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Integrated Approach for Screening Groundnut Genotypes and Unveiling Morphological and Biochemical Factors Associated with Resistance to Thrips, *Scirtothrips dorsalis* Hood

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Thrips is an important sucking insect pest and are the major problem in the groundnut. The pressure from thrips is higher in the summer. One species of thrips i.e., *Scirtothrips dorsalis* Hood was reported in the present investigation. To minimize crop losses, it is important to efficiently manage thrips, *Scirtothrips dorsalis* Hood. Finding the source of resistance is one strategy to reduce yield losses. In the summers of 2020 and 2021, forty-four groundnut varieties were screened in the field to determine their resistance to thrips occurrence. Nineteen genotypes were chosen for additional research, including host preference and oviposition preference tests in greenhouse conditions and host plant resistance studies, based on preliminary screening studies conducted at the field level in 2020 and 2021. None of the genotypes were totally free from thrips damage. Nonetheless, three genotypes (Dh-256, RST-1-2020-12, and INS-1-2020-11) were classified as resistant. Ten genotypes were very vulnerable, 14 were susceptible, and 17 were somewhat resistant. The biochemical and morphological examination results showed that resistance against thrips was conferred by increased levels of phenols, tannins, trichome density, and leaf colour.

Keywords: Groundnut; phenols; sugars; tannins; thrips; trichomes.

1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a vital legume crop globally contributing significantly to both human nutrition and agricultural economies. It is primarily grown for its high-quality edible oil and digestible protein. Small-holder farmers in Asia and Africa produce 90% of the world's groundnuts under rainfed conditions [1] However, the cultivation of groundnut is often challenged by various pests, among them, leafhoppers and thrips pressure is more during summer Sonawane et al., [2] with the thrips species *Scirtothrips dorsalis* emerging as a notable threat. Thrips infestations can cause substantial damage to groundnut crops, affecting yield and quality. Their incidence commences right from vegetative stage till the harvesting. They live in young folded groundnut leaflets and blossoms and are known to spread peanut bud necrosis disease (PBND) (Rajashree et al., [3]. Nymphs and adults feed on fragile leaves and blossoms, causing distorted leaves and stunted plants [1]. Thrips damage is identified by the "silvering" of leaves [4]. Several species of thrips have been found to infest groundnut and they are also known to transmit viral diseases [1]. Heavy infestation of thrips at the early stage of the crop could result in losses of biomass and kernel yield. Insecticides are commonly used to control thrips, and frequent usage is necessary for optimal results. Frequent use of pesticides is not effective against thrips, as they can acquire resistance to them [1]. Hence, resistant cultivars will be one of the most promising alternative control measures since they are low-cost, ecologically benign, and easily combined with other treatments. Efforts to enhance groundnut resilience to thrips involve a multifaceted approach, including the systematic screening of genotypes for resistance and the exploration of morphological and biochemical elements associated with this resistance. The purpose of this study was to assess groundnut genotypes/varieties for thrips resistance and understand the biochemical basis of resistance to *Scirtothrips dorsalis* Hood.

2. MATERIALS AND METHODS

2.1 Screening of Groundnut Genotypes

Forty-four genotypes of groundnut were evaluated for resistance to thrips under field conditions with three replications. The crop was grown during the 2020 and 2021 summer season at the Main Agricultural Research Station, Dharwad. The TAG-24 was used as a susceptible check. Each genotype was sown in two rows of 5-meter length with a spacing of 30 × 10 cm with susceptible checks after every 2^{nd} entry. The response of varieties for thrips infestation was recorded based on visual observation of damage *i. e*., curling of leaves by following 1 to 9 per cent standard scale (Ranga Rao and Wightman 1996) and also counting the number of thrips per terminal bud from randomly selected five plants in every genotype from each replication during early morning hours including susceptible check at 30, 40, 50, 60, 70, 80 and 90 days after germination, considering the peak activity of pests, the data recorded at 40 DAG has been considered for analysis and interpretation. Later categorization of genotypes was made based on the damage score. Based on the resistance evaluation studies at field level in 2020 and 2021, few genotypes from each category, collectively 19 genotypes were selected for further studies such as host preference studies and oviposition preference studies in greenhouse and host plant resistance by pest infestation evaluation in field.

