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Plant Resistance

Diverse sources of resistance to *Thrips palmi* (Thysanoptera: Thripidae) in chili (*Capsicum annuum* and *C. chinense*)

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Thrips are the most devastating pests globally and significantly reduce productivity and quality of chili plants and fruits. Thrips infest chili crops, causing direct damage by feeding on leaves, fruits, and flowers and indirect damage as vectors for tospoviruses. Enhancing host plant resistance is a sustainable and eco-friendly approach to managing pests. Twenty-three entries, previously identified as resistant to the twospotted spider mite (*Tetranychus urticae* Koch), along with thrips-resistant entries identified through field-based observations, were evaluated against *Thrips palmi* Karny under controlled environmental conditions. Three *Capsicum annuum* and 6 *C. chinense* entries were identified as resistant to thrips. Validation screening confirmed these 9 entries as being resistant to *T. palmi*. A total of 7,072 single nucleotide polymorphisms (SNPs) identified through ddRAD sequencing of the 9 resistant entries were used for phylogenetic analysis. The entries clustered by species, with *C. chinense* forming a distinct clade separate from *C. annuum*; however, within each clade, the highly resistant entries were genetically divergent, suggesting the presence of diverse resistance genes. The diverse sources of host resistance to *T. palmi* identified provide a basis for future research in understanding host–arthropod interactions and breeding schemes to achieve higher levels of resistance in chili peppers.

Keywords: double digest restriction-site associated DNA sequencing, host plant resistance, hot pepper, phylogenetic analysis, single nucleotide polymorphism.

Introduction

Chili (*Capsicum annuum*) is an important spice and vegetable crop grown worldwide (Bosland and Votava 2012). Chilies are produced across various agroecological conditions, including the humid tropics, deserts, and cool temperate climates. Globally, dry chili is grown on 1.6 million ha with a production of 4.9 million tons, and green chili is grown on 2.02 million ha with a production of 36.9 million tons (Food and Agriculture Organization of the United Nations 2022). It has been estimated that approximately a quarter of the world's population consumes chili daily (Halikowski-Smith 2015).

Irrespective of the production system, chili growers will almost certainly face some production challenges associated with abiotic and biotic stresses (Barchenger et al. 2018, Chhapekar et al. 2018, Parisi et al. 2020, Nalla et al. 2023). Pests and pathogens are among the most common causes of reduced productivity in chili, and thrips (Thysanoptera: Thripidae) are one of the most devastating pests on a global scale (Raghavendra et al. 2023, Barik et al. 2025). At least, 16 species of thrips are pests of chili, which cause direct damage by feeding on chili fruits, flowers, and leaves. Feeding on leaves can affect leaf shape and size and thus carbon allocation in the plant, reduce photosynthetic capacity, and ultimately decrease yields (Shipp et al. 1998). Bronzing and silvering of the fruit skin and a subsequent reduction in market quality are consequences of thrips feeding damage on the fruits. In addition, thrips can also cause indirect damage by serving as vectors for virus transmission through saliva during feeding, with members of tospoviruses being among the most devastating for chili production (Dhall et al. 2021). A total of 15 thrips species globally have been identified as vectors of tospoviruses (Rotenberg et al. 2015, Suganthy et al. 2016, Ghosh et al. 2017, Singha et al. 2019). These viruses are responsible for causing yield losses of up to 100% in various crops, including chili (Kunkalikar et al. 2010).

Thrips palmi Karny, commonly known as the melon thrips, was first described by Karny (1925) from specimens collected in Sumatra and Java, Indonesia. This species is highly polyphagous, having been recorded on over 200 plant species from more than 36 families, including many economically important crops, such as chili, in which significant losses can occur, particularly in tropical and subtropical regions (Collins 2022). The rapid spread and role as a vector for tospoviruses have made melon thrips a significant concern for chili production worldwide. Effective management of *T. palmi* is challenging due to its rapid reproduction and resistance to many insecticides (Seal 2005, Shi et al. 2020, Venkatesan et al. 2022). In recent years, *Thrips parvispinus* (Karny), a destructive and highly polyphagous pest originating from Thailand (Collins and Mound 2000), has emerged as a significant threat to Asian chili production. The outbreak of *T. parvispinus* during the late wet season of 2021 caused severe damage to chili crops in India (Raghavendra et al. 2023), similar to what was previously reported in Indonesia (Sartiami and Mound 2013). This alarming scenario underscored the vulnerability of chili production systems and highlighted the urgent need for sustainable pest management strategies. Conventional management practices for thrips primarily rely on chemical treatments. However, these practices often fail to provide complete control, negatively impacting farmers, consumers, and the environment.

