



Dissecting host plant resistance in tomato against sucking pests

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ABSTRACT: An experiment on screening tomato genotypes against major sucking pests was conducted during the Rabi season 2023- 24. The study identified NDT-2021-1 and NDT-2022-2, along with NDT-2021-3 and NDT-2022-4, as promising genotypes against whitefly, *Bemisia tabaci* (Gennadius), jassids, *Amrasca biguttula biguttula* (Ishida), and aphid, *Aphis gossypii* Glov. Anatomical traits such as trichomes on the leaf and calyx and pericarp thickness, together with the biochemical compound phenol, played an important role in imparting resistance in these tomato genotypes. In contrast, protein, lycopene, carbohydrate, chlorophyll, carotenoid, and peroxidase enzyme activity showed positive correlation with pest incidence. The study therefore indicates that both biophysical parameters and biochemical characteristics contribute significantly to the mechanisms of resistance.

Keywords: Aphid, genotype, jassids, resistance, tomato, whitefly

INTRODUCTION

Tomato (*Lycopersicon esculentum* Linn.) is one of the most important vegetable crops, cultivated mainly in tropical and subtropical regions worldwide. In recent years, tomato has gained a high global rank due to increasing consumption and demand (Ali *et al.*, 2019). India, the world's second-largest producer of vegetables after China, contributes about 11% of global production, with an annual tomato output of 18.70 metric tons grown on 0.88 million hectares. In Uttar Pradesh, tomato is cultivated on 22.60 thousand hectares, producing 902.38 thousand metric tons (Anonymous, 2021). However, as with other vegetable crops, tomato production is constrained by several biotic and abiotic stresses. Tomato is vulnerable to many insect pests from the seedling stage until fruit harvest. More than 100 insect pests and 25 non-insect pests have been reported to damage tomato fields (Gupta *et al.*, 2020; Kumar and Singh, 2022). Among these, whitefly (*Bemisia tabaci* Genn.), tomato fruit borer (*Helicoverpa armigera* Hübner), cotton aphid (*Aphis gossypii* Glov.), leaf miner (*Liriomyza trifolii* Burgess), thrips (*Thrips tabaci*) and jassid (*Amrasca biguttula biguttula*) are major pests (Gupta *et al.*, 2020; Kumar and Singh, 2022). Whitefly, *B. tabaci*, can cause serious crop damage ranging from 10% to 90%, depending on

infestation intensity and crop stage (Setiawati *et al.*, 2009; Dubey *et al.*, 2020). Generalist herbivores such as *B. tabaci* are often more strongly influenced by plant defence responses than specialists (Agrawal, 2000). In addition, *A. (Aphis gossypii* Glov.) feed by sucking plant sap and injecting toxic saliva, leading to bud blighting, leaf curling and brown spotting on foliage (Metcalf and Flint, 1978). Tomato is also severely affected by jassids (*A. biguttula biguttula*), resulting in heavy losses. Besides direct feeding damage, jassids can transmit viruses, and their honeydew promotes black sooty mould that reduces photosynthesis and yield (Das, 2014; Pandey *et al.*, 2022).

Recognizing the limitations of conventional pest management and the environmental concerns associated with heavy insecticide use, this study explores resistant plant varieties as a sustainable alternative for pest suppression. Host plant resistance is a key component of integrated pest management (IPM) and can make plants unsuitable hosts without inducing or inheriting resistance in insects (Khan *et al.*, 2017). Resistant varieties can reduce pest pressure and complement chemical control. Plant traits such as trichomes and cuticle thickness can affect insect movement and feeding rate (Amin *et al.*, 2016). Leaf morphological traits

including trichome density, leaf shape, lamina thickness and leaf area may interfere with whitefly oviposition and feeding (Taggar and Gill, 2012; Hasanuzzaman *et al.*, 2016). In addition, biochemical composition and nutrient status of the host plant strongly influence the survival, growth and reproduction of phytophagous insects, and plant biochemical traits are central to varietal resistance. Therefore, understanding these physio-morphological and biochemical factors is essential for identifying sources of resistance to insect pests (Dhillon *et al.*, 2005). With this background, the present investigation was undertaken to screen tomato genotypes and evaluate traits associated with resistance to major sucking pests.