Percent of leaf damage = Number of damaged leaflets per plant / Total number of leaflets per plant * 100

2.2 Studies on Oviposition and Survivability of Thrips under Caged Condition

A pot experiment was carried out in the summer of 2021 to investigate the egg laying and survivability of thrips in greenhouse conditions. Nineteen distinct genotypes of different categories, resistant, moderately resistant, susceptible, and severely susceptible, were chosen based on their field performance against thrips and cultivated in pots. The trial followed a completely randomized design, with three replications each genotype. After 30 days of seeding, around 20 pairs of thrips (nymphs) were released per plant, and the container was covered with fine muslin cloth cages. After 25 days of release, leaf samples were randomly taken from each cage and checked for egg laying. The egg count was conducted using the method given by Parrella and Robb [5]. The procedure to count the eggs is as follows: The leaflets were cooked in a lactophenol acid solution for three to five minutes before cooling for three to five hours. The lactophenol acid fuchsion was made by combining one part glycerin and one part lactic acid to form a solution (1:1000). Excess pigment was removed by rinsing the leaves and delicate shoots with warm water, which were then placed to petridishes containing warm water. A stereoscopic binocular microscope was used to count the total number of eggs laid for each genotype and variety. The eggs absorb the pigment, making them simple to distinguish from other plant parts and empty punctures. Furthermore, after 30 days, the muslin cloths were removed, and the number of thrips that survived each plant was determined [6].

2.3 Biochemical and Morphological Characterization

Tender leaves of selected groundnut genotypes were powdered by grinding in liquid nitrogen (-196^{0}c) with mortar and pestle. Biochemical components in the leaf powder of different genotypes of groundnut were estimated using standard protocols**.** Reducing and total sugars in extract were calculated using Nelson's [7] method. Reducing sugars were estimated in 0.4 ml of aliquot by adding 1.0 ml of Nelson's reagent A + Nelson's reagent-B. The mixture was heated for 20 min. After cooling, 1.0 ml of arsenomolybdate solution was added and finally the volume was made upto 10.0 ml with distilled water. The absorbance was read at 510 nm. A standard graph was constructed using glucose solution as a standard. Total sugars and non-reducing sugars were hydrolyzed in 1.0 ml of 1.0 N H_2SO_4 to 0.5 ml of aliquot and heated for 30 minutes in a boiling water bath. One to two drops of phenolphthalein indicator were added after cooling under running water. After that, 1.0 N NaOH was added drop by drop to neutralise the acid in the hydrolysate till it turned pink. After that, 1.0 N H_2SO4 was added to render it colourless, and the volume was increased to 10.0 ml with distilled water before the absorbance was measured at 510 nm. The total phenol content was calculated using the method proposed by Malick and Singh [8]. 100 mg of oven-dried powdered sample was extracted in 10 ml of warm 80 % ethanol for 1 h at room temperature. An aliquot sample of 0.1 ml was diluted to 3 ml with water and 0.5 ml of Folin–Ciocalteu reagent (FCR) was added and mixed. Exactly after 3 min, 2 ml of 20 % sodium carbonate solution was added and kept in boiling water bath for one min. After cooling under running tap water, the absorbance was read at 650 nm. A standard graph was constructed with catechol as a standard in the range of 20-100 µg. The total phenol content was expressed as mg/g of oven dried sample. The total tannin content was calculated using the procedure given by Burns [9]. 100 mg of oven-dried powdered sample was extracted with 5 ml of methanol for 24 hours at room temperature with occasional stirring. The extract was centrifuged at 5000 rpm for 10 minutes. The supernatant was used for the estimation of total tannins. A standard graph was constructed using catechin as a standard. The total tannin content is expressed as mg g^{-1} d.wt .

Morphological characteristics such as leaf thickness, leaf colour, and trichome density were determined from the top completely opened leaflets of selected genotypes at 50 DAS. The leaf thickness was measured from five leaves of each test entry with a Vernier caliper and was estimated by the following formula and represented in millimeters (Sonawane et al*.,* 2019). M S D + V S D + L C (M S D = Main Scale Division reading, V S D = Vernier Scale Division read, L C = Least Count). Trichomes were analyzed according to the technique (Maite et al*.,* 1980). Wherein five fully developed leaves from selected genotype were heated with 20 ml of distilled water in a test tube for five minutes, 20 ml of 96 per cent ethanol was added and the samples heated again for 10 minutes at 80°C. The alcohol was decanted and the same procedure was repeated 3 times so that chlorophyll content was removed completely. Finally, 20 ml of 90 per cent concentrated lactic acid was added and heated again at 85 °C for 45 minutes until leaf segments were cleared. Later, the test tubes were cooled and leaf segments were mounted on glass slide and a drop of lactic acid was added and observed under stereoscopic binocular microscope and number of trichomes on one mm length of midrib was counted. Similarly, the number of laminar trichomes (abaxial surface) per square millimeter area were counted. The leaf color was determined by visual inspection and classified as dark green, green, or light green.