Several studies have been conducted to develop strategies to minimize future losses caused by thrips infestations (Bulle et al. 2023, Rodríguez and Coy-Barrera 2023, Abana and Amarasekare 2024). Recently, IIHR-B-HP-79 (*C. frutescens*) was found to have high levels of resistance to *T. parvispinus* among 481 *Capsicum* germplasm accessions evaluated (Pavani et al. 2024). Before that, 6 entries, 4 *C. annuum* and 2 *C. baccatum*, were identified as sources of resistance against *T. parvispinus* and *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) (Maharijaya et al. 2011). However, studies on resistance in *Capsicum* to *T. palmi* are limited (Gniffke et al.2013, Visschers et al. 2019a, Saeko et al. 2020), and no resistant varieties or hybrids are currently available. Resistance to thrips in *Capsicum* spp. is influenced by site-specific conditions and geographic regions, making the identification of sources of broad-spectrum host resistance, with the ability to resist diverse thrips species challenging (Visschers et al. 2019a).

The development of thrips-resistant varieties has great potential for management by enhancing the effectiveness of control strategies and mitigating the transmission of tospoviruses. However, knowledge gaps in sources of stable resistance that represent resistance in the production systems, the genetic mechanisms of thrips resistance, quantitative trait loci, and molecular markers associated with resistance limit approaches to breed thrips-resistant chili varieties. Due to the tremendous damage caused by thrips on a global scale and the overall lack of sources of host resistance, there is a clear and urgent need to study host resistance. Therefore, this study was conducted to evaluate entries of *C. annuum* and *C. chinense* for resistance to *T. palmi* under controlled environmental conditions, validate the identified host resistance, and investigate the genetic diversity among the resistant entries using SNP-based phylogenetic analysis. The identified resistant sources will facilitate the development of thrips-resistant chili cultivars.

Materials and Methods

Initial Screening against *Thrips palmi*

Chili entries previously identified as resistant to twospotted spider mite and those identified as resistant from field-based observations in Taiwan and Bangladesh, as well as entries that exhibited resistance to *T. parvispinus* during field trials in Hyderabad, India, during the devastating 2021 season were screened against *T. palmi*. Entries with resistance to twospotted spider mite have been reported to potentially also be resistant to thrips (unreported data). Thus, we selected 14 twospotted spider mite-resistant entries for screening. A total of 23 entries belonging to C. annuum (14) and C. chinense (9) including 2 susceptible checks, AVPP9905 and PBC 1867 (Table 1), were used in the initial screening against *T. palmi*. Five plants per entry were sown in 3-in pots containing a sterilized mixture of soil and substrate (Kingroot No. 1) in a 7:3 ratio. The plants were arranged in a completely randomized design in a climate-controlled greenhouse (temperature: 25 °C, humidity: 70% to 80%) in Shanhua, Tainan, Taiwan (lat. 23.1°N, long. 120.3°E, elevation 12 m.a.s.l.). Plants were maintained as uniformly as possible, following best management practices (Berke et al. 2005). Eight wk after sowing (at the 6- to 8-leaf stage), each plant was infested with 20 adult female thrips (0 to 3 d after emerging from pupae), obtained from the Agricultural Chemicals Research Institute, Taichung, Taiwan in 2021, and reared on white Dutch runner beans (*Phaseolus coccineus* L.). Plants were scored 21 d after infestation (DAI) using a 6-point scale (Srinivasan and Rakha 2019). Scores ranged from 0 to 6, where 0 indicates no symptoms, 1 represents tiny eruptions in the interveinal area or on the dorsal side of the terminal 3 to 4 leaves, 2 is characterized by curling along the leaf margin in the terminal 3 to 4 leaves, 3 signifies severe scarring on the terminal and a few basal leaves or on the dorsal side while the ventral side remains unaffected, 4 denotes stunted plants with severely curled leaves and greatly reduced leaf area, 5 represents plants with no leaves, leaving only the stem, and 6 indicates dead plants (Supplementary Fig. S1). Additionally, the number of adults and larval thrips on the first 3 leaves at the apical meristem was recorded at 21 DAI.

