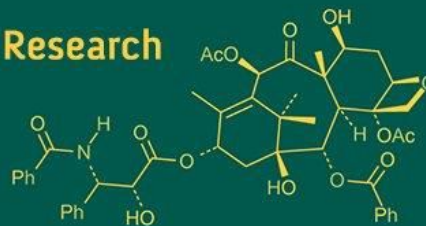


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693

ISSN Online: 2617-4707

NAAS Rating (2026): 5.29

IJABR 2026; 10(4): 35-43

www.biochemjournal.com

Received: 27-01-2026

Accepted: 01-03-2026

M Safna

Department of Agricultural
Entomology, College of
Agriculture, Kerala Agricultural
University, Thrissur, Kerala, India

Berin Pathrose

Department of Agricultural
Entomology, College of
Agriculture, Kerala Agricultural
University, Thrissur, Kerala, India

M Allada

Department of Plant Pathology,
G.B. Pant University of
Agriculture and Technology,
Uttarakhand, India

Naduvilthara U Visakh,

Department of Agricultural
Entomology, College of
Agriculture, Kerala Agricultural
University, Thrissur, Kerala, India

Haseena Bhaskar

Department of Agricultural
Entomology, College of
Agriculture, Kerala Agricultural
University, Thrissur, Kerala, India

MT Ranjith

Department of Agricultural
Entomology, College of
Agriculture, Kerala Agricultural
University, Thrissur, Kerala, India

RR Rachana

ICAR-NBAIR, Bengaluru,
Karnataka, India

A Latha

Agricultural Research Station,
Mannuthy, Kerala Agricultural
University, Thrissur, Kerala, India

Mani Chellappan

Department of Agricultural
Entomology, College of
Agriculture, Kerala Agricultural
University, Thrissur, Kerala, India

Corresponding Author:**M Safna**

Department of Agricultural
Entomology, College of
Agriculture, Kerala Agricultural
University, Thrissur, Kerala, India

Diversity of thrips (order: Thysanoptera) in leguminous crops: A comprehensive review

M Safna, Berin Pathrose, M Allada, Naduvilthara U Visakh, Haseena Bhaskar, MT Ranjith, RR Rachana, A Latha and Mani Chellappan

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i4a.8053>

Abstract

Thrips (order: Thysanoptera) are reported in almost all the pulse crops and are economically important insect pests worldwide. This review analyses current knowledge on the diversity of thrips species infesting legume crops, encompassing species documented across diverse agroecosystems. Thrips cause direct feeding damage, flower abortion, pod deformation, and indirect losses by transmission of tospoviruses on leguminous crops such as cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogaea*), soybean (*Glycine max*), common bean (*Phaseolus vulgaris*), chickpea (*Cicer arietinum*), pigeon pea (*Cajanus cajan*), lentil (*Lens culinaris*), pea (*Pisum sativum*), mung bean (*Vigna radiata*) and black gram (*Vigna mungo*), leading to total crop failure in severe conditions. Key thrips species were *Megalurothrips usitatus*, *Megalurothrips distalis*, *Thrips parvispinus*, *Thrips palmi*, *Frankliniella schultzei*, *Caliothrips indicus*, *Scirtothrips dorsalis*, and *Thrips florum*, causing major economic losses across different geographical regions. The review addresses species taxonomy, classification, geographic distribution, invasiveness, seasonal dynamics, host-plant interactions, and biotic and abiotic factors affecting diversity. Moreover, the importance of early detection and morphological and molecular identification of these cryptic insects in integrated pest management (IPM) is emphasized. A significant knowledge gap exists in understanding thrips diversity in many understudied legumes, the presence of thrips complexes within each crop, the occurrence of cryptic species within the order, and their ecological interactions. This study provides valuable insights into the sustainable management of thrips in legume agroecosystems, laying the foundation for future research.

Keywords: Thripidae, Phytophagous thrips, Species diversity, Fabaceae, Crop damage, Integrated pest management

1. Introduction

Leguminous crops (Family: Fabaceae) are important food sources with high protein content and are adaptable to diverse agroclimatic conditions. It provides essential dietary fibres and protein for human and livestock consumption (Singh *et al.*, 2003) ^[80], while contributing to atmospheric nitrogen fixation through root nodules, making them an integral part of sustainable agricultural production systems (Kolawole *et al.*, 2000; Giller, 2001; Zhu *et al.*, 2005) ^[21, 39, 98]. It contributes to the supply of lysine-rich proteins, which are deficient in cereal-based diets (Ufaz and Galili, 2008) ^[90]. It helps alleviate poverty and micronutrient deficiencies among millions of people around the world. Major legume crops such as groundnut (*Arachis hypogaea*), soybean (*Glycine max*), pigeon pea (*Cajanus cajan*), common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*) are grown in tropical, subtropical and temperate regions. Pulses occupy 90-96 million hectares, producing 87.7 million tonnes globally (FAOSTAT, 2023) ^[18].

However, insect pests are among the major biotic stresses, particularly thrips, which are affecting legumes and hindering the attainment of maximum yield potential. These destructive pests belong to the order Thysanoptera, and the major agriculturally important species belong to the family Thripidae, suborder Terebrantia. Major morphological characters include asymmetrical mouthparts, with the right mandible absent, and fringed wings, with complex life cycles that include two larval instars and two pupal stages (prepupa and pupa) (Kumar and Omkar, 2021) ^[42, 43]. The shorter lifecycle leads to rapid reproduction

rates, producing several generations that contribute to their explosive population dynamics and invasiveness (Lewis, 1973) [44, 45]. Thrips cause direct feeding damage, leading to leaf distortion, flower abortion, and bronzing of pods, resulting in yield losses of 20-80% (Singh and Allen, 1980) [81]. Flower bud abortion is a major constraint affecting pod yield. Their role as vectors of tospoviruses such as Tomato Spotted Wilt Virus (TSWV) is equally significant, causing severe yield losses in crops (Culbreath *et al.*, 2003) [15].

Despite their ecological and economic importance, knowledge of the diversity of thrips species across different legume host plants, their geographical expansion across tropical, subtropical, and temperate regions, their invasiveness, and their functional ecology remains incomplete. There is no single published work with a comprehensive synthesis. The present review aims to compile existing knowledge on species diversity, distribution, geographical patterns, ecology, economic importance, and destructive potential associated with pulse crops, and to provide a foundation for future integrated pest management interventions targeting these pests.

2. Taxonomy and classification of thrips

2.1 Taxonomic position and suborders

Thrips (Thysanoptera) are classified into two suborders, Terebrantia and Tubulifera. Major phytophagous thrips species belong to Terebrantia and are characterized by a saw-like ovipositor (terebrata) in females, which helps them lay eggs inside plant tissues. In contrast, Tubulifera deposit eggs on the plant surface using a tube-like structure formed by the posterior end of the abdomen (Mound, 2005) [56], and Phlaeothripidae is the only family in Tubulifera.

More than 2000 species are present in Terebrantia, of which most of the agriculturally important species belong to the Family Thripidae (Mound and Morris, 2007) [55]. The key genera, such as *Thrips*, *Frankliniella*, *Scirtothrips*, *Sericothrips* and *Megalurothrips*, form pest complexes in pulse crops. The key thrips pest of legume crops is *Megalurothrips usitatus* worldwide (Mound and Marullo, 1996; Tyagi and Kumar, 2016) [54, 88]. Many tubuliferan genera, such as *Haplothrips*, are phytophagous and some of which are mycophagous and predatory in nature (Mound and Marullo, 1996; Mound, 2005) [54, 56].