2.4 Statistical Analysis

The data was statistically analyzed by subjecting to the correlation 'r' formula between biochemical, morphological parameters and per cent foliage damage, number of thrips, oviposition, survivability [10].

3. RESULTS

3.1 Screening for Resistance to Thrips under Field Conditions

Thrips were found to be active throughout the cropping season. One species of thrips *i.e.*, *Scirtothrips dorsalis* Hood was reported in the experimental plot. The data presented in the Tables 1 and 2 revealed that, among 44 genotypes screened against thrips, none of them were completely free from thrips damage, three were resistant (Dh 256, RST-1-2020-12 and INS-1-2020-11), 17 were moderately resistant, 14 were susceptible and 10 were highly susceptible (INS-I- 2020-1, INS-I- 2020-5, INS-I- 2020-9, INS-I- 2020-17, INS-I- 2020-18, INS-I- 2020-27, AIS-2020-7, TG-37A, TAG-24, Higholeic 107).

Table 1. Reaction of groundnut genotypes against thrips during summer 2020 and 2021

S. No.	Genotypes	Summer 2020		Summer 2021		Damage grade	Category
		Thrips/ terminal bud	Foliage damage (%)	Thrips/terminal bud	Foliage damage (%)		
1	INS-I-2020-1	6.95	38.00	6.45	35.15	4	HS
2	INS-I-2020-2	4.85	19.75	4.78	19.53	2	MR
3	INS-I- 2020-3	4.70	18.20	4.60	17.62	2	MR
4	INS-I- 2020-4	5.30	22.00	5.20	21.56	3	S
5	INS-I- 2020-5	8.40	45.50	7.82	41.43	5	HS
6	INS-I- 2020-6	5.68	26.50	5.60	25.40	3	S
7	INS-I- 2020-7	5.15	20.00	5.00	19.95	2	MR
8	INS-I- 2020-8	3.68	13.20	3.62	12.95	2	MR
9	INS-I- 2020-9	7.10	39.00	6.75	38.36	4	HS
10	INS-I- 2020-11	3.32	9.95	3.10	9.85	1	R
11	INS-I- 2020-12	5.46	25.50	5.36	23.85	3	S
12	INS-I- 2020-13	5.58	27.00	5.45	24.25	3	S
13	INS-I-2020-14	6.00	29.40	5.80	28.60	3	S
14	INS-I-2020-15	5.50	26.20	5.40	23.91	3	S
15	INS-I-2020-16	5.38	24.00	5.35	23.66	3	S
16	INS-I-2020-17	7.80	40.00	7.24	39.50	4	HS
17	INS-I- 2020-18	6.40	36.00	6.20	34.80	4	HS

S. No.	Genotypes	Summer 2020		Summer 2021		Damage grade	Category
		Thrips/ terminal bud	Foliage damage (%)	Thrips/terminal bud	Foliage damage (%)		
18	INS-I-2020-20	6.10	29.80	5.86	29.00	3	S
19	INS-I-2020-21	4.92	19.86	4.85	19.82	2	MR
20	INS-I-2020-22	4.25	14.80	4.10	14.60	2	MR
21	INS-I- 2020-23	3.70	13.50	3.92	13.15	2	MR
22	INS-I-2020-24	5.60	27.50	5.65	24.60	3	S
23	INS-I-2020-25	5.00	19.90	4.91	19.85	2	MR
24	INS-I-2020-26	5.70	27.60	5.85	26.50	3	S
25	INS-I-2020-27	7.50	39.50	6.64	38.50	4	HS
26	INS-I-2020-28	5.40	24.60	5.25	23.80	3	S
27	AIS-2020-1	4.30	15.00	4.18	14.65	2	MR
28	AIS-2020-2	4.45	16.50	4.35	15.56	2	MR
29	AIS-2020-3	5.62	25.50	5.55	24.80	3	S
30	AIS-2020-4	3.85	14.00	3.67	13.63	2	MR
31	AIS-2020-5	5.95	28.70	5.75	27.52	3	S
32	AIS-2020-6	4.65	18.00	4.56	17.56	2	MR
33	AIS-2020-7	9.00	47.20	7.75	41.46	5	HS
34	K1812	3.40	13.00	3.34	12.00	2	MR
35	Dhanalaxmi	5.80	28.20	5.65	27.35	3	S
36	Girnar 4	4.10	14.50	3.82	14.10	2	MR
37	KDG-123	4.76	18.60	4.66	17.80	2	MR
38	TG-37A	6.60	36.20	6.27	34.90	4	HS
39	ICG-86031	4.60	17.60	4.54	17.10	2	MR
40	ICGV-91114	4.80	19.00	4.75	18.50	2	MR
41	TAG-24 (SC)	10.20	49.50	8.12	43.56	5	HS
42	Dh 256	2.70	9.00	2.56	8.95	1	R
43	RST-1-2020-12	2.92	9.70	2.80	9.50	1	R
44	Higholeic 107	8.0	43.20	7.56	41.25	5	HS
'r' value		0.98*		0.98*			

