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Review Article

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A Review of the Pest, Tospoviruses Vector Status of Melon Thrips, *Thrips palmi* and its Natural Enemies for Biological Control

R.R. Rachana[1,*], G.T. Jayasimha[2], and V. Richa[3]

[1]Department of Insect Systematics, National Bureau of Agricultural Insect Resources, Bengaluru 560024, India

[2]Department of Entomology, Agricultural College and Research Institute, Madurai 625104, India

[3]Department of Insect Ecology, National Bureau of Agricultural Insect Resources, Bengaluru 560024, India

*Corresponding Author E-mail: vavarachana@gmail.com

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ABSTRACT

Thrips palmi Karny, the melon thrips is an economically important pest of various crops, especially vegetables, has rapidly spread worldwide, but remains absent from Europe. Moreover, T. palmi tends to be the predominant thrips vector species in tropical and sub-tropical Asia and transmits several different tospoviruses. Vector status of T. palmi is reviewed and discussed, primarily in the context of new strains of knowntospoviruses and completely new tospovirus species continue to be described from various parts of the world and have the potential to cause damaging epidemics. Successful natural enemies of T. palmi reported from various countries are also reviewed with an emphasis for the utilization of biological control of the pest.

Keywords: *Thrips palmi; melon thrips; vector; natural enemies; biological control*

INTRODUCTION

Melon thrips, *Thrips palmi* Karny (Thysanoptera: Thripidae) is a polyphagous pest, feeding on more than 50 plant species representing over 20 taxonomic families[146]. It especially attacks members of the Cucurbitaceae, Solanaceae, Leguminaceae and Orchidaceae[144]. Initially described in Indonesia by Karny[70], *T. palmi* has become widely distributed in tropical and sub-tropical regions, including Southeast Asia, the Pacific Islands, the Caribbean Islands and South America[98,136]. It is presumed to be absent in Europe, although it was detected in flowers of kiwi fruit (*Actinidia deliciosa* (A. Chev.) C.F. Liang. & A.R. Ferguson) in North West Portugal in 2004[20,41]. Thrips transmitted tospoviruses (genus Tospovirus, family Bunyaviridae) are a major group of plant viruses affecting at least 1,090 host plant species in 15 monocotyledonous and 69 dicotyledonous families worldwide[111]. So far, 20 Tospovirus species have been identified globally along with 14 thrips species in the family Thripidae that can serve as vectors[52,63,138]. Among all the identified thrips vector species, *T. palmi* tends to be the predominant one in tropical and sub-tropical Asia by transmitting several different tospoviruses[117].

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Biological control of *T. palmi* is gaining impetus due to a number of factors including broad range of vegetable crops fed upon, high reproductive capacity, rapid life cycle and resistance to various insecticide chemical classes. The resistance of thrips to insecticides has enabled quick transmission of viruses, the transient nature of their populations being essentially responsible for the infection[7]. Several natural enemies of *T. palmiviz.*, *Orius sauteri* Poppius, *Campylomma livida* Reuter, *Geocoris orchopterus* Fabr., and *Arthrocnodax occidentalis* Eeit. have been reported and evaluated for biological control[26].

Geographic Distribution

T. palmi was first described as a new speciesfrom specimens of tobacco plants in Sumatra and Java[70]. Owing to taxonomic confusion, the species remained little known until 1980, when a detailed description with illustration was published and its presence recorded from Pakistan, Taiwan, Singapore, the Philippines, Thailand and Indonesia[12,54]. Ananthakrishnan[6] first reported *T. palmi* as a pest of Sesame pods from South India. Laterit has been reported as a pest in Asia, Africa, Central and South America[23,50,62,73,96,98,102,143,146,159], the Caribbean[44,48], Australia, the Pacific, Florida and West Africa[16,98,129]. A diagnostic protocol for the identification of *T. palmi*has been published as an EPPO Standard[42].

Asia

T. palmi was initially described as a new species from specimens on tobacco in Sumatra and Java of Indonesia by Karny[70], where it subsequently also became a pest of cotton and soybean[35,90]. Later in the 1980s, *T. palmi* had become an important pest of potato in the highlands of Java and Sumatra especially during dry seasons[134]. Thus, *T. palmi* is a native to the island of Sumatra[102], and has dispersed throughout the world[43,82,96]. An outbreak of *T. palmi* has been reported in 1987 on eggplant garden of Penang, Malaysia[54], where it subsequently also became a pest of cucumber, chilli and tomato[46].The incidence of *T. palmi* had not been recorded from Philippines until an outbreak on watermelon shattered economy of Philippines in 1977, destroying almost 80 per cent of the watermelon plantations in Central Luzon and Laguna[87,125]. Since then, various destructive outbreaks of melon thrips have been recorded on cotton, watermelon and muskmelon gardens sprayed with insecticides in the suburbs of Manila[14]. Bernardo[10] collected *T. palmi* from 16 species of crops and had been reported to cause severe damage on watermelon, muskmelon, cucumber, tomato, eggplant and potato grown in low elevation areas of Philippines. In spite of several efforts to manage them, it still holds a major pest status of vegetables in Philippines[43,149]. *T. palmi* was first recorded in Taiwan in 1979, causing damage to cucurbits, eggplant, bell pepper and potato[25,27,147] and has become a major vegetable pest of Cucurbitaceae and Solanaceae[26]. A review of *T. palmi*from Taiwan was published by Wang and Chu[146]. In Thailand, Wangboonkong[145]reported that *T. palmi* had first been recognised in 1978 or 1979 on cotton, and became the most serious pest of fruit vegetables, eggplant and orchids in the drier areas of north eastern and western part of Thailand[8]. Two heavy outbreaks of *T. palmi* have been reported on cucumber gardens severely affecting production in Suphan Bud area of Thailand[54] and now rapidly spreading different areas of Thailand[43]. A review of *T. palmi* in Southeast Asia was published by Talekar[135].