2.2 Cryptic species and species identification challenges

Thrips are minute in size, and slide mounting is essential to identify specific characteristics of each genus (Mound and Kibby, 1998) [53, 89]. The major taxonomic characters are longitudinal wing venation, antennal sensoria, ocellar setae, seta of pronotum, mesonotum and metanotum, abdominal tergite and ctenidia (Mound and Kibby, 1998; Moritz *et al.*, 2004) [49, 53, 89]. Usually, the identification process requires expert knowledge and detailed analysis of slide-mounted specimens with suitable dichotomous keys. However, cryptic species within the same genus are challenging, and identifying them is cumbersome. Some characters show considerable variations, complicating reliable identification. Integration of morphological identification with molecular characterization can confirm these insects to the species level and is found to be more reliable (Hebert *et al.*, 2003; Rebijith *et al.*, 2014) [25, 67].

The advent of modern approaches such as DNA barcoding using the cytochrome c oxidase subunit I (COI) gene, in silico sequence analysis, and the construction of

phylogenetic trees using software such as MEGA has revolutionized thrips taxonomy (Marullo *et al.*, 2020) [47]. Computerized key-based photomicrographs and videos of thrips species are helpful to address morphological characters (Moritz *et al.*, 2000) [48]. Semi-automated identification of biological objects can be achieved using artificial intelligence (Fedor *et al.*, 2008) [19]. The morphometric analysis based on quantitative and qualitative characters, followed by principal component analysis, allows for distinguishing between cryptic species (Kucharczyk and Kucharczyk, 2009; Kucharczyk, 2010) [40, 41]. Recently, complete genome sequencing has been performed for *Frankliniella occidentalis* and *Thrips palmi* (Rotenberg *et al.*, 2020) [76]. These promising tools are reliable and easier for thrips identification than traditional procedures. Multilocus phylogenetics, high-throughput sequencing/metabarcoding, and integrative taxonomy are among the novel methods adopted for thrips identification (Batovska *et al.*, 2021) [9]. The application of genomic and transcriptomic (omics) technologies was most recently utilized to understand thrips diversity. Long-read sequencing (PacBio/Illumina) and Hi-C scaffolding is employed to synthesize high-quality genomes for species such as *Stenchaetothrips biformis* (Hu *et al.*, 2023) [26].

3. Thrips species diversity in legumes

3.1 Thrips diversity worldwide

Earlier literature documents a diverse group of thrips species associated with pulse crops and approximately 60 thrips species are reported from legume production systems (Lewis, 1997; Mound and Marullo, 1996; Morse and Hoddle, 2006; Tyagi and Kumar, 2016) [44, 45, 54, 88]. The thrips are attracted to legumes and infest leaves, flowers, and pods depending on growth stage, host plant cues, geographic patterns, altitude, and season. Tropical and subtropical regions support more abundant and diverse thrips species than temperate regions (Wang *et al.*, 2014) [93]. Rainfall patterns also adversely affect thrips population buildup and the crop pest interactions are highly complex (Morsello *et al.*, 2008) [51]. Major thrips species documented in legumes are listed in Table 1.

Jandricic *et al.* (2024) [30] documented *F. occidentalis* and *T. tabaci*, as well as the newly invasive *Thrips parvispinus*, *Frankliniella schultzei*, and *Echinothrips americanus*, from an Ontario greenhouse during a survey from 2016 to 2024. *Frankliniella occidentalis* has been reported from at least sixty-nine countries (He *et al.* 2020; Fan *et al.* 2024) [17, 23, 24]. *Thrips palmi* is a key pest in legumes and a major tospovirus vector (WBNV and GBNV) on legumes in India. Distinct genetic signatures (microsatellite allele frequency distributions) were observed in *T. palmi* populations associated with legumes, indicating host-associated selection pressure on the species (Rehsawla *et al.*, 2025) [68]. A multiyear study (2015-2018) on thrips associated with soybean highlighted the diverse assemblage of 20 thrips species across Eastern Europe, with two dominant species, viz., *T. tabaci*, *Aeolothrips intermedius*, and *Thrips fuscipes*. However, *Kakothrips robustus*, which specifically attacks crops in the Fabaceae, was absent in soybean (Twardowski *et al.*, 2024) [86]. Molecular studies revealed the presence of cryptic species within *Megalurothrips usitatus*, *T. palmi*, and *T. tabaci* in legume cropping systems (Rebijith *et al.*, 2014; Nault *et al.*, 2014; Kadirvel *et al.*, 2013) [31, 59, 67]. A

diverse thrips fauna occurs in legumes globally, according to earlier literature.

4. Geographical distribution patterns

4.1 Tropical and subtropical regions

Sub-Saharan Africa, South Asia, and Southeast Asia are the major thrips diversity hubs, with the highest species richness and abundance. Tropical and subtropical ecosystems support several thrips species in legumes (Srinivasan *et al.*, 2017) [83]. In Africa, *Megalurothrips sjostedti* is the major thrips species occurring in cowpea (Togola *et al.*, 2019; Ngakou *et al.*, 2008) [60, 85]. *Frankliniella schultzei* was recorded as the most abundant and widely distributed species in Brazil, Colombia, Central America. Some invasive species, such as *T. parvispinus* and *T. palmi*, were reported tropical and subtropical regions than in temperate regions. *Heliothrips ceylonicus*, *Frankliniella intonsa*, *Ceratothripoides claratris*, *Microcephalothrips abdominalis*, *Megalurothrips typicus* and *Craspedothrips minor* were reported as new species occurring in vegetables and pulses in Central India (Akanand *et al.*, 2026) [5]. *Scirtothrips dorsalis*, *F. schultzei*, *T. palmi* and *Caliothrips indicus* are the most common thrips species in groundnut (Kandakoor *et al.*, 2014) [32].

The tropical and sub-tropical regions are favourable and support exceptionally high thrips diversity. These are major centers of diversity for several thrips genera (Mound, 2005)

[56]. Dry weather (30.3 mm rainfall) with moderately high temperatures (15.6-28.2 °C) was found favourable to *T. tabaci*, whereas high humidity and rainfall negatively affected its population (Waiganjo *et al.*, 2008) [92]. Most of the thrips species complexes recorded in tropical and subtropical legume systems are economically important and require timely interventions and management strategies.

4.2 Temperate regions

Species richness is comparatively low in legume crops across Europe, North America, and Temperate Asia. A severe winter with temperatures near 10 °C did not support thrips populations in the temperate region, whereas high temperatures in June (25.8 °C) led to thrips population peaks (Lopez *et al.*, 2007) [99].

Neohydatothrips variabilis is the major thrips species infesting soybean in North America, which transmits Soybean Vein Necrosis Virus (SVNV) (Keough *et al.*, 2016) [35]. *Frankliniella occidentalis* is another species that is invasive, causing significant crop losses in beans and peas across Europe and parts of Asia. In western and northern Europe, *Kakothrips pisivorus* has been documented as a host-specific thrips of pea and faba bean, whereas *T. tabaci* has been reported as a common and widely distributed species in parts of the Mediterranean region (Reitz, 2009) [71].