** significant at p=0.05; r - correlation coefficient; SC- Susceptible Check; R-resistant; MR-Moderately Resistant; S-Susceptible; HS- Highly Susceptible*

The genotypes which expressed differential responses have been categorized into different categories based on preliminary field screening data. There was no difference between the two years in terms of population and foliage damage. In both years, every genotype was placed in the same group. The population in the summer of 2020 varied in genotypes from 2.70 (Dh-256) to 10.20 (TAG-24) per terminal bud, while the percentage of foliage damage varied from 9.00 (Dh 256) to 49.50 (TAG-24). In several genotypes, the population varied from 2.56 (Dh-256) to 8.12 (TAG-24) per terminal bud during the summer of 2021, while the percentage of foliage damage varied from 8.95 (Dh 256) to 43.56 (TAG-24).

3.2 Studies on Oviposition and Survivability of Thrips under Caged Condition

Nineteen genotypes were selected based on their field performance for studying the oviposition and survivability of thrips under caged condition and the results were presented in Table 3. The least number of eggs were observed on resistant genotype Dh 256 (0.40 egg/terminal bud) followed by RST-1-2020-12 (0.50 egg/terminal bud) and least number of thrips survived on Dh 256 (2/plant). While, highest oviposition and thrips survivability was recorded in highly susceptible genotypes TAG-24 (2.8 eggs/terminal bud and 13.5 thrips/plant) (Table 3). Table 5 shows the correlation coefficients for the host plant's morphological and biochemical characteristics with oviposition and thrips survivability and the perusal of data indicated that, trichome density, leaf colour, total phenols and tannin content were negatively correlated with both oviposition and survivability of thrips. Whereas, total sugars had significant and positive relationship with both the oviposition and number of thrips survived per plant. Further, leaf thickness and reducing sugars did not had any influence on oviposition and survivability of thrips.

3.3 Biochemical Basis of Resistance

The role of biochemical constituents of host plants in offering resistance against thrips was studied. Biochemical measurements demonstrated a distinction between susceptible and resistant genotypes. Biochemical Parameters like total sugars, reducing sugars, total phenols and tannins were estimated in order to study the biochemical basis of induced resistance in groundnut (Table 4, 5 and Fig. 1).

The total phenol content (Fig. 1b) was highest in the resistant genotype, Dh-256 (0.56 mg/g). Similarly, the resistant genotypes had higher quantities of tannins (Table 4) *viz*., Dh-256 (0.0044) and RST-1- 2020-12 (0.0038) mg per gram of leaf sample. A clear trend of general higher amount of total phenol and tannins was found in resistant genotypes. Hence, they showed the significant negative relationship with thrips population, foliage damage, oviposition and survivability at five per cent level of significance (Table 5). In contrast to the above trend resistant genotype, Dh-256 (1.76 mg/g) showed lowest quantity of total sugars (Table 4). While highest quantity of total sugars was noticed in highly susceptible genotypes *viz*., TAG-24 (7.87 mg/g), Higholeic 107 (6.52 mg/g). Hence, total sugar content showed the significant and positive correlation with thrips population, foliage damage, oviposition and survivability at five per cent level of significance (Table 5). The lowest amount of reducing sugar (Fig. 1a) was found in AIS-2020-6 (0.09 mg/g) which belongs to the moderately resistant group. Whereas, highest amount of 0.63 mg/g was recorded in INS-I- 2020-20, belongs to the susceptible group. Hence, this indicates that there is no significant role of reducing sugars with thrips population, foliage damage, oviposition and survivability at five per cent level of significance (Table 5).

3.4 Studies on Morphological Basis of Resistance against Thrips

Morphological characters *viz*., leaf thickness, trichome density and leaf colour were studied from the top fully opened leaflets of selected genotypes at 50 DAS. The parameters were correlated with thrips population, foliage damage, oviposition and survivability and the results were presented (Table 4, 5 and Fig.1).

