

Field evaluation of germplasm lines of extra-long staple cotton (*Gossypium barbadense*) for Tobacco Streak Virus (TSV) resistance based on symptoms expression

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Abstract

Background

The necrosis disease caused by *Tobacco streak virus* (TSV) is highly destructive. Conventional management practices for TSV includes cultural methods such as crop rotation, maintaining field sanitation, rouging of infected plants, intercropping with non-host crops of short duration, eliminating weed hosts like *Parthenium* and insecticide application to control vectors. However, the most efficient and convenient approach to combat this devastating disease is to cultivate resistant varieties.

Results

TSV distribution in the germplasm of ELS cotton, *Gossypium barbadense*, appears to be significant. In a consecutive two-season screening at ICAR-Central Institute for Cotton Research (CICR), Regional Station, Coimbatore, total of three hundred *G. barbadense* germplasm lines were evaluated for natural occurrence of TSV. Among them, fourteen germplasm lines were categorized as Resistant (R), twenty-two as Moderately Resistant (MR), one hundred and sixty-eight as Moderately Susceptible (MS), and ninety-four as Susceptible (S) lines.

Conclusion

The identified fourteen resistant germplasm lines of *G. barbadense* can be valuable resources in breeding programs as donor parents to develop TSV-resistant lines. Utilizing these lines in breeding efforts can contribute to the development of resistant varieties against TSV.

Background

Cotton, known as the "King" of fibre crops, is a significant kharif crop. In terms of both botanical variety and fibre quality, the Indian cotton crop stands out as the most diverse globally. According to the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare in New Delhi, the estimated cotton production in India for the period of 2022-23 is 323.11 lakh bales of 170 kg each, grown across 124.69 lakh hectares of land, with a productivity of 441 kg lint per hectare (Anon. 2024). Three species of *Gossypium*, namely *hirsutum*, *arboreum*, and *herbaceum*, are commercially cultivated in India, contributing to the cotton trade and industrial consumption. Globally, the ELS (Extra Long Staple) cotton is primarily contributed by the

G. barbadense species. However, in India, both *G. barbadense* and hybrids between *G. hirsutum* and

G. barbadense are responsible for the production of ELS cotton. The ELS category is particularly sought worldwide for the production of superior ring spun yarns, with a length of 35 mm or more. Due to its notable attributes such as high length, strength, and micronaire, it is favoured for the manufacturing of

high-quality ring-spun yarns. However, unlike the other three cultivated species, *G. barbadense* is highly vulnerable to diseases and pests.

Cotton productivity is hindered by various bacterial, fungal and viral diseases. Among the viral diseases that affect cotton, *Cotton Leaf Curl Virus* (CLCuV) and *Tobacco Streak Virus* (TSV) hold significance. The most devastating one is necrosis disease caused by *Tobacco Streak Virus* (TSV). TSV, which was initially described by Johnson in 1936, belongs to the Ilarvirus genus of the Bromoviridae family. It exhibits quasiisometric particles measuring 27 to 35 nm in size (Fauquet et al., 2005). TSV has a broad range of hosts, infecting over 200 plant species across 30 dicotyledonous and monocotyledonous plant families (Fulton, 1985; EPPO, 2005). TSV has been documented in over 26 countries globally (EPPO, 2005). In India, TSV was first identified in sunflower affected by sunflower necrosis disease (SND) and groundnut affected by peanut stem necrosis disease (PSND) in Andhra Pradesh (Prasada Rao et al., 2000; Reddy et al., 2002). Since its initial discovery, the virus has been found to cause significant damage to groundnut, sunflower and diverse annual crops in in Andhra Pradesh, Karnataka, Maharashtra, and Tamil Nadu (Kumar et al., 2006; Jain et al., 2008). Despite its global prevalence, the virus is not known to trigger destructive epidemics on the scale witnessed in India (Prasada Rao et al., 2000) and more recently in Australia (Report, 2006; Sharman et al., 2008). Common symptoms of TSV include leaf chlorosis, necrosis, streaks on stems and floral parts, leading to stunted growth. TSV can cause premature death in seedlings and often goes unnoticed in weed hosts like parthenium, which show no symptoms. During the SND/TSV epidemics, extensive yield losses primarily resulted from the premature death of plants. In 2005, a TSV outbreak affected around 20,000 hectares of cotton fields in Khammam and Warangal districts of Andhra Pradesh (Kumar and Prasada Rao, unpublished data). These observations emphasize the need for a careful evaluation of cotton disorders associated with TSV. Prasada Rao et al., (2009) described TSV infection in cotton fields, characterized by chlorotic and necrotic lesions on leaves, accompanied by leaf purpling, necrotic buds and drying of young bolls. The incidence of the disease was higher in Bt cultivars compared to non-Bt cultivars. Over the past five years, the necrosis disease caused by TSV has been frequently documented in cotton-growing regions of India. Jagtap et al., (2012) conducted a study on the host range and transmission of TSV, which leads to the development of cotton mosaic disease.