Table 1: Major thrips species in leguminous crops

Sl. No.	Thrips species	Family	Host crops	Location	Key findings	Reference
1	<i>M. sjostedti</i> , <i>F. schultzei</i> , <i>Hydatothrips adolfifrigeri</i> , <i>Florithrips traegardhi</i> , <i>A. mexicanus</i>	Thripidae	Cowpea	Burkina Faso	<i>Arorathrips mexicanus</i> was identified on only cowpea	Ouedraogo <i>et al.</i> , 2025 [61]
2	<i>T. palmi</i> , <i>M. usitatus</i> , <i>F. occidentalis</i> , <i>F. bispinosa</i> , <i>F. insularis</i>	Thripidae	Snap bean	Southern Florida	Sex ratios are biased towards females for all species	Ivey <i>et al.</i> 2024 [27]
3	<i>F. schultzei</i> , <i>C. phaseoli</i>	Thripidae	Soybean	Brazil	Widespread species with seasonal variation	Warpechowski <i>et al.</i> 2024 [94]
4	<i>T. parvispinus</i> , <i>M. usitatus</i> , <i>T. palmi</i>	Thripidae	Mung bean	India	New host record in India for <i>T. parvispinus</i>	Gothi and Panickar, 2024 [22]
5	(19 species) <i>F. intonsa</i> , <i>T. tabaci</i> , <i>S. dorsalis</i> <i>T. palmi</i>	Thripidae	Legumes	Bangladesh	10 new species reported	Khatun <i>et al.</i> , 2024 [36]
6	<i>M. usitatus</i> , <i>Thrips palmi</i>	Thripidae	Snap bean	Florida	The highest number of thrips was in flowers followed by leaves and pods	Adhikari <i>et al.</i> 2023 [1]
7	<i>M. usitatus</i> , <i>T. parvispinus</i> , <i>T. hawaiiensis</i> <i>C. brunneus</i>	Thripidae	Long bean, French bean and winged bean	Malaysia	<i>M. usitatus</i> was abundant during hot and dry weather, but lower in the rainy season.	Zafirah and Azidah, 2018 [96]
8	<i>M. sjostedti</i>	Thripidae	Cowpea	Uganda	Severe yield losses upto 100%	Agbahoungba <i>et al.</i> , 2017 [3]
9	<i>T. palmi</i> , <i>F. schultzei</i> , <i>S. dorsalis</i>	Thripidae	Groundnut, cowpea	India	Documented tospovirus vectors	Ghosh <i>et al.</i> , 2017 [20]
10	<i>C. phaseoli</i> , <i>F. brevicaulis</i> , <i>F. gardenia</i> , <i>F. insularis</i> , <i>F. schultzei</i> , <i>F. tritici</i> ,	Thripidae, Phlaeothripidae	6 fabaceous crops, including cowpea	Brazil	Biological information about damage and hosts	Lima <i>et al.</i> 2013 [46]

	<i>H. gowdeyi</i> <i>S. minimus</i>					
11	<i>C. phaseoli</i> , <i>Frankliniella gossypiana</i> , <i>E. americanus</i>	Thripidae	Soybean	Puerto Rico	Thrips were abundant in leaves and flowers	Viteri <i>et al.</i> 2009 ^[91]
12	<i>F. schultzei</i>	Thripidae	Groundnut	USA	Major vector of Groundnut ringspot orthotospovirus (GRSV) and Tomato spotted wilt orthotospovirus (TSWV)	Culbreath <i>et al.</i> (2003) ^[15]
13	<i>T. palmi</i>	Thripidae	Beans	Colombia	A potential source of resistance was identified	Cardona <i>et al.</i> 2002 ^[13]

4.3 Invasiveness of thrips and global expansion through legume systems

International trade of plant material is a major driver of the emergence of invasive species. The absence of natural enemies in the introduced region leads to rapid multiplication and spread across a large geographical area. *Frankliniella occidentalis*, a native of the United States, now spreads across Europe (Kirk and Terry, 2003; Reitz, 2009) ^[38, 71]. *Megalurothrips usitatus*, present in Florida in 2020, was found to be spread across the United States, Mexico, and Cuba, posing a significant threat to leguminous crops such as soybean, snap bean, and cowpea (Reitz *et al.*, 2020; Kumar *et al.*, 2021; Adhikari *et al.*, 2023) ^[1, 42, 43, 70]. It is widely distributed worldwide (Tang *et al.*, 2023). The characters developed in invasive species, such as polyphagy, rapid reproductive potential, insecticide resistance, haplotype and virus transmission potential, are attributed to their dominance, causing the displacement of native thrips fauna (Reitz, 2009; Kirk and Terry, 2003; Riley *et al.*, 2011) ^[38, 71, 73]. *Thrips palmi*, *S. dorsalis*, *T. parvispinus* were recorded as invasive in many legume crops (Rebjiith *et al.*, 2014) ^[67].

A comprehensive barcoding survey of legumes, vegetables, and ornamentals in Bangladesh revealed that *T. tabaci*, *F. schultzei*, *T. palmi*, and *C. indicus* were confirmed using COI barcoding, and that *T. parvispinus* was recorded as invasive and newly documented in Bangladesh (Khatun *et al.*, 2024) ^[36]. *Thrips parvispinus* was recorded in Florida and other warm US states and studies were conducted to manage this pest using conventional and biorational insecticides (Ataide *et al.*, 2024) ^[8]. *Thrips parvispinus* was first recorded on pepper, and its detection is significant for legume production in Central America, as pepper and common bean are cultivated alongside in the same agroecological zones (Rodríguez Arrieta *et al.*, 2025) ^[74]. It is now recorded across multiple continents globally distributed in legumes and other crops (Tyagi *et al.*, 2015; Sridhar *et al.*, 2021) ^[82, 87]. A global invasion of *T. parvispinus* witnessed during the past few years urged tracing the invasion roots and genetic basis of the species' explosive global spread. The haplotype pattern revealed that all populations in Europe, the Americas, and Africa were derived from a single dominant haplotype, confirming a homogeneous founder effect (Ahmed *et al.*, 2024) ^[4]. Stringent quarantine measures and surveillance systems are essential for detecting and managing invasive thrips species in legume agroecosystems.

5. Functional ecology of thrips in legume systems

5.1 Host- plant phenology

Some thrips species show a preference for leaves, flowers or pods. *Thrips tabaci*, *F. occidentalis* and *T. palmi* commonly

occur during seedling and early vegetative stages (Ren *et al.*, 2025; Rudramuni *et al.*, 2022; Bottenberg *et al.*, 1997; Jackai and Adalla, 1997) ^[10, 28, 72, 78]. As plants reach reproductive stages, these species are replaced by *M. usitatus*, *F. occidentalis* and *T. parvispinus*, which prefer flowers (Reitz *et al.*, 2020; Yasmin *et al.*, 2022; He *et al.*, 2020; Alabi *et al.*, 2003) ^[7, 23, 24, 70, 95]. Thrips population peaks synchronized with the flowering stage (Twardowski *et al.*, 2024) ^[86]. Jackai and Daoust (1986) ^[29] highlighted that thrips cause bronze discolouration and distortion on pods unfit for market.