Table 2. Categorization of groundnut genotypes against thrips during summer 2020 and 2021

Scale	Foliage damage (%)	Reaction	Genotype
1	1-10	Resistant	INS-I- 2020-11, Dh 256, RST-1-2020-12
2	11-20	Moderately resistant	INS-I-2020-2, INS-I-2020-3, INS-I- 2020-7, INS-I- 2020-8, INS-I-2020-21, INS-I-2020-22, INS-I-2020-23, INS-I-2020-25, AIS-2020-1, AIS-2020-2, AIS-2020-4, K1812, ICG-86031, Girnar 4, AIS-2020-6, ICGV-91114, KDG-123
3	21-30	Susceptible	INS-I-2020-4, INS-I-2020-6, INS-I-2020-12, INS-I-2020-13, INS-I-2020-14, INS-I-2020-15, INS-I-2020-16, INS-I-2020-20, INS-I-2020-24, INS-I-2020-26, INS-I-2020-28, AIS-2020-3, AIS-2020-5, Dhanalaxmi
4-5	31-50	Highly susceptible	INS-I-2020-1, INS-I-2020-5, INS-I-2020-9, INS-I-2020-17, INS-I-2020-18, INS-I-2020-27, AIS-2020-7, TG-37A, TAG-24, Higholeic 107