MATERIALS AND METHODS

Experimental site

The Department of Entomology, Plant Physiology and the Main Experimental Station (Horticulture) are located on the main campus of the university on the left side of the Ayodhya-Raebareli Road, approximately 42 km from the Ayodhya district headquarters.

Details of experiment

Twenty tomato genotypes were screened, obtained from the Department of Vegetable Science of the university. Seedlings were raised on beds measuring 3.6 m in length, 1.5 m in width and 0.15 m in height in an insect-proof net house. The seedbed was enriched with sieved FYM and fine sand and leveled properly. To prevent damping off, a mixture of water and carbendazim 50 WP (15-20 g per 10 liters of water) was applied after moistening the bed. Seeds were sown 2–3 cm deep, covered lightly with soil and watered gently using a watering can. Irrigation was provided as required until germination was complete. Thirty-day-old seedlings were transplanted in the field at a spacing of 60 cm × 40 cm in a Randomized Block Design (RBD) with three replications. Recommended agronomic practices were followed during the Rabi season 2023–24, except for plant protection measures.

Observations

Screening for sucking pests: Nymphs and adults of whitefly (*B. tabaci*), aphid (*A. gossypii*) and nymphs of jassid (*A. bigutella bigutella*) were recorded on three leaves (one each from bottom, middle and top) of five randomly selected plants per replication in each genotype. Observations were made in early morning

hours at weekly intervals. Population was expressed as number per three leaves.

Biophysical parameters: Biophysical traits such as plant height (cm), shoot thickness (2.5 cm below tip), number of primary and secondary branches, leaf length and width (cm), trichome density (upper and lower leaf surfaces within 25 mm² using a stereomicroscope), calyx length (cm), number of fruits per plant, fruit length (cm), fruit shape and colour were recorded. Trichome density on the leaf surface was recorded at 30 DAT, while trichome density on the calyx, number of calyx per fruit, fruit diameter, fruit shape, petiole length, number of fruits, fruit pericarp thickness, leaf length and width were recorded at 70 DAT.

Biochemical parameters: Biochemical traits such as chlorophyll (Arnon, 1949), lycopene content (mg/100 g) (Ranganna, 2000), total phenols (Sadasivan and Manickam, 1996), total protein (Lowry *et al.*, 1951), peroxidase activity (Putter, 1974), carotenoid content (mg/g fresh weight) (Price and Hendry, 1991) and total leaf soluble carbohydrate content (Hedge and Hofreiter, 1962) were estimated. At 40 DAT, biochemical characteristics of tomato leaves and fruits were analysed in the genotypes.

Statistical analysis: Data were analysed following Gomez and Gomez (1984). Critical difference was calculated to compare treatment means at 5% level of significance.

Determination of correlation coefficient: Correlation between major insect pests and abiotic factors was calculated using the formula.

$$R = \frac{\sum dndy}{Nn \sqrt{\frac{\sum d^2xi}{N} \times \frac{\sum d^2y}{N}}}$$

Where-Y = insect population; xi = biophysical and biochemical parameters N = number of observations; Σ = summation

RESULTS AND DISCUSSION

Screening for whitefly (*B. tabaci*)

Among the tomato genotypes evaluated, the lowest *B. tabaci* population was recorded on NDT-2022-2 (1.27 ± 0.01 whitefly/3 leaves), followed by NDT-2022-4 (1.37 ± 0.04 whitefly/3 leaves) and NDT-2021-3 (1.37 ± 0.02 whitefly/3 leaves). The highest whitefly population

Table 1: Screening of certain tomato genotypes against sucking pests during *Rabi* 2023-24