5.2 Seasonal population dynamics

Abiotic factors, such as rainfall, temperature, and planting dates, strongly influence thrips population dynamics in legumes. An increase in thrips population was observed during the dry season, with low humidity, in tropical regions (Waiganjo *et al.*, 2008) ^[92]. Temperate regions have peak populations during summer, coinciding with the optimal temperature during the flowering period (Lopez *et al.*, 2007) ^[99].

5.3 Thrips flower interactions

Complex ecological interactions are involved between legumes and flower-infesting thrips. Many thrips feed on pollen and floral exudates and hide inside papilionaceous flowers, which protect them from natural enemies and pesticide sprays. Beyond simple herbivory, they facilitate pollen exchange during foraging, thereby establishing a facultative mutualism. However, the negative effects of feeding on sap from flowers cause discolouration, flower deformation, and eventually flower bud abortion, which directly affect productivity by reducing pod set. The microhabitat within the closed floral structure is a potential barrier to effective control, as spray penetration into the flowers is comparatively low (Jackai and Daoust, 1986) ^[29].

6. Thrips-virus interactions in legume crops

6.1 Orthotospoviruses transmitted by thrips in legumes

Thrips are vectors of orthotospovirus (Family: Tospoviridae). Orthotospoviruses such as tomato spotted wilt orthotospovirus (TSWV), groundnut ringspot orthotospovirus (GRSV), iris yellow spot orthotospovirus (IYSV) and watermelon silver mottle orthotospovirus (WSMoV) are enveloped, negative ssRNA viruses transmitted in a persistent propagative manner solely by 1st instar larvae of thrips belonging to the family Thripidae. Twenty-nine tospoviruses are transmitted by sixteen thrips species globally (Ghosh *et al.*, 2017) ^[20]. Tomato spotted wilt orthotospovirus (TSWV) affects a wide range of legumes and is transmitted by *F. occidentalis* (Rotenberg *et al.*, 2015) ^[77], whereas IYSV is transmitted by *T. tabaci*

(Pandi *et al.*, 2024) ^[63]. Cowpea, groundnut, and soybean were found affected by WSMoV transmitted by *T. palmi* (Mou *et al.*, 2021; Pradeep *et al.*, 2024) ^[52, 66], whereas Groundnut bud necrosis orthotospovirus (GBNV) transmits mungbean, cowpea, french bean, field pea, urdbean and wild *Vigna* species are severely affected by (Akram *et al.*, 2026) ^[6]. Groundnut Ringspot Virus (GRSV) is transmitted by *F. schultzei* (Riley *et al.*, 2011; Pappu *et al.*, 2009) ^[64, 73]. The major virus in soybean is Soybean Vein Necrosis Virus (SVNV), which is transmitted by *Neohydatothrips variabilis* (Rotenberg *et al.*, 2015; Schwartz *et al.*, 2020) ^[77, 100]. Major thrips species that transmit viruses associated with legumes cause substantial yield losses and require integrated pest management strategies to reduce thrips populations below the economic threshold.

6.2 Transmission efficiency of the thrips species

The epidemiology of orthotospovirus diseases is directly influenced by thrips abundance in legumes and susceptibility of plants (Pappu *et al.*, 2009; Rotenberg *et al.*, 2015) ^[64, 77]. Young seedlings are affected severely compared to older plants. A high thrips population is directly linked to rapid virus infection (Riley *et al.*, 2011) ^[73]. Furthermore, environmental factors can influence virus transmissions and thrips population (Rotenberg *et al.*, 2015; Keough *et al.*, 2018) ^[35, 77]. Resistance varieties, cultural control, and insecticide applications are integrated to effectively prevent virus transmission through vectors.

7. Damage mechanisms and economic impact

7.1 Direct feeding damage

Asymmetric rasping and sucking mouth parts with reduced mandibles leave lacerations on plant tissue caused by rupture of epidermal and mesophyll cells. The silvery streaks and bronzing, combined with leaf distortion and malformation, cause defoliation and stunted growth in young plants (Kumar and Omkar, 2021) ^[42, 43]. Flowers are significantly affected by thrips feeding, with discolouration and malformation ultimately leading to abortion of flower buds and crop failure.

7.2 Yield loss assessment

A possible yield loss from 80-100% was reported from previous studies (Singh and Allen, 1980; Nault *et al.*, 2006) ^[81, 101]. The simultaneous occurrence of thrips complexes in crop fields, their detection, identification, direct and indirect damage assessment, resistance development, and host plant resistance are attributed to the complexity of thrips management in legumes (Riley *et al.*, 2011) ^[73]. EIL was established at seven thrips per inflorescence for *M. sjostedti* infesting cowpea (Nabirye *et al.*, 2003) ^[58]. Similarly, a loss of 36.65% of pods was experienced on green beans due to thrips damage (Duff *et al.*, 2014) ^[16].

8. Management of thrips diversity in legumes

8.1 Cultural and agronomic Approaches

Cultural control includes field sanitation, use of reflective mulches, intercropping, trap cropping and crop rotation (Buckland *et al.*, 2013; Shelton *et al.*, 2005; Reitz *et al.*, 2012) ^[12, 69, 79]. Field sanitation is adopted to eliminate potential breeding sites of thrips. A chemotactic approach based on a push-pull strategy using an alarm pheromone and an aggregation pheromone was followed against western flower thrips (Kim *et al.*, 2023) ^[37].

Drip irrigation reduces thrips populations compared to sprinkler irrigation.

The cultural practices minimise chemical interventions in integrated pest management (Rodriguez *et al.*, 2023) ^[75]. Optimising these control tactics based on specific crop and environmental factors is essential for effective thrips management.

8.2 Host plant resistance

Breeding and use of resistant varieties are widely considered sustainable approaches for managing thrips in legumes. It is the most economically accessible management strategy for marginal farmers. There are three resistance mechanisms associated with legumes to sustain yields despite thrips infestation, viz., antixenosis, antibiosis, and tolerance (Painter, 1951) ^[62]. Numerous studies have been conducted on screening legume germplasm for resistance to thrips (Yasmin *et al.*, 2022; Alabi *et al.*, 2011; Agbahoungba *et al.*, 2018) ^[2, 7, 95]. Advances in genomic approaches, such as QTL mapping and marker-assisted selection (MAS), are accelerating resistance breeding in legumes (Muchero *et al.*, 2009; Boukar *et al.*, 2016) ^[11, 57].

8.3 Biological control

Predatory mites (*Amblyseius cucumeris*, *Neoseiulus barkeri* and *Typhlodromips montdorensis*) and predatory thrips, *Orius* sp., *Geocoris* sp., entomopathogenic fungi (*Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillium lecanii*) and entomopathogenic nematodes are natural enemies documented against thrips. *Beauveria bassiana*, predatory mites and pirate bugs are important bioagents against thrips infesting legumes (Chi *et al.*, 2024) ^[14]. Biological control is considered variable, depending on environmental factors. Reduced pesticide use, timing of applications, and maintenance of landscape heterogeneity can conserve natural enemies.