Validation Screening

The most resistant individuals among the selected entries that were putatively resistant to *T. palmi* were self-pollinated one generation to increase homozygosity and, ultimately, homogeneity. The validation screening was conducted using self-pollinated seed from the 9 most resistant entries identified during the preliminary screening, along with the susceptible check, PBC 1867. As AVPP9905 was not highly susceptible in the initial screening, PBC 1867—being more susceptible—was used as the susceptible check in this experiment. Forty plants per entry were arranged in a completely randomized design. For validation, all plants were maintained under the same conditions as the initial screening. Thrips were reared and released following the same protocols as the initial screening. Plants were scored 28 DAI using a 6-point scale (Srinivasan and Rakha 2019).

Table 1. *Capsicum* entries screened against *Thrips palmi* in a controlled environment greenhouse

Entry[y]	Species	Origin or pedigree	User feedback or observation
PBC 145	*C. annuum*	India	Broad spectrum tolerance
C03938A	*C. annuum*	Costa Rica	Tolerant
C00069	*C. annuum*	Costa Rica	Tolerant
PBC 140	*C. annuum*	India	Tolerant
PBC 141	*C. annuum*	Hungary	Tolerant
PBC 142	*C. annuum*	India	Tolerant
PBC 204	*C. annuum*	Malaysia	Tolerant
PBC 460	*C. annuum*	Sri Lanka	Tolerant
PBC 473	*C. annuum*	Indonesia	Tolerant
PBC 535	*C. annuum*	Indonesia	Tolerant
PBC 716	*C. annuum*	India	Tolerant
PBC 188	*C. chinense*	Brazil	Resistant to twospotted spider mite
PBC 190	*C. chinense*	Brazil	Resistant to twospotted spider mite
PBC 911	*C. chinense*	Tanzania	Resistant to twospotted spider mite
PBC 1787	*C. chinense*	Mexico	Resistant to twospotted spider mite
PBC 1794	*C. chinense*	USA	Resistant to twospotted spider mite
PBC 1803	*C. chinense*	China	Resistant to twospotted spider mite
PBC 1909	*C. chinense*	Taiwan	Resistant to twospotted spider mite
PBC 1910	*C. chinense*	Taiwan	Resistant to twospotted spider mite
PBC 1912	*C. chinense*	Taiwan	Resistant to twospotted spider mite
AVPP9905	*C. annuum*	Taiwan	Susceptible check
AVPP2003	*C. annuum*	[z]Jin'sJoy/4/Bangchang-selex///HDA210/Szechwan10//MC4///Jin's Joy//Kulai*3/PBC932/Jin's Joy//Kulai*3/PBC932///Kulim/HDA248/4/Bangchang-selex///HDA210/Szechwan10//MC4	Tolerant to *Thrips parvispinus* in a field trial in Hyderabad, India, in 2021
PBC 1867	*C. annuum*	Mexico	Susceptible check

[y] AVPP = Asian vegetable pepper; PBC = Pepper breeding collection; C = collection

[z] Pedigree annotation used is from Purdy et al. (1968), where / = A x B, // = (A x B) x (C x D), /// = [(A x B) xC], //// = [A x (B xC)] x [Dx (Ex F)], and * = backcross preceded by the number of backcross generations.

DNA Isolation and Sequencing

Genomic DNA was isolated from the fresh leaved using the DNeasy Plant Mini Kit (Qiagen, Hilden, Germany) following the manufacturer's instructions. Illumina sequencing libraries were constructed as described by Meyer and Kirchner (2010) with minor modifications. Genomic DNA (200 ng) was cleaved using restriction enzymes *PstI-HF* (CTGCAG, New England Biolabs Inc., Ipswich, Massachusetts, USA) and *MspI* (CCGG, New England Biolabs Inc., Ipswich, Massachusetts, USA). After restriction digest, samples were ligated with 2 adapters for sequencing, followed by polymerase chain reaction to amplify the target DNA fragments. Then, the DNA fragments between 350 and 600 bp were selected to complete the sequencing library preparation. The sequencing library was sequenced by Illumina Hiseq_X using a double-end 150 bp run. After performing SNP calling, a total of 7,545,864 SNPs were identified across the 9 resistant entries. The SNPs were filtered based on a coverage depth threshold of 10 and a minimum count of 15, resulting in a final set of 7,072 SNPs. The refined dataset was then utilized to construct a Neighbor-Joining tree in MEGA11 (Tamura et al. 2021), illustrating the distance-based relationships among the resistant entries.

Statistical Analysis

In the validation screening, the severity score and the number of larval and adult *T. palmi* observed on the apical 3 leaves of the 40 plants per entry were used for analysis. The severity scores, number of larval, and adult *T. palmi* were analyzed using a Kruskal–Wallis test to assess differences among entries (Kruskal and Wallis 1952). Post-hoc analysis was conducted using Dunn's test with a Bonferroni adjustment ($\alpha = 0.05$) (Dunn 1964). All analyses were performed using R (R Core Team 2023).