Sr. No.	Genotypes	Whitefly/three leaves	Jassids / three leaves	Aphid /three leaves
1	NDT-2022-1	5.39±0.10	3.23±0.02	6.34±0.04
2	NDT-2022-2	1.27±0.01	2.11±0.01	2.09±0.08
3	NDT-2022-3	1.64±0.02	1.88±0.05	2.17±0.10
4	NDT-2022-4	1.37±0.04	1.63±0.05	2.25±0.08
5	NDT-2022-5	6.23±0.09	5.22±0.02	7.34±0.17
6	NDT-2022-6	4.76±0.10	3.85±0.04	6.79±0.18
7	NDT-2022-7	5.91±0.26	5.09±0.17	7.31±0.07
8	NDT-2021-1	1.69±0.02	0.96±0.01	1.87±0.03
9	NDT-2021-2	4.98±0.18	2.89±0.04	5.43±0.03
10	NDT-2021-3	1.37±0.02	1.21±0.01	2.10±0.09
11	NDT-2021-4	1.74±0.03	1.13±0.01	1.95±0.04
12	NDT-2021-5	6.12±0.23	5.16±0.02	7.45±0.05
13	NDT-2021-6	3.23±0.10	2.10±0.09	4.21±0.04
14	NDT-2021-7	4.38±0.16	2.62±0.08	5.22±0.17
15	NDT-2021-8	4.14±0.16	3.61±0.02	4.82±0.02
16	NDT-2021-9	5.14±0.13	3.14±0.12	6.42±0.21
17	NDT-2021-10	3.24±0.08	2.29±0.02	4.24±0.15
18	NDT-2021-11	6.02±0.09	3.10±0.05	6.95±0.08
19	NDT-2021-12	4.10±0.12	2.17±0.08	5.67±0.12
20	NDT-2021-13	2.12±0.05	1.11±0.02	1.92±0.02
S. Em ±	0.032	0.071	0.035	0.062
CD @ 5%	0.091	0.203	0.100	0.179
CV	2.778	3.271	2.216	0.179
DF	59	59	59	59

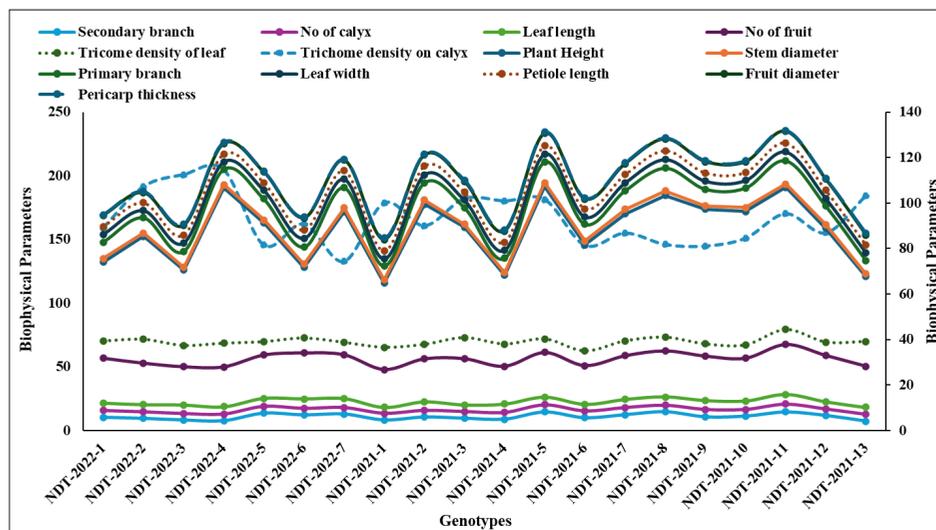


Fig. 1. Different biophysical parameters of tomato genotypes during *Rabi* season-2023-24

was recorded on NDT-2022-5 (6.23 ± 0.09), followed by NDT-2021-5 (6.12 ± 0.23 whitefly/3 leaves) and NDT-2021-11 (6.02 ± 0.09 whitefly/3 leaves) (Table 1). In earlier work, cultivar GS 600 (0.86 nymphs/2 cm² and 1.95 adults/leaf) was categorized as resistant to whitefly, possibly due to associated defensive traits (Jaiswal *et al.*, 2021; Dibbad *et al.*, 2022).