8.4 Chemical control and insecticide resistance

The most important management tool for thrips in the legume production system is synthetic insecticides. Neonicotinoids, organophosphates, and pyrethroids are among the insecticide groups used against thrips. Seed treatment with neonicotinoids, such as thiamethoxam, is widely practised. Spinetoram and spinosad are reported as the most effective insecticides for *M. usitatus*. Moreover, broflanilide, emamectin benzoate and cyantraniliprole were also recorded as alternative insecticides against this species (Peng *et al.*, 2025) ^[65]. Seed treatment with thiamethoxam and imidacloprid was found effective against *M. sjostedti* infesting cowpea (Kaushik *et al.*, 2015) ^[3, 4].

However, insecticide resistance is a major threat in thrips management. Even new insecticide molecules are reported to be less effective against thrips populations. Field evolved resistance of bean flower thrips, *M. usitatus*, to broflanilide with LC₅₀ values ranging from 7804.77 to 20 594.08 mg/L (Kang *et al.*, 2026) ^[33]. Resistant management strategies, including insecticide rotation with insecticides of different modes of action, leaving refugia for susceptible populations, and integrating with non-chemical methods, are essential to slow down resistance development.

9. Conclusion

Substantial knowledge gaps remain in the basic understanding of thrips diversity and management, and these

need to be addressed. Systematic documentation of thrips diversity in understudied legume cultivating regions, identification of cryptic species complexes within genera by molecular characterisation using sophisticated techniques, elucidation of underlying crop-pest interaction mechanisms, detailed epidemiological studies of virus diseases, investigation of genetic basis of host plant resistance, assessment of the effect of climatic factors on thrips population dynamics and evaluation of resistance development in legume thrips are identified as important future line of research.

Thrips are a major pest associated with legumes worldwide. There are diverse thrips species distributed in tropical, sub-tropical and temperate regions. Most thrips are highly polyphagous. These pests are responsible for significant economic damage and yield losses through direct feeding damage and indirect damage through virus transmission keeps them the most challenging pests of legumes. Species identification, using both morphological and molecular methods, is integrated to confirm cryptic and major species, which is essential for decision-making and effective management.

An integrated management approach is required to achieve effective, environmentally safe population reduction below ETL. It includes host plant resistance, cultural control, biological control and chemical management. Breeding of resistant varieties using modern genomic tools and multiple field evaluations of varietal performance against thrips accelerates their development and deployment. The environmental factors influencing thrips population and community dynamics in legume ecosystems, and the effects of natural enemies, determine thrips buildup in legume ecosystems.

The global threat posed by invasive species like *T. parvispinus* and *T. palmi*, and their expansion, urges immediate action to reduce thrips infestations in legume systems. Rising concerns about the devastating effects of the thrips species on yield losses and crop productivity demand effective pest management strategies. This review provides a foundation of baseline data on thrips diversity in legumes over the last ten years and helps to catalyse further research on sustainable thrips management to safeguard legume production and food security

Acknowledgements

The authors thank the Department of Agricultural Entomology, College of Agriculture, Vellanikkara

Conflict of interest

No conflict of interest.

References

- Adhikari R, Seal DR, Schaffer B, Liburd OE, Khan RA. Within-plant and within-field distribution patterns of *Asian bean thrips* and *melon thrips* in snap bean. *Insects*. 2023;14(2):175. DOI: 10.3390/insects14020175
- Agbahoungba S, Karungi J, Odong TL, Badji A, Kumi F, Mwila N, *et al*. Biochemical constituents influencing the resistance to flower bud thrips in cowpea (*Vigna unguiculata* (L.) Walp.) germplasm. *J Anim Plant Sci*. 2018;28(1):161-171.
- Agbahoungba S, Karungi J, Odong TL, Badji A, Sadik K, Rubaihayo PR. Stability and extent of resistance of cowpea lines to flower bud thrips in Uganda. *Afr Crop Sci J*. 2017;25(1):1-24. DOI: 10.4314/acsj.v25i1.1
- Ahmed MZ, *et al*. Global invasion of *Thrips parvispinus* (Karny) (Thysanoptera: Thripidae) across three continents associated with its one haplotype. *J Appl Entomol*. 2024;148(10):1021-1035. DOI: 10.1111/jen.13312
- Akanand D, Rana DK, Sivalingam PN, Dixit A, Tyagi K, Sridhar J. Report of six new thrips species on vegetable and pulse crops in central India. *Curr Sci*. 2026;130(2):245-252. DOI: 10.18520/cs/v130/i2/245-252
- Akram M, Kumar D, Jamil A, Pratap A, Nair RM, Dixit GP. *Groundnut bud necrosis orthotospovirus*: an emerging viral problem of pulse crops. *Arch Virol*. 2026;171(4):128. DOI: 10.1007/s00705-026-06128-x
- Alabi OY, Odebiyi JA, Jackai LEN. Field evaluation of cowpea cultivars (*Vigna unguiculata* [L.] Walp.) for resistance to flower bud thrips (*Megalurothrips sjostedti* Trybom) (Thysanoptera: Thripidae). *Int J Pest Manag*. 2003;49(4):287-291. DOI: 10.1080/09670870310001596324
- Ataide LMS, *et al*. Efficacy of conventional and biorational insecticides against the invasive pest *Thrips parvispinus* (Thysanoptera: Thripidae) under containment conditions. *Insects*. 2024;15(1):48. DOI: 10.3390/insects15010048
- Batovska J, Piper AM, Valenzuela I, Cunningham JP, Blacket MJ. Developing a non-destructive metabarcoding protocol for detection of pest insects in bulk trap catches. *Sci Rep*. 2021;11:7946. DOI: 10.1038/s41598-021-86945-9
- Bottenberg H, Tamò M, Arodokoun D, Jackai LEN, Singh BB, Youm O. Population dynamics and migration of cowpea pests in northern Nigeria: implications for integrated pest management. In: Singh BB, Raj MDR, Dashiell KE, Jackai LEN, editors. *Advances in cowpea research*. Ibadan: IITA; 1997. p. 271-284.
- Boukar O, Fatokun CA, Huynh BL, Roberts PA, Close TJ. Genomic tools in cowpea breeding programs: status and perspectives. *Front Plant Sci*. 2016;7:757. DOI: 10.3389/fpls.2016.00757
- Buckland K, Reeve JR, Alston D, Nischwitz C, Drost D. Effects of nitrogen fertility and crop rotation on onion growth and yield, thrips densities, *iris yellow spot virus* and soil properties. *Agric Ecosyst Environ*. 2013;177:63-74. DOI: 10.1016/j.agee.2013.06.005
- Cardona C, Frei A, Dorn S. Resistance of common bean cultivars to *Thrips palmi*. *J Econ Entomol*. 2002;95(5):1066-1073. DOI: 10.1603/0022-0493-95.5.1066
- Chi Y, Yu C, Feng M, *et al*. Effects of field releases of *Neoseiulus barkeri* on *Megalurothrips usitatus* abundance and arthropod diversity. *Sci Rep*. 2024;14:14247. DOI: 10.1038/s41598-024-64740-y
- Culbreath AK, Todd JW, Brown SL. Epidemiology and management of tomato spotted wilt in peanut. *Annu Rev Phytopathol*. 2003;41:53-75. DOI: 10.1146/annurev.phyto.41.052002.095557
- Duff JD, Church CE, Healey MA, Senior L. Thrips incidence in green beans and the degree of damage caused. In: XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and