The occurrence, host range and symptom expression of TSV in cotton-growing areas of Tamil Nadu were reported by Rageshwari et al., (2016). The disease was observed in Dharmapuri, Perambalur, and Salem districts in 2010, with an incidence ranging from 12.6–38.8%. This disease has been known to cause a maximum yield loss of 60–65%. Vinodkumar et al., (2017) reported that the surveyed locations in central and southern states of India, Telangana had the highest incidence of TSV of 51.11% in hybrid RCH659. Valarmathi and Dhamayanthi, (2020a) studied the distribution of TSV in the ELS germplasm of *G. barbadense* in Coimbatore over a period of two-year from 2017 to 2019. The percentage of disease incidence varied from 5.81% (DB 3, DB 25) to 26.60% (ICB 71). In recent years, TSV has caused panic among farmers in Kurnool and Nandyal districts of Andhra Pradesh, affecting approximately 10–15% of the cotton crop (Anonymous, 2022a). Survey conducted in cotton-growing districts, namely Guntur,

Krishna and Kurnool, recorded incidences of TSV in different hybrids ranging from 0–30.0% in farmers' fields (Anonymous, 2023).

TSV primarily spreads through pollen, with thrips assisting in its transmission (Thysanoptera: *Thripidae*) and can also be experimentally transmitted through mechanical sap inoculation, grafting and the dodder plant (*Cuscuta campestris*). However, it is not transmitted through contact or soil (Fulton, 1985). The symptoms resulting from TSV infection in cotton plants closely resemble physiological or nutritional disorders and herbicide phytotoxicity, making it challenging to differentiate them. Therefore, the detection of TSV in cotton requires special attention. For TSV diagnosis, confirmatory testing using serological or nucleic acid-based diagnostic assays is essential. Polyclonal antibodies raised against TSV have been employed for virus detection through immunosorbent electron microscopy (ISEM) and enzyme-linked immunosorbent assay (ELISA) (Reddy et al., 2002). Serological assays using double antibody sandwich enzyme-linked immunosorbent assay (DAS-ELISA) have shown the presence of TSV in various parts of the cotton plant, including leaves, squares, stems, roots, petioles, and pollen grains of *G. barbadense* germplasm and advanced generations. Among these, leaf samples exhibited the highest absorbance, followed by petioles and squares in terms of TSV detection (Valarmathi and Dhamayanthi, 2020b).

In India, TSV isolates were found to be serologically related and the antiserum raised against one isolate could be effectively used for detecting other isolates. Detection of TSV was also carried out using the reverse transcription-polymerase chain reaction (RT-PCR) assay (Bhat et al., 2002; Reddy et al., 2002). Molecular confirmation and serological assays using Direct Antigen Coating-ELISA were conducted on the CO 14 cotton variety, as confirmed by Rageshwari et al., (2017). Gawande et al., (2019) for the first time optimized the protocol for rapid diagnosis of infected cotton samples using Reverse Transcription-Loop Mediated Isothermal Amplification (RT-LAMP). The combined role of *Thrips palmi* and *Parthenium* pollen grains in TSV transmission was studied, revealing that thrips facilitate the movement of TSV-infected pollen grains, thereby contributing to the active spread of the virus in cotton (Shanmuga Prema et al., 2020).

The most cost-effective and practical approach to managing TSV is through the cultivation of resistant varieties. However, resistance to TSV has not been identified in cultivated species in India. For example, a study evaluating 150 groundnut cultivars and advanced breeding lines found them to be susceptible to TSV (Kalyani et al., 2005). Similarly, a large number of sunflower germplasm evaluated under field conditions in Andhra Pradesh at the Regional Agricultural Research Station in Nandyal were also found to be susceptible to TSV (Jain et al., 2008). Nevertheless, variations in symptom expression were observed among different genotypes of groundnut and sunflower, indicating that not all cultivars are equally susceptible to TSV. Ahmed et al., (2005) investigated the natural occurrence of TSV in cotton in Pakistan and screened for resistant sources. Screening germplasm to identify resistant sources is an essential step towards addressing the challenges posed by this hazardous virus. Such screening can be utilized in breeding programs to develop TSV-tolerant or resistant cotton varieties. Since the existing

literature suggests the lack of any known resistance sources for TSV in ELS cotton, the present study primarily focuses on field evaluation of *G. barbadense* germplasm to identify resistance against TSV.

Methods

Screening of germplasm of *G. barbadense* against TSV

A total of three hundred germplasm lines of *G. barbadense* were screened for *Tobacco streak virus* (TSV) under natural field conditions for two consecutive cropping seasons, from winter 2018 to 2020, at ICAR-Central Institute for Cotton Research (CICR), Regional Station in Coimbatore.