Results

Initial Screening against *Thrips palmi*

Out of 23 entries screened for resistance to *T. palmi*, 9 highly resistant entries were identified. An average score of 2.5 ($n = 115$ plants) was recorded, and no entries were found to have average rating scores of >4 or 0. The 4 most resistant entries were members of *C. chinense*, with PBC 911 having the lowest score (1.1 ± 0.7), followed by PBC 1910 (1.2 ± 0.3), PBC 1787 (1.3 ± 0.3), and PBC 1803 (1.6 ± 0.5) (Fig. 1). The susceptible check, PBC 1867 (*C. annuum*), had the highest score (3.9 ± 0.2) followed by C03938A (3.7 ± 0.4) and PBC 141 (3.4 ± 0.4) (Fig. 1). An overall average of 1.9 adult thrips and 2.3 larval thrips was observed on the first 3 leaves at the apical meristem when counted at 21 DAI (Fig. 2). The fewest number of larval thrips were observed in the apical 3 leaves of PBC 911 (0.4 ± 0.5 larvae), followed by PBC 1787 (0.6 ± 0.9) and PBC 140 (0.8 ± 1.3 larvae) (Fig. 2). The entries PBC 460, PBC 1910, AVPP2003, and PBC 140 had the fewest number of adult thrips (0.6 ± 0.5, 0.6 ± 0.5, 0.6 ± 0.9, and 0.8 ± 0.5, respectively) (Fig. 2). The greatest number of adults and larval thrips was recorded in PBC 141 (3.6 adult thrips and 6.2 larval thrips) at 21 DAI (Fig. 2). Importantly, AVPP9905 was not highly susceptible in our experiment, while PBC 1867 was (Figs 1 and 2). Therefore, we utilized PBC 1867 as our susceptible check in downstream experiments.

Validation Screening

In the validation screening of the 9 most resistant entries identified in our preliminary experiment compared with a susceptible check, all entries were found to be resistant to thrips (Fig. 3). Score at 28 DAI ($\chi^2 = 195.7$, df = 9, $P < 0.01$) number of adult ($\chi^2 = 50.8$, df = 9, $P < 0.01$), and larval thrips ($\chi^2 = 30.1$, df = 9, $P < 0.01$) in the apical 3 leaves significantly differed among entries. Similar to the initial screening, no entries had a symptom severity rating of 0 or >4,

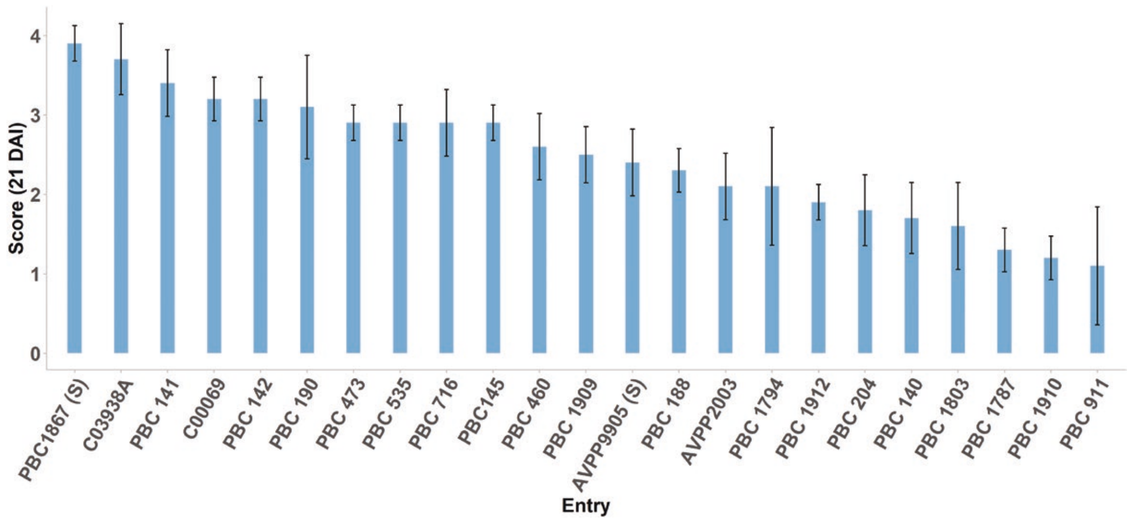

Fig. 1. Average symptom severity scores (mean ± SD) at 21 d after infestation of 23 *Capsicum* entries, including 2 putative susceptible checks, PBC 1867 and AVPP2003, screened against *Thrips palmi*.