Screening for jassid (*A. biguttula biguttula*)

The lowest mean jassid population was observed on NDT-2021-1 (0.96 ± 0.01 jassid/3 leaves), followed by NDT-2021-13 (1.11 ± 0.02 jassid/3 leaves) and NDT-2021-4 (1.13 ± 0.01 jassid/3 leaves). In contrast, the highest jassid populations were recorded on NDT-2022-5 (5.22 ± 0.02 jassid/3 leaves), followed by NDT-2021-5 (5.16 ± 0.02 jassid/3 leaves) and NDT-2022-7 (5.09 ± 0.17 jassid/3 leaves) (Table 1). These results are comparable with Solangi *et al.* (2017), who reported the highest mean population of 3.61 jassids/leaf on Nagina genotypes.

Screening for aphid (*A. gossypii*)

In the case of aphid, the minimum mean population was recorded on NDT-2021-1 (1.87 ± 0.03 aphid/3 leaves), followed by NDT-2021-13 (1.92 ± 0.04 aphid/3

leaves) and NDT-2021-4 (1.95 ± 0.04 aphid/3 leaves). The maximum mean aphid populations were observed on NDT-2021-5 (7.45 ± 0.05 aphid/3 leaves), followed by NDT-2022-5 (7.34 ± 0.17 aphid/3 leaves) and NDT-2022-7 (7.31 ± 0.07 aphid/3 leaves) (Table 1). These observations are similar to Wade *et al.* (2020), who screened 15 tomato genotypes and reported N-2257 as promising (2.10 aphids/three leaves), while SUN-7610 was the most infested (3.05 aphids/three leaves).

Biophysical parameters

Among the genotypes, NDT-2021-5 recorded the maximum plant height (107.34 ± 8.59 cm), whereas the minimum height was observed in NDT-2021-1 (64.78 ± 3.89 cm). NDT-2021-8 recorded the maximum stem diameter (2.05 ± 0.04 cm), while the minimum stem diameter was observed in NDT-2021-13 (1.09 ± 0.04 cm). The maximum number of primary branches was recorded in NDT-2021-11 (10.24 ± 0.61), while the minimum was recorded in NDT-2021-13 (5.95 ± 0.51). The maximum number of secondary branches was recorded in NDT-2021-8 (14.80 ± 0.74), whereas NDT-2021-13 recorded the minimum (7.24 ± 0.43). The minimum number of calyxes per fruit was recorded in NDT-2021-12 (5.11 ± 0.07), while the maximum was observed in NDT-2021-

Table 2: Correlation between biophysical parameters and sucking pests infesting tomato during Rabi 2023-24

Biophysical and biochemical parameters	Insect Pests		
	Whitefly	Jassid	Aphid
Plant height (cm)	0.461*	0.476*	0.474*
Stem diameter (cm)	0.431	0.355	0.428
Number of primary branches /plants	0.730**	0.727**	0.727**
Secondary branch /plant	0.818**	0.811**	0.829**
No. of calyx /fruit	0.401	0.143	0.349
Leaf length (cm)	0.449*	0.414	0.460*
Leaf width (cm)	0.573**	0.592**	0.553*
Petiole length (cm)	0.518*	0.356	0.497*
Fruit diameter (cm)	0.471*	0.371	0.470*
Pericarp thickness (cm)	-0.881**	-0.842**	-0.901**
No. of fruits /plant	0.655**	0.510*	0.683**
Trichome density of leaf/ 25mm	-0.848**	-0.736**	-0.875**
Trichome density on calyx /25mm	-0.738**	-0.602**	-0.738**

** Correlation is significant at the 0.001 % level *Correlation is significant at the 0.005% level

Table 3: Correlation matrix between biochemical parameters sucking pests infesting tomato during *Rabi* 2023-24

Biochemical parameters	Insect Pests		
	Whitefly	Jassid	Aphid
Carbohydrate (mg/g) DW	0.614**	0.607**	0.658**
Chlorophyll (mg/g) FW	0.490*	0.621**	0.546*
Carotenoid (mg/g) FW	0.575**	0.464*	0.552*
Phenol (mg/g) FW	-0.596**	-0.567**	-0.628**
Lycopene (mg/100g) FW	0.787**	0.739**	0.790**
POD (g-1min-1) FW	0.842**	0.810**	0.839**
Protein (mg/g) FW	0.572**	0.461*	0.531*