The germplasm lines were sown in two rows individually, following an augmented design with duplicate rows for maintenance breeding. Planting was done in a row with a width of 90 cm, with ten dibbles and a plant-to-plant spacing of 45 cm. Normal crop production package of practices were followed and appropriate plant protection measures were taken as necessary to safeguard the crop from insect damage. The percentage of TSV was determined by counting the number of infected plants compared to healthy plants within a row of the germplasm at 45 and 90 days after sowing by using the following disease rating scale and mean TSV disease incidence were presented (Table 1).

Table 1
Disease rating scale (0–4) for TSV

Scale	Grade	Symptoms	Per cent disease incidence
0	Immune	Free from the disease	0
1	Resistant	Few upper leaves showing chlorosis /necrosis	0.1 to 5.0%
2	Moderately resistant	Moderate square drying and few branches affected	5.1 to 10.0%
3	Moderately susceptible	Severe burning of squares and more branches affected	10.1 to 20.0%
4	Susceptible	Severe stunting inclusive of above symptoms	> 20.0%

Source: Sheo Raj, 1988; Anon. 2022b. AICCIP, ICAR- Bt Cotton Annual Report for South Zone (2017–2018) pg.33.

Percent disease incidence was calculated using the formula proposed by Wheeler (1969) was used to calculate incidence of TSV.

Per cent Disease incidence (PDI) = $\frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$

The population of thrips in the germplasm was determined by taking the average of three observations during 30,60 and 90 days after sowing. These observations were made on three leaves per plant (top, middle and bottom). A total of ten plants were counted to assess the thrips population in each germplasm lines.

Evaluation of the resistant/susceptible *G. barbadense* lines to TSV/thrips in separate plot

The resistant lines (14) and susceptible lines (94) of *G. barbadense*, which were identified during the two-season natural screening for TSV occurrence from 2018 to 2020, were planted in separate plots. The variety Suvin was included in the experiment as control (Fig. 1). The plot size of the experiment was 0.25 acres with augmented design. Each row in the plot was 4.5 meters long, and ten plants were maintained in each row. The spacing between rows and between individual plants was set at 90x45 cm.

A total of four rows of susceptible lines, along with one row of resistant line were sown in the plot. Additionally, a single row of bhendi (Hybrid Co4), black gram (Co6) and Chilli (Variety Bullet) were planted in one row. Normal package of practices was followed. Parameters such as the percentage of TSV disease incidence and thrips population were recorded using the disease rating scale outlined as in Table 1. Biometric measurements including plant height, number of sympodial branches, number of bolls per plant and boll weight were observed for both the susceptible and resistant lines.

Results

A total of three hundred germplasm lines were subjected to screening for *Tobacco streak virus* (TSV) under natural field conditions for the winter cropping seasons of 2018–2020. Among these lines, fourteen germplasm lines, namely ICB 84, ICB 85, ICB 86, ICB 87, ICB 90, ICB 91, ICB 122, ICB 124, ICB 125, ICB 127, ICB 153, ICB 161, ICB 162, and ICB 163, were categorized as Resistant (R) with a disease grade of 1. Additionally, twenty-four germplasm lines, including ICB 41, ICB 43, ICB 45, ICB 46, ICB 47, ICB 48, ICB 50, ICB 51, ICB 53, ICB 54, ICB 55, ICB 58, ICB 59, ICB 60, ICB 61, ICB 62, ICB 65, ICB 67, ICB 70, ICB 71, ICB 72, ICB 74, ICB 75, and ICB 76 were categorized as Moderately Resistant (MR). The remaining 168 germplasm lines were categorized as Moderately Susceptible (MS), while 94 germplasm lines were categorized as Susceptible (S) (Table 2). In *G. barbadense*, the symptom expression for TSV infection was distinct, characterized by dark purple necrotic spots and drying of squares. The initial symptoms in leaves were distinct with necrotic spots, dark purple in colour at 45 days after sowing and later it spreads to petiole and stem. Other symptoms include necrosis on crown region, terminal and drying of squares. At later stage of the cotton crop due to the abiotic stress like winter period and biotic stress like the viral disease results in the partial withering of the cotton bolls (Fig. 2 &3).