- Landscapes (IHC2014). Acta Hort. 2014;1105:19-26. DOI: 10.17660/ActaHortic.2015.1105.3
17. Fan ZF, Chen YP, Fan R, Chen B, Qian L, Gui FR. Effects of elevated \$CO_2\$ and spinetoram on the population fitness and detoxification enzymes activities in *Frankliniella occidentalis* and *F. intonsa*. J Pest Sci. 2024;97(2):933-950. DOI: 10.1007/s10340-023-01689-3
 18. FAO. Crops and livestock products. FAOSTAT. Rome: Food and Agriculture Organization of the United Nations; 2023. Available from: <https://www.fao.org/faostat/en/#data/QCL>
 19. Fedor P, Malenovský I, Vaňhara J, Sierka W, Havel J. Thrips (Thysanoptera) identification using artificial neural networks. Bull Entomol Res. 2008;98:437-447. DOI: 10.1017/S000748530800587X
 20. Ghosh A, Dey D, Timmanna, Basavaraj YB, Mandal B, Jain RK. Thrips as the vectors of tospoviruses in Indian agriculture. In: Mandal B, *et al.*, editors. A century of plant virology in India. New Delhi: Springer; 2017. p. 465-492. DOI: 10.1007/978-981-10-4904-0_20
 21. Giller KE. Nitrogen fixation in tropical cropping systems. Wallingford: CAB International; 2001.
 22. Gothi HR, Panickar BK. First report of (*Thrips parvispinus*) Karny infestation on mungbean in Gujarat, India. J Sci Res Rep. 2024;30(6):833-837. DOI: 10.9734/jsrr/2024/v30i62100
 23. He Z, Guo JF, Reitz SR, Lei ZR, Wu SY. A global invasion by the thrip, *Frankliniella occidentalis*: current virus vector status and its management. Insect Sci. 2020;27(4):626-645. DOI: 10.1111/1744-7917.12721
 24. He Z, Guo JF, Reitz SR, Lei ZR, Wu SY. A global invasion by the thrip, *Frankliniella occidentalis*: current virus vector status and its management. Insect Sci. 2020;27(4):626-645.
 25. Hebert PDN, Cywinska A, Ball SL, deWaard JR. Biological identifications through DNA barcodes. Proc R Soc B. 2003;270:313-321. DOI: 10.1098/rspb.2002.2218
 26. Hu QL, Ye ZX, Zhuo JC, Li JM, Zhang CX. A chromosome level genome assembly of *Stenchaetothrips biformis* and comparative genomic analysis highlights distinct host adaptations among thrips. Commun Biol. 2023;6:813. DOI: 10.1038/s42003-023-04801-x
 27. Ivey C, Hahn PG, Vallad GE, Soto-Adames FN, Hochmuth R, Beuzelin J, Jean-Louis A, Smith HA. Abundance of *Megalurothrips usitatus* (Bagnall) (Thysanoptera: Thripidae) and other thrips in commercial snap bean fields in the Homestead Agricultural Area (HAA). Fla Entomol. 2025;108(1):33-48. DOI: 10.1515/flaent-2024-0075
 28. Jackai LEN, Adalla CB. Pest management practices in cowpea: a review. In: Singh BB, Raj MDR, Dashiell KE, Jackai LEN, editors. Advances in cowpea research. Ibadan: IITA; 1997. p. 240-258.
 29. Jackai LEN, Daoust RA. Insect pests of cowpeas. Annu Rev Entomol. 1986;31:95-119. DOI: 10.1146/annurev.en.31.010186.000523
 30. Jandricic SE, Summerfield A, Maw HEL, Brunet BM, Buitenhuis R. Thrips species composition in Ontario greenhouse floriculture: innovative identification tools and implications for integrated pest management. Insects. 2024;15(3):211. DOI: 10.3390/insects15030211
 31. Kadirvel P, Srinivasan R, Hsu YC, Su FC, De La Pena R. Application of cytochrome oxidase I sequences for phylogenetic analysis and identification of thrips species occurring on vegetable crops. J Econ Entomol. 2013;106(1):408-418. DOI: 10.1603/EC12232
 32. Kandakoor SB, Khan HK, Chakravarthy AK, Kumar CA, Venkataravana P. Biochemical constituents influencing thrips resistance in groundnut germplasm. J Environ Biol. 2014;35(4):675-681.
 33. Kang JJ, Li HJ, Chen JC, Tian HP, Shen XJ, Wang SY, Chen QY, Yuan FM, Gong YJ, Guo SK, Wei SJ. Field-evolved resistance of the bean flower thrips *Megalurothrips usitatus* to a novel insecticide broflanilide. Pest Manag Sci. 2026;82(5):1120-1132. DOI: 10.1002/ps.70652
 34. Kaushik AK, Yadav SK, Srivastava P. Comparative efficacy of some insecticides for thrips control in cowpea (*Vigna unguiculata* L.). Ann Plant Prot Sci. 2015;23(2):294-297. DOI: 10.5958/0974-0112.2015.00056.X
 35. Keough S, Han J, Shuman T, Wise K, Nachappa P. Effects of *Soybean vein necrosis virus* on life history and host preference of its vector, *Neohydatothrips variabilis*, and evaluation of vector status of *Frankliniella tritici* and *Frankliniella fusca*. J Econ Entomol. 2016;109(5):1979-1987. DOI: 10.1093/jee/tow145
 36. Khatun MF, *et al.* Genetic diversity and DNA barcoding of thrips in Bangladesh. Insects. 2024;15(2):107. DOI: 10.3390/insects15020107
 37. Kim CY, Khan F, Kim Y. A push-pull strategy to control the western flower thrips, *Frankliniella occidentalis*, using alarm and aggregation pheromones. PLoS One. 2023;18:e0279646. DOI: 10.1371/journal.pone.0279646
 38. Kirk WDJ, Terry LI. The spread of the western flower thrips *Frankliniella occidentalis* (Pergande). Agric For Entomol. 2003;5(4):301-310. DOI: 10.1046/j.1461-9563.2003.00192.x
 39. Kolawole GO, Tian G, Singh BB. Differential response of cowpea lines to aluminum and phosphorus application. J Plant Nutr. 2000;23(6):731-740. DOI: 10.1080/01904160009382055
 40. Kucharczyk H, Kucharczyk M. *Thrips atratus* HALIDAY, 1836 and *Thrips montanus* PRIESNER, 1920 (Thysanoptera: Thripidae)—one or two species? Comparative morphological studies. Acta Zool Acad Sci Hung. 2009;55:349-364.
 41. Kucharczyk H. Comparative morphology of the second larval instar of the *Thrips* genus species (Thysanoptera: Thripidae) occurring in Poland. Olsztyn: Mantis Publ. Comp.; 2010. p. 1-152.
 42. Kumar B, Omkar. Thrips. In: Polyphagous pests of crops. Singapore: Springer Singapore; 2021. p. 373-407. DOI: 10.1007/978-981-15-8075-8_9
 43. Kumar B, Omkar. Thrips. In: Polyphagous pests of crops. Singapore: Springer Singapore; 2021. p. 373-407.
 44. Lewis T, editor. Thrips as crop pests. Wallingford: CAB International; 1997.
 45. Lewis T. Thrips: their biology, ecology and economic importance. London: Academic Press; 1973.