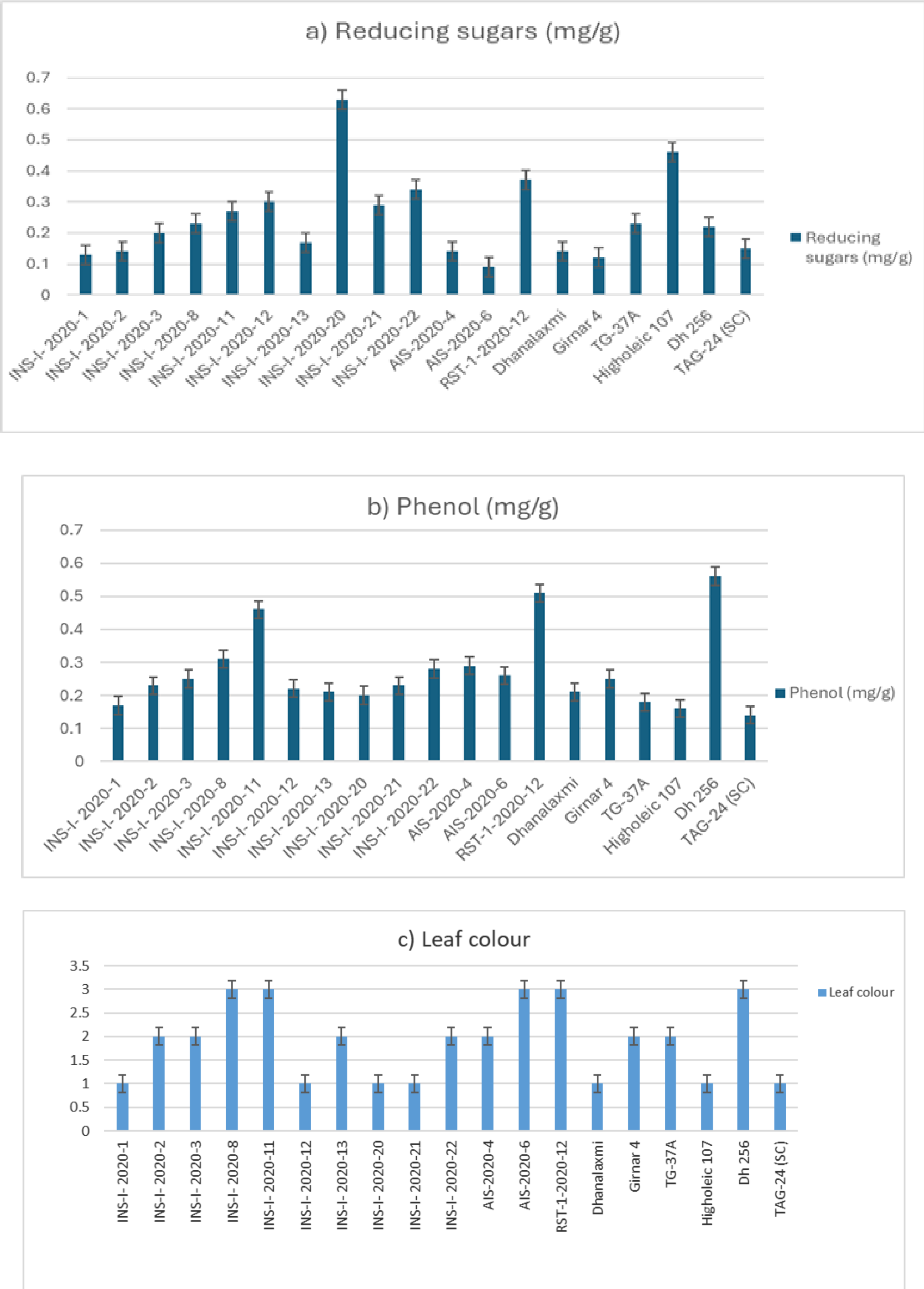

Fig. 1 a) Reducing sugar content among the genotypes b) Total phenol content among the genotypes, c) Leaf colour

Table 3. Preference of groundnut genotypes for oviposition and survivability of thrips under caged condition during summer 2021

Sl. No.	Genotypes	Oviposition preference (Mean no. of eggs/plant)	Host preference (No. of thrips survived/plant)	Reaction
1	INS-I- 2020-1	2.40	11.5	HS
2	INS-I- 2020-2	1.13	8.40	MR
3	INS-I- 2020-3	1.10	8.00	MR
4	INS-I- 2020-8	0.80	6.00	MR
5	INS-I- 2020-11	0.60	5.00	R
6	INS-I- 2020-12	1.38	9.20	S
7	INS-I- 2020-13	1.65	9.80	S
8	INS-I- 2020-20	2.00	10.00	S
9	INS-I- 2020-21	1.25	8.80	MR
10	INS-I- 2020-22	1.02	7.60	MR
11	AIS-2020-4	0.95	6.50	MR
12	AIS-2020-6	1.08	7.75	MR
13	RST-1-2020-12	0.50	4.00	R
14	Dhanalaxmi	1.81	10.00	S
15	Girnar 4	1.00	7.00	MR
16	TG-37A	2.20	11.00	HS
17	Higholeic 107	2.60	12.00	HS
18	Dh 256	0.40	2.00	R
19	TAG-24 (SC)	2.80	13.50	HS

Note: 20 pairs of thrips released/cage; R=resistant, MR= moderately resistant, S= susceptible, HS= highly susceptible SC- susceptible check

Trichome density (Table 4) of genotypes varied significantly among all the genotypes and ranged from 2.86 (TAG-24) to 12.64 (Dh-256) per mm^2 on leaf lamina and midrib. The least trichomes were recorded in TAG-24 (2.86/mm^2) which is highly susceptible genotype. While highest trichome density was noticed in resistant genotypes *viz.*, Dh-256 (12.64/mm^2), RST-1-2020-12 (11.65/mm^2). Resistant genotypes had dark green leaves which is graded as 3 *viz.,* Dh-256 and RST-1-2020-12 (Fig. 1c). Whereas, highly susceptible genotypes showed a light green leaves *viz.,* TAG-24 and Higholeic 107. Therefore, Trichome density and leaf colour showed the significant difference and negative correlation with thrips population, per cent foliage damage, oviposition and survivability at five per cent level of significance (Table 5). Whereas, in case of leaf thickness (Table 4) the least thickness was observed in Dh-256 and Higholeic 107 which belongs to resistant and highly susceptible category respectively. And highest leaf thickness was recorded in AIS-2020-6 which is moderately resistant genotype. This indicates that there is no significant role of leaf thickness with thrips population, foliage damage, oviposition and survivability (Table 5).

4. DISCUSSION

In this study, we utilized morphological investigations, biochemical profiling, greenhouse trials, and field-level screening to identify groundnut genotypes resistant to thrips. From the initial screening of forty-four genotypes in 2020 and 2021, nineteen promising genotypes were selected for further investigation, including host preference and oviposition preference studies in the greenhouse, and host plant resistance assessment through pest infestation evaluation in the field. The two-year screening process significantly aided in the selection of stable resistance strains. Among those tested, Dh-256, RST-1-2020-12, and INS-1-2020-11 demonstrated resistance to thrips during field screening, although none were entirely free from thrips damage. The results indicated a positive correlation between thrips population and the percentage of leaf damage. Due to differences in genotypes screened, direct comparisons with previous studies were not feasible. However, similar screening efforts against thrips conducted by previous researchers on various genotypes are discussed below. Patwari [11] evaluated 36 groundnut genotypes and found 33 to be fairly resistant/tolerant, with ISKI-2017-05 exhibiting the lowest thrips population. Kandakoor [12] assessed 56 genotypes for thrips resistance, identifying 13 as resistant and 7 as vulnerable, yet none displayed tolerance to thrips injury.