Table 2
Screening of germplasm of *G. barbadense* under natural occurrence of TSV

Scale	Grade	Disease reaction	Germplasm
1	Resistant	R	ICB 84, ICB 85, ICB 86, ICB 87, ICB 90, ICB 91, ICB 122, ICB 124, ICB 125, ICB 127, ICB 153, ICB 161, ICB 162, ICB 163 (14)
2	Moderately Resistant	MR	ICB 41, ICB 43, ICB 45, ICB 46, ICB 47, ICB 48, ICB 50, ICB 51, ICB 53, ICB 54, ICB 55, ICB 58, ICB 59, ICB 60, ICB 61, ICB 62, ICB 65, ICB 67, ICB 70, ICB 71, ICB 72, ICB 74, ICB 75, ICB 76 (24)
3	Moderately Susceptible	MS	ICB 1, ICB 2, ICB 3, ICB4, ICB 6, ICB 11, ICB 13, ICB 16, ICB 18, ICB 23, ICB 24, ICB 26, ICB 27, ICB 28, ICB 30, ICB 34, ICB 36, ICB 37, ICB 38, ICB 39, ICB 40, ICB 77, ICB 78, ICB 79, ICB 81, ICB 82, ICB 92, ICB 94, ICB 96, ICB 97, ICB 99, ICB 100, ICB 104, ICB 106, ICB 108, ICB 109, ICB 110, ICB 114, ICB 119, ICB 121, ICB 128, ICB 129, ICB 130, ICB 133, ICB 134, ICB 36, ICB 137, ICB 138, ICB 140, ICB 141, ICB 142, ICB 143, ICB 145, ICB 146, ICB 165, ICB 171, ICB 172, ICB 173, ICB 174, ICB 175, ICB 176, ICB 177, ICB 178, ICB 180, ICB 181, ICB 182, ICB 183 (168)
4	Susceptible	S	ICB 184, ICB 185, ICB 188, ICB 189, ICB 190, ICB 191, ICB 192, ICB 193, ICB 194, ICB 195, ICB 196, ICB 198, ICB 199, ICB 200, ICB 201, ICB 202, ICB 203, ICB 204, ICB 205, ICB 207, ICB 208, ICB 209, ICB 210, ICB 211, ICB 212, ICB 213, ICB 214, ICB 215, ICB 216, ICB 217, ICB 218, ICB 219, ICB 220, ICB 222, ICB 223, ICB 224, ICB 225, ICB 226, ICB 227, ICB 231, ICB 233, ICB 235, ICB 237, ICB 238, ICB 240, ICB 241, ICB 242, ICB 244, ICB 247, ICB 248, ICB 249, ICB 250, ICB 251, ICB 254, ICB 256, ICB 257, ICB 258, ICB 259, ICB 260, ICB 261, ICB 262, ICB 263, ICB 264, ICB 265, ICB 266, ICB 267, ICB 268, ICB 269, ICB 270, ICB 271, ICB 272, ICB 273, ICB 274, ICB 275, ICB 276, ICB 278, ICB 280, ICB 283, ICB 284, ICB 287, ICB 288, ICB 290, ICB 299, ICB 300, ICB 303, ICB 306, ICB 308, ICB 310, ICB 313, ICB 317, ICB 318, ICB 320, ICB 323, ICB 325 (94)

Resistant and susceptible germplasm lines of *G. barbadense* were evaluated under natural field conditions to assess their reaction to *Tobacco streak virus* (TSV) in a separate plot (Fig. 4).

In order to create disease pressure and thrips population, crops such as bhendi, black gram and chilli were also sown along with Suvin as control. Among the resistant lines, the average disease incidence ranged from 3.2–5.0%. Notably, ICB 162R showed a lower disease incidence of 3.2%, while ICB 86R recorded a disease incidence of 3.6%. In contrast, the susceptible lines exhibited an average disease incidence ranging from 19.2–28.5%, with the control variety Suvin having a disease incidence of 32.5% (Table 3, Fig. 5). The mean thrips population ranged from 2.5 to 11.3 in both the susceptible and resistant lines. Among the resistant lines, ICB 162R had a lower mean thrips population of 4.0, while ICB 86R had a mean thrips population of 6.2. A positive correlation with a correlation coefficient (*r*) value of 0.11 was observed between the mean disease incidence and mean thrips population.

Table 3
Evaluation of resistant/susceptible germplasm lines of *G. barbadense* for TSV disease/ thrips population

S. No	Germplasm	Mean TSV disease incidence (%)	Mean Thrips population (no./3 leaves)
1.	ICB 84 R	5.0	5.3
2.	ICB 85 R	4.5	11.3
3.	ICB 86 R	3.6	6.2
4.	ICB 87 R	5.0	4.8
5.	ICB 90 R	4.9	3.3
6.	ICB 91 R	4.3	6.7
7.	ICB 122 R	4.8	9.3
8.	ICB 124 R	3.5	3.0
9.	ICB 125 R	4.2	3.8
10.	ICB 127 R	4.3	9.2
11.	ICB 153 R	4.5	9.0
12.	ICB161 R	4.2	7.2
13.	ICB 162R	3.2	4.0
14.	ICB 163 R	3.5	4.0
15.	ICB 184	19.2	3.0
16.	ICB 224	19.6	7.8
17.	ICB 212	19.2	8.0
18.	ICB 213	21.3	6.2
19.	ICB 214	21.7	8.3
20.	ICB 215	24.6	7.5
21.	ICB 216	23.3	6.5
22.	ICB 217	24.2	2.5
23.	ICB 218	27.5	2.5
24.	ICB 241	26.9	7.0
25.	ICB 242	25.6	7.7
26.	ICB 244	26.1	7.5