** significant at the 0.001 % ; * significant at the 0.005%

11 (6.16 ± 0.023). Leaf length was maximum in NDT-2021-11 (7.39 ± 0.29 cm) and minimum in NDT-2021-1 (4.81 ± 0.01 cm). Leaf width was maximum in NDT-2022-6 (3.91 ± 0.01 cm) and minimum in NDT-2022-2 (3.19 ± 0.12 cm). Petiole length was maximum in NDT-2021-11 (3.91 ± 0.02 cm) and minimum in NDT-2021-13 (3.26 ± 0.11 cm). Fruit diameter was maximum in NDT-2021-5 (5.45 ± 0.03 cm) and minimum in NDT-2022-3 (4.23 ± 0.10 cm). Maximum pericarp thickness was recorded in NDT-2021-1 (0.74 ± 0.03 cm), while minimum pericarp thickness was observed in NDT-2022-5 (0.35 ± 0.05 cm). The maximum number of fruits per plant was recorded in NDT-2021-11 (39.57 ± 2.37), while the minimum was recorded in NDT-2021-1 (35.23 ± 1.76). Trichome density on leaf surface was maximum in NDT-2021-13 (19.45 ± 1.17) and minimum in NDT-2021-9 (9.45 ± 0.57). Trichome density on the calyx also varied significantly, with maximum recorded in NDT-2022-4 (136.23 ± 3.90) and minimum in NDT-2022-7 (63.61 ± 3.18) (Fig. 1).

Biochemical parameters

Total carbohydrate content was highest in NDT-2022-5 (181.28 ± 1.63 mg/g) and lowest in NDT-2021-3 (129.00 ± 0.35 mg/g). Chlorophyll content was maximum in NDT-2021-8 (1.87 ± 0.02 mg/g) and minimum in NDT-2021-7 (1.34 ± 0.03 mg/g). Carotenoid content was highest in NDT-2022-1 (1.98 ± 0.06 mg/g) and lowest in NDT-2021-1 (1.11 ± 0.00 mg/g). Phenol content was maximum in NDT-2021-13 (7.13 ± 0.06 mg/g) and minimum in NDT-2022-7 (4.62 ± 0.20 mg/g). Lycopene content was lowest in NDT-2021-13 (8.16 ± 0.09 mg/100 g) and highest in NDT-2021-8 (16.44 ± 0.64 mg/100 g).

Peroxidase activity was highest in NDT-2021-9 (423.33 ± 1.20 g⁻¹ min⁻¹ fresh weight) and lowest in NDT-2021-4 (213.00 ± 2.88 g⁻¹ min⁻¹). Protein content was maximum in NDT-2021-8 (1.61 ± 0.05 mg/g) and minimum in NDT-2021-1 (1.03 ± 0.01 mg/g) (Fig. 2).

Correlation of sucking pests with biophysical and biochemical parameters

Plant height showed significant positive correlations with *B. tabaci* ($r = 0.461^*$), aphid *A. gossypii* ($r = 0.474^*$) and jassids, *A. bigutella bigutella* ($r = 0.476^*$). Secondary branches showed highly significant positive association with whitefly ($r = 0.818^{**}$), aphid ($r = 0.829^{**}$) and jassid ($r = 0.811^{**}$). Leaf length showed significant positive correlations ($r = 0.449^*$, $r = 0.460^*$) with whitefly and aphid populations. Leaf width showed significant positive correlations with whitefly ($r = 0.573^*$), aphid ($r = 0.553^*$) and jassid ($r = 0.592^*$). Petiole length showed significant positive correlation with whitefly ($r = 0.518^*$) and aphid ($r = 0.497^*$). Fruit diameter also showed significant positive correlation with whitefly and aphid populations ($r = 0.518^*$, $r = 0.497^*$). Number of fruits per plant showed highly significant positive correlation with whitefly ($r = 0.655^{**}$, $p = 0.683^{**}$) and significant positive correlation with aphid ($r = 0.510^*$, $p = 0.05$). Trichome density on leaf surface had a strong, significant negative association with fruit borer, whitefly, aphid and jassid populations ($r = -0.908^{**}$, $r = 0.848^{**}$, $r = -0.875^{**}$, $r = -0.736^{**}$), respectively. Trichome density on the calyx showed strong significant negative association with whitefly, aphid and jassid populations ($r = -0.738^{**}$, $r = 0.738^{**}$, $r = -0.602^{**}$), respectively. Total carbohydrate content showed strong positive correlation with whitefly, aphid