Plant resistance to insect pests involves complex interactions between insects and plants. Secondary metabolites, such as alkaloids, play a crucial role in thrips resistance alongside morphological features [4]. These components, both qualitatively and quantitatively, affect insect growth by interfering with various biochemical elements like total sugars, reducing sugars, phenols, tannins, and other plant metabolites. Such interference disrupts insect feeding, oviposition, development, and survival, known as an anti-biosis resistance mechanism. Hence, research was conducted to assess the impact of biochemical factors on insect pest resistance. The findings demonstrated significant correlations between biochemical markers and thrips population, leaf damage percentage, oviposition, and survivability. Notably, total soluble sugars showed a positive correlation with population, leaf damage, oviposition, and survivability, while total phenols and tannins exhibited a negative correlation with these factors. However, reducing sugars did not show significant correlations.

Sugar primarily acts as a feeding stimulant for insects [13]. The genotype TAG-24, highly susceptible to thrips, exhibited the highest overall sugar concentration. Total sugars showed positive correlations with thrips population, leaf damage percentage, oviposition, and survivability across various studies (Kandakoor et al., [12], Naik and Somashekhar, [14], Rao et al., [15], Sonawane et al., [2], Rajashree et al., [3], Rudramuni et al., [1]. However, reducing sugars were found to have no significant impact on host plant resistance (Somashekhar and Patil, [16], Naik and Somashekhar, [14]. This aligns with findings indicating that susceptible genotypes had both the lowest and highest amounts of reducing sugar [17], suggesting reducing sugar's negligible role in determining resistance or susceptibility.

Phenols are abundant plant allelochemicals known to decrease the palatability of plant sap to insects, thereby inhibiting feeding, altering metabolism, and reducing fertility [18], They inhibit insect growth and diminish survival rates by inducing toxicity through defense enzyme activation and mediation of transduction pathways, leading to the oxidation of toxic compounds like quinines (Bhonwong et al., [19], Golla et al*.,* [20]. This likely explains the low incidence of sucking insect pests in resistant genotypes. High phenol content in plant varieties is directly associated with thrips resistance (Kandakoor et al., [12], Rao et al., 2015; Rajashree et al., [3], Naik and Chakravarthy, [21], Sonawane et al., [2], Rudramuni et al., [1]. Similarly, tannins exhibited significant negative correlations with thrips population, leaf damage percentage, oviposition, and survivability. Resistant groundnut varieties demonstrated higher levels of tannins compared to susceptible lines (Kandakoor et al., [12], Naik and Chakravarthy, [14], Rajashree et al., [3], indicating that tannins contribute to resistance against sucking insect pests.

Each plant possesses inherent mechanisms to resist pest attacks, often expressed through diverse morphological traits. Morphological characteristics like leaf thickness, trichome density, and leaf color influence insect feeding, oviposition, development, and survival. Consequently, research aimed to understand the impact of these morphological traits on insect pest resistance. Leaf thickness was found to have a non-significant relationship with thrips population, leaf damage percentage, oviposition, and survivability (Naik and Somashekhar, [14], Sonawane et al., [2], suggesting its limited role in host plant resistance. Trichome density, including those on leaf midribs, emerged as crucial contributors to resistance, with significant negative correlations observed with thrips population, leaf damage percentage, oviposition, and survivability (Rao et al., [15], Naik and Chakravarthy, 2017; Sonawane et al., 2019). Higher trichome density resulted in reduced thrips incidence. Leaf color also plays a pivotal role, with resistant genotypes typically exhibiting dark green leaves, which are less attractive to insects (Amin et al., 1985; Rao et al., 2015; Sonawane et al., 2019). These findings underscore the importance of morphological traits in imparting resistance to sucking pests like thrips in groundnut plants.