S. No	Germplasm	Mean TSV disease incidence (%)	Mean Thrips population (no./3 leaves)
27.	ICB 247	27.5	6.5
28.	ICB 248	25.5	4.0
29.	ICB 249	21.7	2.8
30.	ICB 250	27.5	4.8
31.	ICB 258	27.5	4.3
32.	ICB 260	28.5	8.3
33.	ICB 263	27.5	9.3
34.	ICB 269	25.8	7.5
35.	ICB 271	27.5	6.0
36.	ICB 273	27.5	7.2
37.	Suin	32.5	12.8
SD		9.7	2.5
S.Em.±		1.6	0.4
CV (%)		0.54	0.39

ICB162R exhibited a mean plant height of 130 cm, with an average number of 19.6 bolls per plant and a boll weight of 3.9. On the other hand, ICB 260 had a mean plant height of 73.6 cm, a reduced number of 5.3 bolls per plant and a boll weight of 2.6. In the case of Suin, the mean plant height was recorded as 74.5 cm, with an average of 5.0 bolls per plant and a boll weight of 3.2. Among the biometric parameters observed, no. of bolls per plant showed a positive correlation with the percentage of TSV disease incidence. Notably, the number of bolls per plant exhibited a significant and positive correlation, with a correlation coefficient (r) value of 0.83. There were no significant differences in other biometric parameters such as plant height and boll weight between the susceptible and resistant germplasm lines (Table 4). However, the number of bolls per plant was higher in the resistant lines compared to the susceptible lines. This can be attributed to the drying of squares observed in susceptible lines during TSV infection, resulting in a reduction in the number of bolls and ultimately leading to decreased yield. *Parthenium* population *in-situ* were not removed as to maintain the TSV inoculum in the field. These plants exhibited necrosis on both the stem and leaves under natural conditions (Fig. 6). These plants also became infected by the virus and served as a source for its spread to healthy plants in the field.

Table 4
Biometric observations in resistant and susceptible lines of *G. barbadense*

S. No	Germplasm	Plant height (cm)	Number of sympodial branches	Number of bolls per plant	Boll weight (g)
1.	ICB 84 R	111.6	28.6	18.3	2.0
2.	ICB 85 R	86.0	24.0	15.6	3.2
3.	ICB 86 R	72.0	22.6	17.6	3.7
4.	ICB 87 R	99.6	24.6	18.0	3.3
5.	ICB 90 R	102.3	23.6	19.0	3.7
6.	ICB 91 R	100.3	26.3	14.3	3.5
7.	ICB 122 R	105.3	26.3	11.0	3.3
8.	ICB 124 R	107.0	22.3	14.6	3.5
9.	ICB 125 R	66.6	18.3	15.0	3.7
10.	ICB 127 R	113.6	30.3	11.3	2.3
11.	ICB 153 R	122.6	26.3	15.0	3.7
12.	ICB161 R	111.0	20.3	10.6	3.5
13.	ICB 162R	130.0	30.6	19.6	3.9
14.	ICB 163 R	89.6	18.6	16.6	3.3
15.	ICB 184	113.6	29.0	10.3	2.3
16.	ICB 224	87.3	20.3	18.3	3.7
17.	ICB 212	102.3	26.3	7.6	3.2
18.	ICB 213	106.0	26.6	10.3	3.4
19.	ICB 214	114.3	23.6	8.3	3.3
20.	ICB 215	117.0	25.6	10.6	3.0
21.	ICB 216	97.0	23.3	10.3	3.2
22.	ICB 217	97.3	22.6	7.6	3.4
23.	ICB 218	99.0	20.0	3.0	3.7
24.	ICB 241	78.6	22.0	7.0	3.5
25.	ICB 242	110.6	30.0	8.6	3.5
26.	ICB 244	96.3	22.6	5.0	3.3

S. No	Germplasm	Plant height (cm)	Number of sympodial branches	Number of bolls per plant	Boll weight (g)
27.	ICB 248	124.3	28.3	6.6	3.6
28.	ICB 249	113.3	31.0	7.0	3.5
29.	ICB 250	102.6	26.0	5.0	3.4
30.	ICB 258	98.3	25.3	2.0	3.2
31.	ICB 259	116.0	27.3	6.0	3.2
32.	ICB 260	73.6	17.3	5.3	2.6
33.	ICB 263	134.6	35.3	3.0	3.2
34.	ICB 269	100.3	26.3	5.0	3.4
35.	ICB 271	125.0	33.6	1.0	3.6
36.	ICB 273	94.6	23.0	3.0	3.1
37.	Suin	74.5	28.0	5.0	3.2
S.Em.±		2.6	0.7	0.9	0.1
CV %		0.15	0.16	0.53	0.13