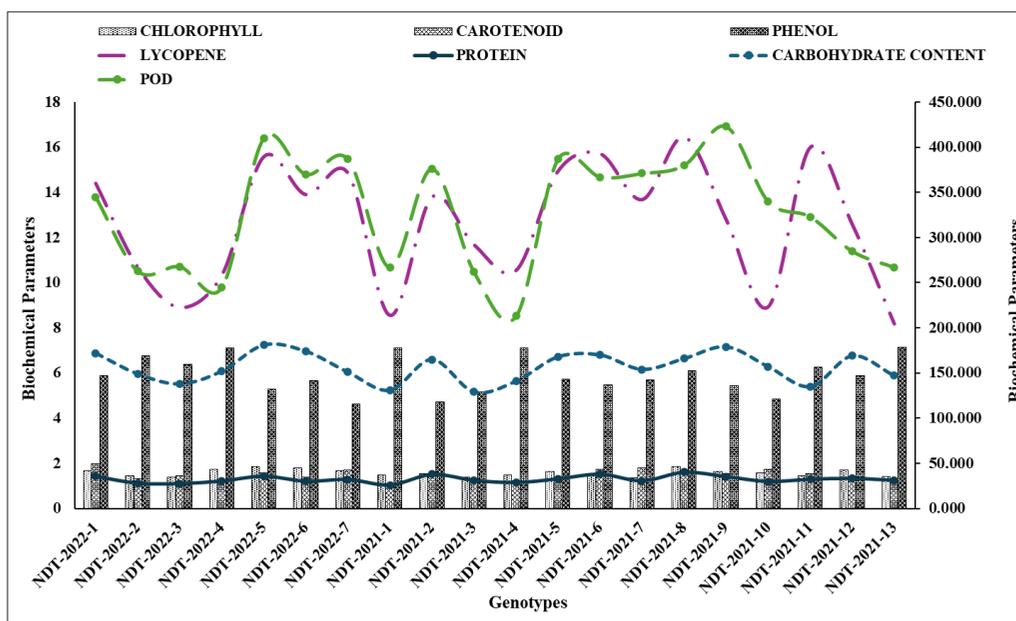


Fig. 2. Biochemical parameters of different tomato genotypes during Rabi season 2023-24

and jassid populations ($r = 0.614^{**}$, $r = 0.658^{**}$ and $r = 0.607^{**}$). Chlorophyll content showed significant positive correlation with fruit borer ($r = 0.463^{*}$), whitefly ($r = 0.490^{*}$) and aphid ($r = 0.546^{*}$), and a highly significant positive correlation ($r = 0.621^{**}$). The correlation study also indicated significant negative correlation between aphid and whitefly populations and total chlorophyll content ($r = -0.553^{**}$, -0.569^{**}). Carotenoid content showed strong positive correlation with whitefly ($r = 0.575^{**}$) and significant positive correlations with aphid ($r = 0.552^{*}$) and jassid ($r = 0.464^{*}$). Phenol showed highly significant negative correlations with whitefly, aphid and jassid populations ($r = -0.596^{**}$, $r = -0.628^{**}$ and $r = -0.567^{**}$). Lycopene showed strong significant positive correlation with whitefly, aphid and jassid populations ($r = 0.790^{**}$ and $r = 0.739^{**}$). Peroxidase activity showed highly significant positive correlation with whitefly, aphid and jassid populations ($r = 0.842^{**}$, $r = 0.839^{**}$ and $r = 0.810^{**}$). Protein content also showed significant positive correlation with aphid ($r = 0.531^{*}$) and jassid ($r = 0.461^{*}$).