46. Lima EFB, Monteiro RC, Zucchi RA. Thrips species (Insecta: Thysanoptera) associated to Fabaceae of agricultural importance in Cerrado and Amazon-Caatinga ecotone from Brazilian Mid-North. *Biota Neotrop.* 2013;13(2):283-289. DOI: 10.1590/S1676-06032013000200027
47. Marullo R, Mercati F, Vono G. DNA barcoding: a reliable method for the identification of thrips species (Thysanoptera, Thripidae) collected on sticky traps in onion fields. *Insects.* 2020;11(8):489. DOI: 10.3390/insects11080489
48. Moritz G, Delker C, Paulsen M, Mound LA, Burgermeister W. Modern methods for identification of Thysanoptera. *EPPO Bull.* 2000;30:591-593. DOI: 10.1111/j.1365-2338.2000.tb00947.x
49. Moritz G, Morris DC, Mound LA. Pest thrips of the world - visual and molecular identification of pest thrips (interactive CD ROM). Brisbane, Australia: Center for Biological Information Technology (CBIT), University of Queensland; 2004.
50. Morse JG, Hoddle MS. Invasion biology of thrips. *Annu Rev Entomol.* 2006;51:67-89. DOI: 10.1146/annurev.ento.51.110104.151040
51. Morsello SC, Groves RL, Nault BA, Kennedy GG. Temperature and precipitation affect seasonal patterns of dispersing tobacco thrips, *Frankliniella fusca*, and onion thrips, *Thrips tabaci* (Thysanoptera: Thripidae) caught on sticky traps. *Environ Entomol.* 2008;37(1):79-86. DOI: 10.1603/0046-225X(2008)37[79:TAPASP]2.0.CO;2
52. Mou DF, Chen WT, Li WH, Chen TC, Tseng CH, Huang LH, *et al.* Transmission mode of *watermelon silver mottle virus* by *Thrips palmi*. *PLoS One.* 2021;16(3):e0247500. DOI: 10.1371/journal.pone.0247500
53. Mound LA, Kibby G. Thysanoptera: An Identification Guide. 2nd ed. Wallingford: CAB International; 1998.
54. Mound LA, Marullo R. The thrips of Central and South America: an introduction. *Mem Entomol Int.* 1996;6. Wallingford: Associated Publishers.
55. Mound LA, Morris DC. The insect order Thysanoptera: classification versus systematics. *Zootaxa.* 2007;1668:395-411. DOI: 10.11646/zootaxa.1668.1.21
56. Mound LA. Thysanoptera: diversity and interactions. *Annu Rev Entomol.* 2005;50:247-269. DOI: 10.1146/annurev.ento.50.071803.130346
57. Muchero W, Ehlers JD, Close TJ, Roberts PA. Mapping QTL for drought stress-induced premature senescence and maturity in cowpea (*Vigna unguiculata* (L.) Walp.). *Theor Appl Genet.* 2009;118(5):849-863. DOI: 10.1007/s00122-008-0944-7
58. Nabirye J, Nampala P, Kyamanywa S, Ogenga-Latigo MW, Wilson H, Adipala E. Determination of damage-yield loss relationships and economic injury levels of flower thrips on cowpea in eastern Uganda. *Crop Prot.* 2003;22(7):911-915. DOI: 10.1016/S0261-2194(03)00076-2
59. Nault BA, Kain WC, Wang P. Seasonal changes in *Thrips tabaci* population structure in two cultivated hosts. *PLoS One.* 2014;9(7):e101791. DOI: 10.1371/journal.pone.0101791
60. Ngakou A, Tamò M, Parh IA, Nwaga D, Ntonifor NN, Korie S, Nebane CLN. Management of cowpea flower thrips, *Megalurothrips sjostedti* (Thysanoptera: Thripidae), in Cameroon. *Crop Prot.* 2008;27(3-5):481-488. DOI: 10.1016/j.cropro.2007.08.003
61. Ouédraogo CP, Traoré F, Boly A, Zongo EN, Drabo E, Waongo A, Pittendrigh BR, Tamò M. Abundance and diversity of thrips associated with host plants in Burkina Faso. *Int J Agric Biol.* 2025;34(6):1313-1320. DOI: 10.17957/IJAB/15.2413
62. Painter RH. Insect resistance in crop plants. New York: Macmillan; 1951.
63. Pandi A, Perumal R, Samuel KJ, Subramanian J, Malaichamy K. *Orthotospovirus iridimaculaflavi* (iris yellow spot virus): an emerging threat to onion cultivation and its transmission by *Thrips tabaci* in India. *Microb Pathog.* 2024;193:106716. DOI: 10.1016/j.micpath.2024.106716
64. Pappu HR, Jones RAC, Jain RK. Global status of tospovirus epidemics in diverse cropping systems: successes achieved and challenges ahead. *Virus Res.* 2009;141(2):219-236. DOI: 10.1016/j.virusres.2009.01.009
65. Peng Z, Li M, Guo C, Zheng H, Wu M, Yin F, Xiao Y, Wang H, Kong X, Zalucki MP, Xie W, Li Z. Field-based evaluation of insecticide effectiveness on *Megalurothrips usitatus* in Guangdong, China: implications for pest control strategies. *Insects.* 2025;16(5):459. DOI: 10.3390/insects16050459
66. Pradeep RM, Rakesh V, Boopathi N, Siva M, Kousalya S, Nagendran K, *et al.* Emerging challenges in the management of *Orthotospoviruses* in Indian agriculture. *Virology.* 2024;593:110029. DOI: 10.1016/j.virol.2024.110029
67. Rebijith KB, Asokan R, Krishna V, Ranjitha HH, Kumar NK, Ramamurthy VV. DNA barcoding and elucidation of cryptic diversity in thrips (Thysanoptera). *Fla Entomol.* 2014;97:1328-1347. DOI: 10.1653/024.097.0407
68. Rehsawla R, Bhandari S, Dey SS, Das A, Sevugapperumal N, Renukadevi P, Ghosh A. Diversity in *Thrips palmi*: exploration of genetic and ecological heterogeneity. *Gene.* 2025;943:149252. DOI: 10.1016/j.gene.2024.149252
69. Reitz SR, Funderburk J. Management strategies for western flower thrips and the role of insecticides. In: Perveen F, editor. *Insecticides*. Rijeka: IntechOpen; 2012. p. 329-350. DOI: 10.5772/31388
70. Reitz SR, Gao Y, Kirk WDJ, Hoddle MS, Leiss KA, Funderburk JE. Invasion biology, ecology, and management of western flower thrips. *Annu Rev Entomol.* 2020;65(1):17-37. DOI: 10.1146/annurev-ento-011019-024947
71. Reitz SR. Biology and ecology of the western flower thrips (*Frankliniella occidentalis*) and onion thrips (*Thrips tabaci*). *Annu Rev Entomol.* 2009;54:67-87. DOI: 10.1146/annurev.ento.54.110807.090511
72. Ren X, He Y, Wei X, Zheng L, Yu H, Huang X, *et al.* Thrips spatio-temporal distribution in cowpea (*Vigna unguiculata* (L.) Walp.) flowers based on the flower structures and floral development stage. *Plants.* 2025;14(24):3753. DOI: 10.3390/plants14243753
73. Riley DG, Joseph SV, Srinivasan R, Diffie S. Thrips vectors of tospoviruses. *J Integr Pest Manag.* 2011;2(1):I1-I10. DOI: 10.1603/IPM10020
74. Rodríguez Arrieta JA, *et al.* First report of the pepper thrips *Thrips parvispinus* (Karny) in Costa Rica. *Int J*