Discussion

TSV (*Tobacco Streak Virus*) affecting cotton fields in Southern parts of India is of recent concern. Bt cultivars exhibited a higher incidence of TSV compared to non-Bt cultivars. Additionally, this emphasizes the need for integrated pest management strategies to tackle multiple threats effectively (Prasada Rao et al., 2009). Rageshwari et al. (2016) stated that TSV has been identified as a cause of considerable decreases in yield, with reported losses reaching up to 60–65%. Vinodkumar et al., (2017) found that Telangana among the surveyed regions in central and southern India, had the highest occurrence of TSV, with a severity index of 51.11 in hybrid RCH659. The presence of TSV was investigated in the germplasm of extra-long staple (ELS) cotton, *G. barbadense* revealed that the disease occurrence ranged from 5.81% (DB 3 and DB 25) to 26.60% (ICB 71) (Valarmathi and Dhamayanthi, 2020a). A survey carried out in cotton-growing districts such as Guntur, Krishna, and Kurnool documented TSV occurrences in various hybrids, reaching up to 30.0% in farmers' fields (Anonymous, 2023).

The development of resistant varieties is considered a crucial long-term strategy to effectively manage and protect crops from the destructive effects of TSV. A primary step in this process involves conducting extensive screening to identify genetic sources that exhibit resistance under disease-favourable conditions. The main goal of the resistance screening is to identify materials or genetic sources that possess desirable traits and can be utilized in hybridization program to create new resistant varieties. The existing literature indicates the lack of any known sources of resistance to TSV in ELS cotton.

Therefore, the primary objective of this study is to evaluate the field performance of *G. barbadense* germplasm lines for resistance to disease. A total of three hundred germplasm lines were screened under natural conditions for TSV occurrence during the winter cropping seasons from 2018 to 2020. Among the germplasm lines evaluated, fourteen were categorized as Resistant (R), twenty-two as Moderately Resistant (MR), one hundred and sixty-eight as Moderately Susceptible (MS), and ninety-four as Susceptible (S) lines. Ahmed et al., (2005) conducted a screening of twenty-six cotton varieties from the *G. hirsutum* group under natural infection conditions of cotton mosaic in various ecological zones in Pakistan. Among these varieties, CIM-70, S-12, B-30, B-496, BH-4, BH-89, BH-94, BH-95 and Krishma exhibited resistance to mosaic disease. However, it was found that these resistant varieties were highly susceptible to cotton leaf curl virus (CLCuV). According to Bhattiprolu and Prasad (2011), a total of twenty-four hybrids exhibited TSV incidence of less than five percent. Notably, Tulasi 144 BG II, Kohinoor Bt, Tulasi Non Bt, Super Kanaka Bt, NECR – 2RC (F1) and Brahma BG II showed no signs of TSV infection during field evaluation conducted at LAM, Guntur. Additionally, Reddy et al., (2015) demonstrated that Mallika BG II and Neeraja BG II were also found to be free from Tobacco Streak Viral disease. Field evaluation at LAM, Guntur revealed that hybrids such as Rakhi BG II, Ajit 155, Indra Vajra, Jackpot BG II, and Kanak BG II exhibited resistance to TSV disease. The incidence of TSV was monitored on the research farm, RCH2, Jaadoo BT hybrids, L100 and NDLH 1938 ranged from 0.5 to 12.6% (Anonymous, 2023). At RARS, Warangal, fifty-two cotton germplasm lines and thirteen Bt cotton hybrids were subjected to natural screening against TSV. Promising entries among the germplasm lines, including HYPS-152, H-1250, and RAH-4, as well as eleven Bt hybrids, namely Bhakti, Raja, Balhwan, Akka, First class, RCH-812, Ankur-3224, ACH-199, RCH-836, RCH-812, and ATM showed resistance to TSV (Vijaya Bhaskar, 2023).

Sunflower necrosis disease (SND) caused by TSV has led to significant yield losses of up to 90% in many sunflower-growing regions of Southern India. Currently, all cultivated hybrids and varieties have demonstrated varying degrees of susceptibility to this disease. Unfortunately, no resistant sources have been identified against SND thus so far. Screening was conducted on various sunflower lines, including R lines, CMS lines, germplasm, and cultivars, through mechanical sap inoculation of the test virus in a controlled environment protected from insects. The results revealed that none of the sunflower lines screened, exhibited immunity or resistance or even moderate resistance to SND (Bhat and Rao, 2014).