The present findings are in agreement with Khanam *et al.* (2003), who reported that average plant height in variety V-187 (100.3 cm) and lowest plant height in V-433 (68.63 cm) had a positive but non-significant correlation ($r = 0.243$). Anu *et al.* (2021) also reported maximum stem diameter in BRDT 3 and Arka Vikas, and minimum in WIR 3956, and earlier correlation studies suggested stem diameter was significantly positively correlated with aphid and whitefly populations ($r = 0.368$ and 0.267). The number of primary branches showed

highly significant positive association with whitefly, aphid and jassid populations ($r = 0.730$, 0.727 and 0.727^{**}). Kaur *et al.* (2021) reported a strong positive correlation ($r = 0.76$, $p < 0.01$) between number of primary branches and jassid density. Sharma *et al.* (2021) observed a moderate positive correlation between secondary branches and aphids ($r = 0.54$, $p < 0.05$), while Bhatt *et al.* (2018) reported significant positive correlation between secondary branches and jassids ($r = 0.632$, $p < 0.01$). Ambule *et al.* (2015) reported a positive but non-significant correlation ($r = 0.3943$) between number of calyx per fruit and infestation, with NTL-14 showing lower calyx number (5.18). Parihar *et al.* (2021) and Dubey *et al.* (2023) reported significant positive correlation between leaf width and whitefly infestation ($r = 0.658$, $p < 0.01$). García-Martínez *et al.* (2022) reported consistent positive correlations between petiole length and *Myzus persicae* ($r = 0.65$, $p < 0.05$). Sharma and Sharma (2016) recorded significant positive correlation between tomato fruit diameter and whitefly ($r = 0.78$, $p < 0.01$). Muñiz and Nombela (2001) reported strong positive correlation between number of fruits per plant and *B. tabaci* population ($r = 0.78$, $p < 0.01$). Ghosh *et al.* (2021) observed a positive correlation between number of fruits per plant and *A. biguttula biguttula* in tomato fields ($r = 0.72$, $p < 0.01$). Taggar and Gill (2012) reported negative correlation between trichome density and whitefly eggs, nymphs and adults, and Bindu and Pramanik (2017) also observed negative correlation between trichome density and whitefly population. Ghosh *et al.* (2021) reported positive correlations between carotenoid content and

aphids ($r = 0.68$) and jassids ($r = 0.71$), and Sharma *et al.* (2019) reported significant positive correlation between carotenoid content and whitefly ($r = 0.82$). Hussain *et al.* (2017) reported significant negative correlation between phenol content and aphid population ($r = -0.843$), and Puthoff *et al.* (2010) reported significant negative correlation between phenol content and whitefly oviposition ($r = -0.712$). Upadhyay *et al.* (2018) reported significant negative correlation between lycopene content and incidence of multiple pests, while Taggar *et al.* (2012) reported positive correlation between peroxidase activity and whitefly ($r = 0.76$). Mahmood *et al.* (2017) reported strong positive correlation between peroxidase activity and resistance to jassid ($r = 0.92$). Bhadauria *et al.* (2017) reported significant positive correlation between protein content and fruit borer infestation ($r = 0.76$), and Babu *et al.* (2015) reported positive correlation of protein with aphid ($r = 0.69$), jassid ($r = 0.73$) and whitefly ($r = 0.68$), indicating that higher protein levels may contribute to susceptibility to these pests.

CONCLUSION

Anatomical traits such as trichomes on the leaf and calyx and pericarp thickness contributed to resistance in the selected tomato genotypes, particularly NDT-2022-2 (1.27 ± 0.01), followed by NDT-2022-4 (1.37 ± 0.04) and NDT-2021-3 (1.37 ± 0.02), which showed lower infestation by whitefly, aphid and jassid. Antibiosis studies further indicated that biochemical traits, especially phenol, played an important role in reducing survival of whitefly, jassid and aphid populations. In contrast, protein, lycopene, carbohydrate, chlorophyll, carotenoid and POD activity showed positive effects associated with pest incidence. Overall, the results indicate that genotypes with dense leaf trichomes, thicker pericarp, dense calyx trichomes and higher phenol content were more resistant, and these can be utilised in hybridisation programmes to develop tomato cultivars resistant to major sucking insect pests.

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AUTHORS CONTRIBUTION

SKT, SKS: conceptualization, methodology, designing and implementation of the experiments and

MS preparation; KRS, VKD, PB, ALK, UC: analysis, planning, supervising and formal analysis and MS finalisation.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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