Mean (68 Trials) |              | 2271               | 2084               |
|       | % 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  | 1.00        |
| 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 |
|--------|-------------|----------|-----------|
| 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 |

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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 of 2785 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 | 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 |
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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