The emergence of stem necrosis disease caused by *Tobacco streak virus* (TSV) as a potential threat to peanut (*Arachis hypogaea*) in the southern states of India was first recognized in 2000. To assess the resistance of groundnut lines to groundnut bud necrosis disease, a field experiment was conducted in Jalgaon, Maharashtra, India, involving forty-four groundnut lines. Results from the experiment showed that six lines exhibited high resistance, eight were resistant, and fourteen were moderately resistant to the disease (Thakare et al., 2002). Currently cultivated peanut cultivars in India are highly susceptible to the virus, prompting the evaluation of wild relatives of peanut to identify potential sources of resistance against TSV infection. At the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), fifty-six germplasm accessions from twenty wild *Arachis spp.*, along with susceptible peanut cultivars (JL 24 and K 1375), were assessed for TSV resistance under greenhouse conditions using mechanical

sap inoculation. This study represents the first report of TSV resistance in *Arachis spp.* Among the evaluated accessions, eight showed resistance to TSV and were found to be cross-compatible with *A. hypogaea*, making them suitable for utilization in breeding programs aimed at developing stem necrosis disease-resistant varieties (Kalyani et al., 2007).

In our study, we conducted an evaluation of *G. barbadense* germplasm lines under natural conditions to assess their resistance or susceptibility to TSV in a separate plot. The disease incidence observed in the resistant lines ranged from 3.2–5.0%. Notably, ICB 162R exhibited a lower disease incidence of 3.2%. On the other hand, in the susceptible lines, the mean disease incidence varied from 19.2–28.5%, with the control variety Suvin showing a TSV incidence of 32.5%. A positive correlation was observed between the mean disease incidence and the mean thrips population, with a positive correlation coefficient (r) value of 0.11.

In ICB162R, the average plant height was measured at 130 cm, with a mean number of bolls per plant of 19.6 and a boll weight of 3.9. Conversely, in the Suvin variety, the average plant height recorded was 74.5 cm, with an average of 5.0 bolls per plant and a boll weight of 3.2. Notably, the number of bolls per plant showed a significant and positive correlation, with a correlation coefficient (r) value of 0.83 with TSV incidence. The resistant lines withhold a higher number of bolls per plant compared to the susceptible lines. This difference can be attributed to the drying of squares observed in susceptible lines during TSV infection, resulting in a reduction in the number of bolls and subsequently affecting the overall yield. The fourteen identified germplasm lines of *G. barbadense* can be effectively utilized as donor parents in breeding programs to develop resistant lines against TSV. To the best of our knowledge, this study represents the first report of identification of resistance to TSV in *G. barbadense* germplasm lines.

Conclusions

From the current study the identified fourteen resistant germplasm lines of *G. barbadense* can be valuable resources in breeding programs as donor parents to develop TSV-resistant lines. Utilizing these lines in breeding, efforts can contribute to the development of resistant varieties against TSV.

Abbreviations

R Resistant, MR Moderately Resistant, MS Moderately Susceptible, S Susceptible lines

ELS Extra Long Staple, TSV *Tobacco Streak Virus*

Declarations

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Authors' contributions

Valarmathi P made significant contributions in the execution of the experiments, recorded the data, statistically analyzed, interpreted the results and drafted the manuscript. Amutha M made significant contributions in execution of the experiments and observation of thrips population in the field study.

Availability of data and materials

All the data relevant to the present study are included in the article. Any further details related to the experiments conducted can be made available by requesting the corresponding author

Ethics approval and consent to participate

Not applicable.

Consent for publication

Manuscript has not been published, or submitted for publication elsewhere.

Competing interests

The authors declare that they have no conflict of interest related the content of this article.