The groundnut variety screening, indicating varying degrees of susceptibility to thrips damage and identifying specific resistant genotypes with enhanced levels of phenols, tannins, trichome density, and leaf color, offer valuable insights for the development of predictive models aimed at forecasting the potential distribution of pests like *S. dorsalis*

Table 4. Influence of biochemical constituents on thrips population and foliage damage during summer

Sl. No.	Genotypes	Thrips/ terminal bud	Foliage damage (%)	Total sugars (mg/g)	Tannin (mg/g)	Leaf thickness (mm)	Trichome density (No./mm^2)	Reaction
1	INS-I- 2020-1	6.45	35.15	5.25	0.0014	0.18	4.86	HS
2	INS-I- 2020-2	4.78	19.53	3.27	0.0025	0.22	7.54	MR
3	INS-I- 2020-3	4.60	17.62	3.15	0.0025	0.17	7.72	MR
4	INS-I- 2020-8	3.62	12.95	2.45	0.0032	0.28	9.12	MR
5	INS-I- 2020-11	3.10	9.85	2.36	0.0035	0.25	9.36	R
6	INS-I- 2020-12	5.36	23.85	3.45	0.0021	0.18	6.55	S
7	INS-I- 2020-13	5.45	24.25	3.65	0.0019	0.25	6.31	S
8	INS-I- 2020-20	5.86	29.33	4.65	0.0016	0.23	5.56	S
9	INS-I- 2020-21	4.85	19.82	3.31	0.0023	0.26	6.84	MR
10	INS-I- 2020-22	4.10	14.6	2.95	0.0027	0.29	8.12	MR
11	AIS-2020-4	3.67	13.63	2.65	0.0029	0.28	8.45	MR
12	AIS-2020-6	4.56	17.56	3.05	0.0026	0.30	7.90	MR
13	RST-1-2020-12	2.80	9.50	1.95	0.0038	0.25	11.65	R
14	Dhanalaxmi	5.65	27.35	4.42	0.0018	0.23	6.12	S
15	Girnar 4	3.82	14.10	3.15	0.0024	0.26	7.82	MR
16	TG-37A	6.27	34.60	5.12	0.0016	0.26	5.34	HS
17	Higholeic 107	7.56	41.25	6.52	0.0012	0.15	3.72	HS
18	Dh 256	2.56	8.95	1.76	0.0044	0.12	12.64	R
19	TAG-24 (SC)	8.12	43.56	7.87	0.0011	0.23	2.86	HS

SC-susceptible Check R- Resistant, MR-Moderately Resistant, S-Susceptible, HS- Highly Susceptible

Table 5. Relationship of morphological and biochemical characters of groundnut genotypes with population, foliage damage, oviposition and survival of thrips

Host plant characters	Field condition ('r' value)		Caged condition ('r' value)	
	Thrips (No.)	Foliage damage	Eggs per plant	No. of thrips survived per plant
Leaf thickness	-0.215^{NS}	-0.268^{NS}	-0.208^{NS}	-0.055^{NS}
Trichome density	-0.963*	-0.928*	-0.945*	-0.989*
Colour of leaf	-0.782*	-0.756*	-0.772*	-0.806*
Total sugars	0.966*	0.972*	0.969*	0.913*

Reducing sugars	0.102^{NS}	0.131^{NS}	0.123^{NS}	0.039^{NS}
Phenol	-0.849*	-0.786*	-0.815*	-0.932*
Tannin	-0.947*	-0.916*	-0.939*	-0.986*

** significant at p=0.05 ; r - correlation coefficient ; ns= Non Significant*

Hood [22]. By understanding which genotypes exhibit resistance traits and the underlying mechanisms of resistance, predictive models can integrate this information to better estimate the regions where susceptible groundnut varieties are grown and environmental conditions favor the spread of pests [23-25]. This integration enables the formulation of more targeted and effective control strategies, such as early detection systems, crop rotation, or the promotion of resistant cultivars, ultimately aiding in the prevention and management of pest outbreaks in agricultural settings [26-27].

5. CONCLUSIONS

In conclusion, the field screening of 44 groundnut genotypes conducted over two consecutive summers in 2020 and 2021, coupled with host preference studies, has identified several promising resistant genotypes for future breeding programs. Notably, genotypes like Dh 256, RST-1-2020-12, and INS-1-2020-11 exhibited significant resistance against thrips. Correlation studies have underscored the crucial role of biochemical constituents and morphological traits in conferring resistance. Higher levels of total sugars showed positive correlations with thrips population and damage, indicating a potential susceptibility factor. Conversely, compounds such as total phenols and tannins, alongside morphological features like trichome density and leaf color, displayed significant negative correlations with thrips infestation and damage, highlighting their contribution to resistance. Overall, the findings emphasize the multifaceted nature of plant resistance mechanisms against thrips infestation. Strategies aimed at enhancing phenolic compounds, trichome density, and other relevant morphological traits associated with resistance could be pivotal in developing groundnut varieties resilient to thrips damage.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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