indicating that resistance in these entries can be considered moderate, but not immune. A greatest number of adult and larval thrips (0.7 ± 0.9 and 1.2 ± 1.6, respectively) were recorded for the susceptible check, PBC 1867. The *C. annuum* entry PBC 140 had the lowest number of adult and larval thrips (0 adult thrips and 0.2 ± 0.4 larval thrips) followed by the *C. chinense* entries PBC 1794 (0.1 ± 0.2 adult thrips and 0.3 ± 0.5 larval thrips), PBC 1803 (0.2 ± 0.4 adult thrips and 0.4 ± 0.9 larval thrips), and PBC 911 (0.2 ± 0.4 adult thrips and 0.4 ± 0.9 larval thrips) (Table 2).

Phylogenetic Analysis

The resistant entries were sequenced to assess genetic relatedness as a basis for downstream breeding and research (Fig. 4). A total of 7,072 SNPs obtained from ddRAD-seq were used for phylogenetic analysis. The evolutionary history was inferred using the Neighbor-Joining method (Saitou and Nei 1987). The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1,000 replicates) are shown above the branches (Fig. 4) (Felsenstein 1985). The minimum bootstrap value observed was 88, indicating strong nodal support and high reliability for the inferred clades in the phylogenetic analysis (Fig. 4). The resistant entries were grouped predominantly by species, with members of *C. chinense* forming a distinct clade separate from the *C. annuum* (Fig. 4). However, the highly resistant entries within each clade, PBC 140 in *C. annuum* and PBC 911, PBC 1787, and PBC 1910 in *C. chinense* were genetically divergent.

Discussion

Chili, an important horticultural crop, is frequently prone to damage by various thrips species, leading to significant yield losses (Shipp et al. 1998, Walsh et al. 2012, Kumar et al. 2013). Identifying and understanding resistance within *Capsicum* can provide a strong foundation for breeding programs addressing these challenges.

To identify sources of host resistance, 23 chili entries were screened against *T. palmi* under controlled conditions. Selection of the entries used for screening was based on either previous observation from field trials or results of previous screening against twospotted spider mites (unpublished data). Out of the 23 entries, we identified 9 resistant entries, which were validated to exhibit host resistance to *T. palmi*, 6 entries being *C. chinense* (PBC 911, PBC 1787, PBC 1794, PBC 1803, PBC 1910, and PBC 1912) and 3 *C. annuum* (PBC 140, PBC 204, and AVPP2003) entries. Validation experiments are essential to confirm the reliability and consistency of observed resistance, especially in arthropod pest resistance screening. Similar to our findings, CGN21557/No. 4661 (*C. chinense*) and CGN16975/AC 1979 (*C. annuum*) were recently identified as being resistant to *T. palmi* (Saeko et al. 2020). Recently, 3 *C. annuum* accessions and 2 *C. chinense* accessions were identified as resistant to *F. occidentalis*, (Macel et al. 2019, Visschers et al. 2019b). In another study, 4 *C. annuum* entries and 2 *C. baccatum* accessions were identified as resistant to 2 species of thrips, *F. occidentalis* and *T. parvispinus* (Maharijaya et al. 2011). Recently, IIHR-B-HP-79 (*C. frutescens*) was found to be highly resistant, while IIHR 4550, IIHR 4501, and IIHR 4410 (*C. chinense*) were moderately resistant to *T. parvispinus* (Pavani et al. 2024). Most work in host resistance to thrips species in chili identified members of *C. annuum* or *C. chinense* as resistant, supporting our findings. However, further research is required to understand host resistance in other chili species and whether resistance modality is different among the different species.

Among the 9 *T. palmi*-resistant entries reported here, 6 (PBC 911, PBC 1787, PBC 1794, PBC 1803, PBC 1910, and PBC 1912) were also resistant to twospotted spider mite. The association might indicate that resistance to these 2 arthropod pests could be conferred by similar mechanisms previously reported in other species such as chrysanthemum (*Chrysanthemum* × *morifolium* Ramat.) (Kos et al. 2014). However, further studies would need to be conducted to validate this cross-resistance association in chili. Similarly, a paprika entry, EC-391082, was previously reported as being resistant to both *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) and broad mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae), demonstrating low symptom incidence and severity (Babu et al. 2002).