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Figures

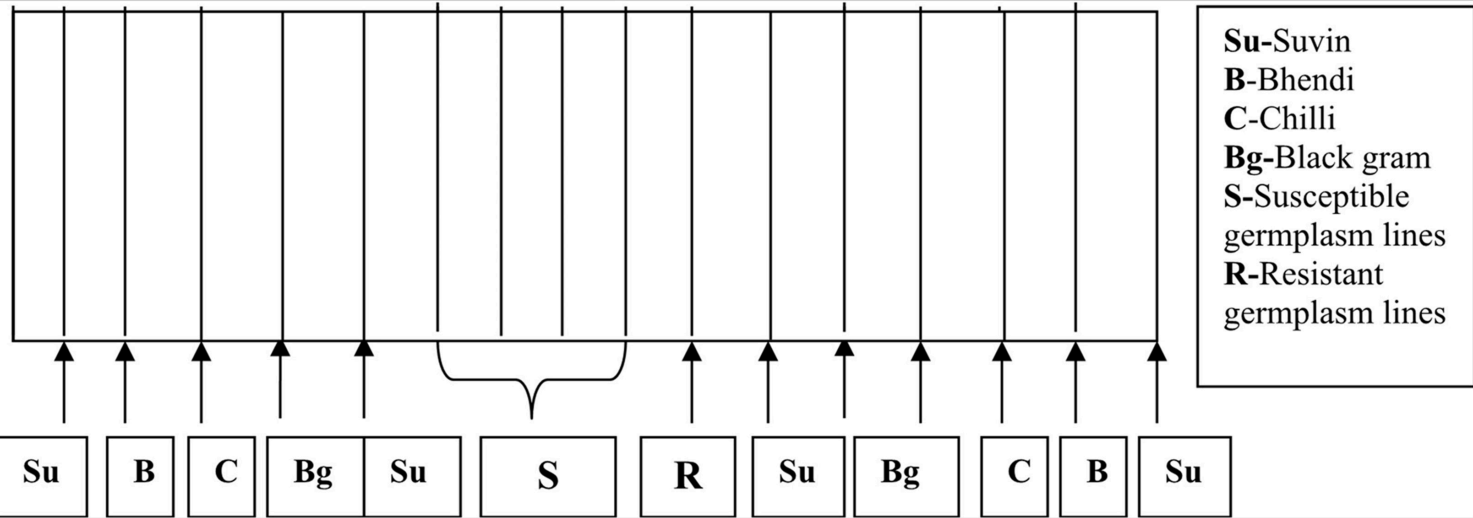


Figure 1

Field view of augmented design for evaluation of resistant /susceptible lines of G. barbadense against TSV



Figure 2

Typical symptoms of necrotic spots with purple colour and drying of squares



Figure 3

Symptoms expression in the germplasm lines of G. barbadense



Figure 4

Field view of resistant and susceptible lines of G. barbadense evaluated against TSV under natural conditions in augmented design

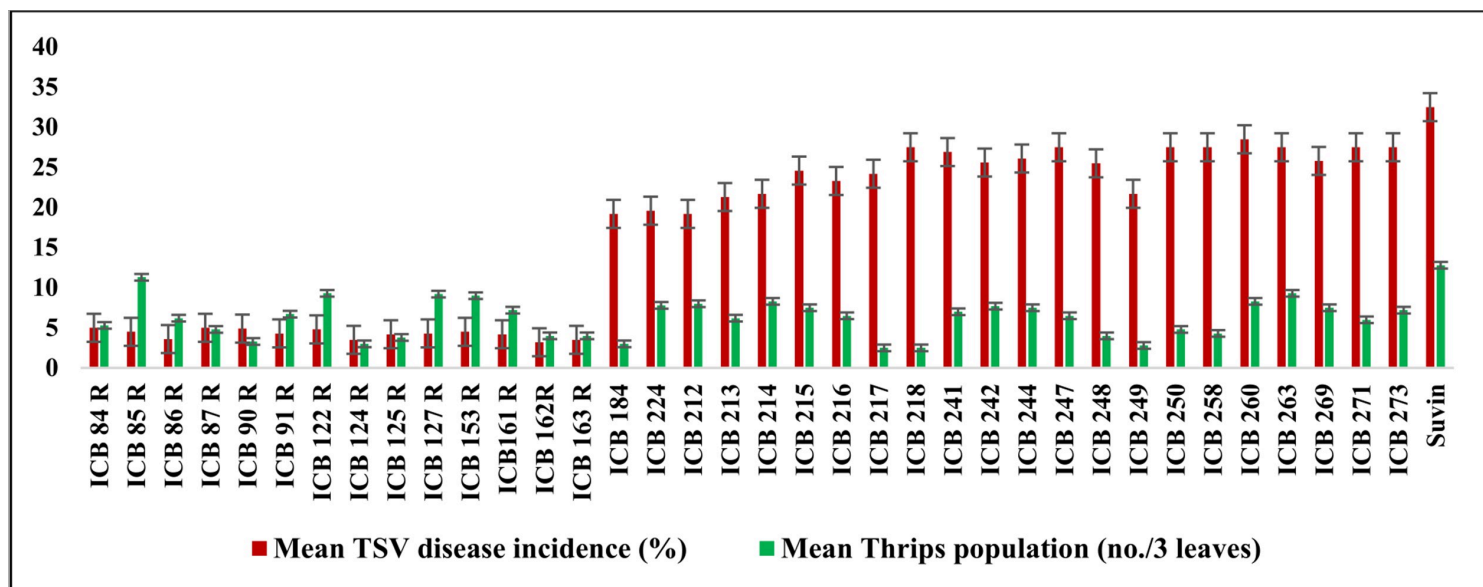


Figure 5

Evaluation of resistant/susceptible germplasm lines of G. barbadense for TSV disease/ thrips population



Figure 6

Expression of TSV symptoms in Parthenium plants (where pollen acts as carrier of the virus)