- Pest Manag. 2025;[Epub ahead of print]. DOI: 10.1080/09670874.2024.2384910
75. Rodríguez D, Coy-Barrera E. Overview of updated control tactics for western flower thrips. *Insects*. 2023;14(7):649. DOI: 10.3390/insects14070649
 76. Rotenberg D, Baumann AA, Ben-Mahmoud S, Christiaens O, Dermauw W, Ioannidis P, Jacobs CGC, Vargas Jentzsch IM, Oliver JE, Poelchau MF, *et al*. Genome-enabled insights into the biology of thrips as crop pests. *BMC Biol*. 2020;18:142. DOI: 10.1186/s12915-020-00872-3
 77. Rotenberg D, Jacobson AL, Schneweis DJ, Whitfield AE. Thrips transmission of tospoviruses. *Curr Opin Virol*. 2015;15:80-89. DOI: 10.1016/j.coviro.2015.08.003
 78. Rudramuni T, Thippaiah M, Onkarappa S, Ganige P. Screening and biochemical analysis of groundnut genotypes against thrips, *Scirtothrips dorsalis* Hood. *J Exp Zool India*. 2022;25(2):1455-1460.
 79. Shelton AM, Badenes-Perez FR. Concepts and applications of trap cropping in pest management. *Annu Rev Entomol*. 2005;51:285-308. DOI: 10.1146/annurev.ento.51.110104.151023
 80. Singh BB, Ajeigbe HA, Tarawali SA, Fernandez-Rivera S, Abubakar M. Improving the production and utilization of cowpea as food and fodder. *Field Crops Res*. 2003;84(1-2):169-177. DOI: 10.1016/S0378-4290(03)00148-5
 81. Singh SR, Allen DJ. Pests, diseases, resistance, and protection in cowpea. In: Summerfield RJ, Bunting AH, editors. *Advances in legume science*. Kew: Royal Botanic Gardens; 1980. p. 419-443.
 82. Sridhar V, Sree Chandana P, Rachana RR. Global status of *Thrips parvispinus* (Karny, 1922), an invasive pest. *J Res PJTSAU*. 2021;49(4):1-11.
 83. Srinivasan R. Thrips as pests of vegetable legumes and their management in Southeast Asia. *Acta Hortic*. 2017;1150:1-12. DOI: 10.17660/ActaHortic.2017.1150.1
 84. Tang LD, Guo LH, Wu JH, Zang LS. Thrips in genus *Megalurothrips* (Thysanoptera: Thripidae): biodiversity, bioecology, and IPM. *J Integr Pest Manag*. 2023;14(1):8. DOI: 10.1093/jipm/pmad004
 85. Togola A, Boukar O, Chamarthi S, Belko N, Tamò M, Oigiangbe N, *et al*. Evaluation of cowpea mini core accessions for resistance to flower bud thrips *Megalurothrips sjostedti* Trybom (Thysanoptera: Thripidae). *J Appl Entomol*. 2019;143(6):683-692. DOI: 10.1111/jen.12618
 86. Twardowski J, Gruss I, Cierpisz M, Twardowska K, Magiera-Dulewicz J, Kozak M. Diversity of thrips species associated with soybean grown in different plant arrangements at various phenological stages. *Agriculture*. 2024;14(9):1501. DOI: 10.3390/agriculture14091501
 87. Tyagi K, Kumar V, Singha D, Chakraborty R. Morphological and DNA barcoding evidence for invasive pest thrips, *Thrips parvispinus* (Thripidae: Thysanoptera), newly recorded from India. *J Insect Sci*. 2015;15(1):105. DOI: 10.1093/jisesa/iev087
 88. Tyagi K, Kumar V. Thrips (Insecta: Thysanoptera) of India: an updated checklist. *Halteres*. 2016;7:64-98.
 89. Mound LA, Kibby G. *Thysanoptera: An Identification Guide*. 2nd ed. Wallingford: CAB International; 1998.
 90. Ufaz S, Galili G. Improving the content of essential amino acids in crop plants: goals and opportunities. *Plant Physiol*. 2008;147:954-961. DOI: 10.1104/pp.108.118307
 91. Viteri D, Cabrera I, Estevez de Jensen C. New record of thrips species associated with soybeans in Puerto Rico. *Fla Entomol*. 2009;92(1):181-185. DOI: 10.1653/024.092.0134
 92. Waiganjo MM, Gitonga LM, Mueke JM. Effects of weather on thrips population dynamics and its implications on thrips pest management. *Afr J Hortic Sci*. 2008;1:82-90.
 93. Wang J, Tong X, Wu D. The effect of latitudinal gradient on the species diversity of Chinese litter-dwelling thrips. *ZooKeys*. 2014;417:9-20. DOI: 10.3897/zookeys.417.7831
 94. Warpechowski LF, Steinhaus EA, Moreira RP, Godoy DN, Preto VE, Braga LE, *et al*. Why does identification matter? Thrips species (Thysanoptera: Thripidae) found in soybean in southern Brazil show great geographical and interspecific variation in susceptibility to insecticides. *Crop Prot*. 2024;178:106592. DOI: 10.1016/j.cropro.2023.106592
 95. Yasmin S, Ali M, Rahman MM, Akter MS, Paul AK, Akter MM, *et al*. Screening certain mung bean varieties against thrips (Thysanoptera: Thripidae) and exploration of resistance sources. *Agrosyst Geosci Environ*. 2022;5(3):e20287. DOI: 10.1002/agg2.20287
 96. Zafirah Z, Azidah AA. Diversity and population of thrips species on legumes with special reference to *Megalurothrips usitatus*. *Sains Malaysiana*. 2018;47(3):433-439. DOI: 10.17576/JSM-2018-4703-02
 97. Zhou J, Tzanetakis IE. *Soybean vein necrosis virus*: an emerging virus in North America. *Virus Genes*. 2019;55(1):12-21. doi: 10.1007/s11262-018-1622-4
 98. Zhu H, Choi HK, Cook DR, Shoemaker RC. Bridging model and crop legumes through comparative genomics. *Plant Physiol*. 2005;137:1189-1196. DOI: 10.1104/pp.104.058891
 99. López MV, Garcia A, Rodriguez L. Sustainable development and corporate performance: A study based on the Dow Jones sustainability index. *Journal of business ethics*. 2007 Oct;75(3):285-300.
 100. Schwartz DA, Graham AL. Potential maternal and infant outcomes from coronavirus 2019-nCoV (SARS-CoV-2) infecting pregnant women: lessons from SARS, MERS, and other human coronavirus infections. *Viruses*. 2020 Feb 10;12(2):194.
 101. Nault BA, Shelton AM, Gangloff-Kaufmann JL, Clark ME, Werren JL, Cabrera-la Rosa JC, Kennedy GG. Reproductive modes in onion thrips (Thysanoptera: Thripidae) populations from New York onion fields. *Environmental Entomology*. 2006 Oct 1;35(5):1264-71.