The similarities in the type of damage and high correlation between damage levels caused by different thrips species (*T. parvispinus* and *F. occidentalis*) suggest that thrips resistance in chili, as well as in other crops, may not be highly species-specific (Maharijaya et al. 2011, Bovio et al. 2025). Resistance in *C. annuum* to *F. occidentalis* was positively correlated with *S. dorsalis* but not with *T. palmi*, suggesting that resistance might be partially thrips species-specific (Visschers et al. 2019a, Saeko et al. 2020). In another study, no correlation between damage caused by *F. occidentalis* and *Thrips tabaci*

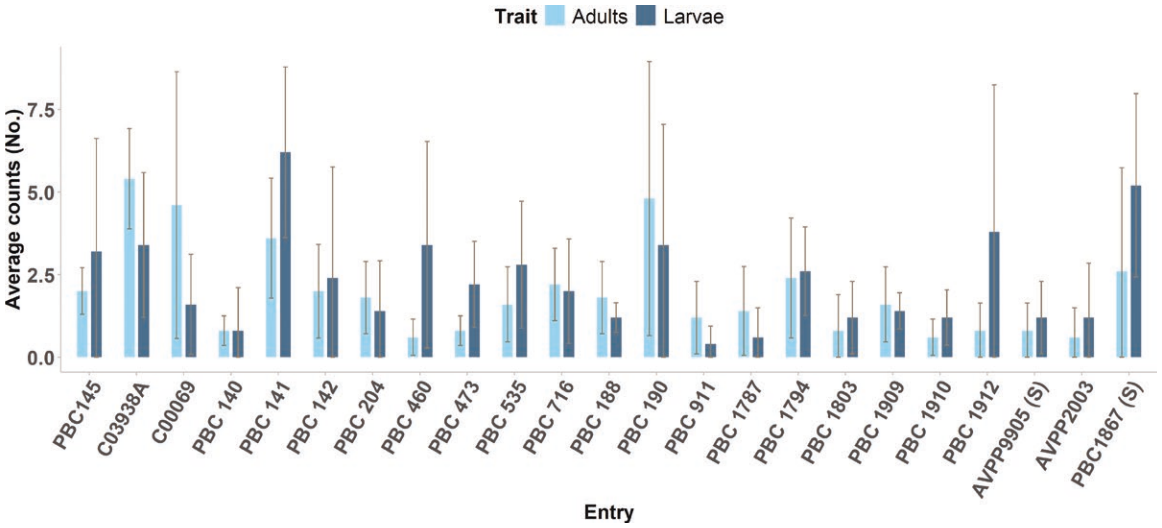

Fig. 2. The average number of larval and adult *Thrips palmi* (mean ± SD) in the apical 3 leaves at 21 d after infestation of 23 *Capsicum* entries.

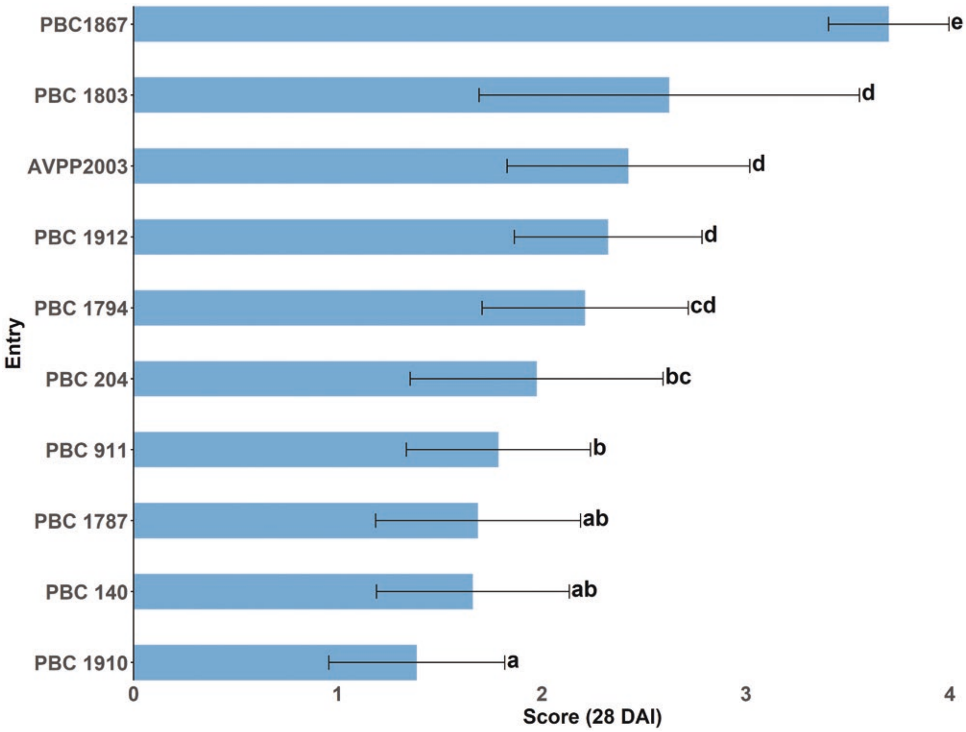

Fig. 3. The average symptom severity score (mean ± SD) of nine *Capsicum* entries and the susceptible check (PBC 1867) at 28 d after infestation with *Thrips palmi*. Letters to the right of each horizontal bar indicate groups that are significantly different based on Dunn's test with Bonferroni adjustment (α = 0.05); bars sharing the same letter are not significantly different.

Lindeman on the same accession was found (Visschers et al. 2019b). Broad-spectrum thrips resistance would be highly beneficial for chili cultivation in areas where multiple thrips species can infest the crop (Gao et al. 2021a, Palanisamy et al. 2023). One *T. palmi*-resistant *C. annuum* entry, AVPP2003, was observed to have high levels of tolerance to *T. parvispinus* under open field conditions in India, in an area with very high incidence, suggesting that broad-spectrum resistance might exist in some *Capsicum* entries. However, our work needs to be expanded to include multiple species of thrips, especially *T. parvispinus*, to validate the existence of broad-spectrum resistance against thrips in chili.

Significant variation observed in adult and larval counts during validation screening highlights the effectiveness of the identified resistant entries in controlling the pest pressure. The *C. annuum* entry AVPP2003, however, supported larval populations similar to those on the susceptible check, suggesting that *T. palmi* was equally attracted to AVPP2003 as a host and potentially attributed to a lack of adverse effects on the thrips biology. Interestingly, higher larval counts observed in AVPP2003 in the validation experiment compared with initial screening may be attributed to differences in growth conditions or the variation in the thrips infestation density during screening. Notably, despite high larval counts, few adult thrips were observed

Table 2. The average number of larval and adult *Thrips palmi* on the 3 apical leaves of 9 *Capsicum* entries and the susceptible check (PBC 1867) at 28 d after infestation. Post-hoc analysis was conducted using Dunn's test with a Bonferroni adjustment (α = 0.05)

Entry	Larvae (mean ± SD)	Adults (mean ± SD)
PBC 1867	1.2 ± 1.6^{b}	0.7 ± 0.9^{b}
PBC 1803	0.4 ± 0.9^{a}	0.2 ± 0.4^{a}
AVPP2003	1.1 ± 2.3^{ab}	0.2 ± 0.4^{a}
PBC 1912	0.8 ± 1.3^{ab}	0.3 ± 0.5^{a}
PBC 1794	0.3 ± 0.5^{a}	0.1 ± 0.2^{a}
PBC 204	0.5 ± 1.0^{a}	0.1 ± 0.3^{a}
PBC 911	0.4 ± 0.9^{ab}	0.2 ± 0.4^{a}
PBC 1787	0.5 ± 1.0^{ab}	0.1 ± 0.3^{a}
PBC 140	0.2 ± 0.4^{a}	0^{a}
PBC 1910	0.5 ± 1.2^{ab}	0.1 ± 0.2^{a}

Means within a column that do not share a common superscript letter differ significantly based on Dunn's test with Bonferroni correction, $\alpha = 0.05$.

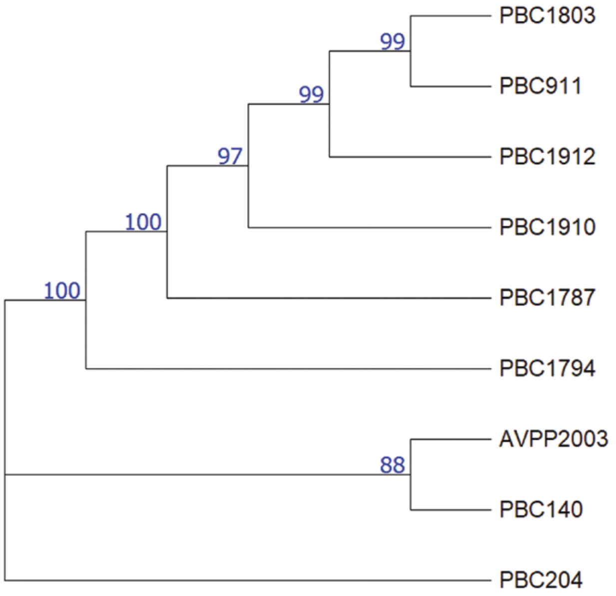

Fig. 4. Genetic diversity among the nine *Thrips palmi* resistant entries identified, based on 7,072 SNPs used to conduct a Neighbor-Joining tree.

in the validation screening. This indicates that AVPP2003 supports larval development but may limit adult survival or reproduction, possibly due to antibiosis. These findings highlight the complexity of pest resistance and emphasize the need for maintaining consistent experimental conditions while evaluating plants for insect resistance. Thus, the thrips resistance exhibited by AVPP2003 may be attributed to tolerance and/or antibiosis (Fery and Schalk 1991). It has been shown that larval thrips are most fastidious, compared with adult thrips, regarding the host plant as a food source and oviposition (Varga et al. 2010). Successful reproduction and larval development of thrips on a plant likely reflects the favorability of the plant as a host for thrips. For *T. palmi*, larval development time is influenced by both temperature and host plant quality (Yadav and Chang 2014, Dhall et al. 2021). *Thrips palmi* complete their development in ~14 d at 15 °C, 5 d at 26 °C, and 4 d at 32 °C, emphasizing the significant role temperature plays in their developmental rate (Capinera 2000). Gao et al. (2021b) found that some hosts of *Thrips flavus* Schrank resulted in shorter development duration, suggesting an oviposition preference. Both larval and adult densities of *T. tabaci* are significantly higher on floral organs than vegetative parts across various host plants (Loredo Varela and Fail 2022). This preference indicates that specific plant structures offer more suitable conditions for thrips development. In addition, larval densities can be useful for assessing plant suitability as thrips hosts. Varying larval densities per flower of *Frankliniella* species on pepper and tomato plants suggest differences in host suitability (Baez et al. 2011). The variations in larval densities can provide insights into the relative favorability of different host plants for thrips populations. Given the association between low symptom severity scores and low numbers of adult thrips and larval thrips, most of the 9 entries could serve as critical genetic resources for further investigations into the biochemical, metabolomic, and molecular basis of resistance to thrips in chili.

Resistance among the nine *Capsicum* entries can be considered moderate, as none exhibited immunity, with symptom severity scores of 0. Similarly, either adult thrips or larval thrips or both were recorded for every entry in the experiment at 28 DAI. Cardona et al. (2002) also reported that in beans (*Phaseolus vulgaris* L.), resistance to *T. palmi* was moderate, with no immune entries. However, the authors found that resistance could be improved by hybridizing 2 intermediate resistant but genetically divergent entries and developing segregating populations, revealing quantitative inheritance patterns.

Phylogenetic analysis of the 9 resistant entries revealed predominant clustering by species, with members of *C. chinense* forming a clade distinct from the *C. annuum* breeding entries. Interestingly, the highly resistant breeding entries within each clade (PBC 140 in *C. annuum* and PBC 911, PBC 1787, and PBC 1910 in *C. chinense*) were genetically distinct. Genetic divergence among the most resistant entries highlights a promising opportunity for future research, as it suggests the presence of potentially different resistance genes (Cardona et al. 2002), and allows gene pyramiding to achieve enhanced resistance levels after identifying the genes responsible for resistance (Joshi and Nayak 2010, Wu et al. 2019, Dormatey et al. 2020). Given the influence of species on the clustering, we did not include susceptible entries in the analysis as our aim was to understand the genetic relatedness among resistant entries, providing insights for downstream breeding research.

Identifying host-resistant entries within *Capsicum* represents a significant step toward developing sustainable solutions for managing thrips, which threaten chili productivity. We identified 9 thrips-resistant entries, 6 exhibiting resistance to twospotted spider mite, suggesting the potential presence of broad-spectrum resistance mechanisms. The lack of close genetic relatedness among the most resistant entries indicates the presence of distinct resistance genes, offering opportunities for gene pyramiding to enhance resistance levels. These findings provide valuable genetic resources and a foundation for further studies to elucidate the molecular and biochemical basis of resistance, paving the way for breeding resilient *Capsicum* cultivars capable of mitigating thrips-induced yield losses.

Supplementary material

Supplementary material is available at *Journal of Economic Entomology* online.

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