T. palmi has been reported from almost 15 provinces in China, including Zhejiang, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Yunnan and Tibet[51], infesting melons, vegetables and ornamentals[43,132].

T. palmi was first recorded in India in 1955, causing damage to Sesame fields of South India[6], later spread throughout India[12]. Since then, *T. palmi* has been reported as pest of groundnut, mango and vegetables[108,139]. Vijaya Lakshmi[140] reported *T. palmi* from Hyderabad in southern India on 44 cultivated and 45 weed species and has become a major vegetable pests of cucurbitaceae, malvaceae, fabaceae and solanaceae[43].

In Japan, Nakazawa[103] reported that *T. palmi* had first been recognised in 1978 on sweet peppers at Miyazaki on Kyushu island, and became the most serious pest of eggplant, cucumber and sweet pepper both in greenhouses and in open fields in the western part of Japan[136]. Since then, various extensive annual outbreaks have been reported severely affecting year round plantings in many vinyl covered warm houses in Okinawa and the warmer coastal strips of Kyushu and Shikoku and further north in central Japan[123]. Kawai[73] reported that *T. palmi* had become the most serious pest of cucumber, watermelon, muskmelon, aubergine and sweet pepper in greenhouse and open fields in the western part of Kyushu and further north there is no overwintering outdoors and greenhouses severe as foci of summer populations. Even though many Japanese applied entomologists carried out various studies on the host plants, biology, population dynamics and control methods of T. *palmi*, it still remains a major pest in Japan, on several greenhouse crops including aubergine, sweet pepper, cucumber and watermelon, although both the severity of the infestations and the total area affected declined somewhat after the initial invasion[20,43,152,153].

In Korea, *T. palmi* was first recorded in 1993 on greenhouse peppers, and ithas become aserious pest of vegetableand ornamentalcrops insouthern coastal areas[1]. Awidespread outbreakonpotatoeson Cheju Island (tothesouthofmainl and Korea) in 1994, shortlyafter the pestfirst invaded, resulted in yieldlossesof around 30%[32].

Africa

T. palmi started to spread within Africa in 1980[2], had established in Mauritius and Reunion and later from Sudan and Nigeria and hence it is probably only a matter of time before it is widely established in Africa[144].*T. palmi*had a majoreconomic impacton cucurbitaceous and solanaceous crops since its first appearancein1980[2]. *T. palmi* has been reported from different provinces in Africa, including Mauritius, Nigeria, Sudan, Reunion islands and not yet invaded Algeria[43].

Severe infestations of *T. palmi* on watermelon was reported in Nigeria and Sudan[18,57]. In Reunion island, *T. palmi*isan economically importantpestof onion, pepper, cucumber and potato[15]; and inMauritius,ofmango and watermelon[107,139].

Australia

In Australia, *T. palmi* was first detected in the Northern Territories in 1989[57] when it seriously damaged cucurbit crops and soon became well established on avarietyof crops and weeds. An infested area approximately 10 km wide and winding 45 km south from Darwin remained constant until September 1991, when monitoring indicated an easterly spread of 20 km following westerly winds. In September 1992 it was recorded in the Katherine rural area (270 km south of Darwin). It was subsequently detectedin Queensland, in1993,and has since been found in various parts of this state[5]. Despite fears that it would spread, the Darwin rural area inthe Northern Territories and south-east Queensland, appear tobetheonlyareasof Australia where *T. palmi* has establishe dpermanent populations[80,160]. Several other Australian states have restricted imports of host produce from within100km of outbreaks of the pest.

The outbreak in the Northern Territories reportedly had serious economic repercussions, notonlydue tothe directcrop damage, but also dueto the imposed quarantine restrictions. In 1988, horticultural exports from theTerritory were worth close to AU$ 7m, but by 1992 this had dropped to little more than AU$2m[3,4]. The initial outbreaksof *T. Palmi* in theNorthern Territories were reportedly sohigh that some cropswereeither abandone or ploughed in, but theeffects of the seinfestations declined markedly in subsequent years to the extent that, in 1993, it was claimed that *T. palmi* no longer caused significant losses. The possibility of eradication was considered in 1989 but rejected because of the wide range of host plants and thearea of distribution atthetime of detection[3,4].

North America

In North America, *T. palmi* has been reported from Florida, Hawaii, Mexico and Wisconsin[33,43,60,102,126,130,137] not yet entered the territory of California, Texas and Bermuda[43].

In 1982and 1983, severe infestations of *T. Palmi* were discovered in Hawaii on cucurbits, eggplant, pepper and amaranthus[102]. On Oahu and Molokai (1984-1985), Hawaii, *T.pa lmi* along with *Aphis gossypii* Glover was reported to be a major pest of cucumber, watermelon and aubergine[61,119]. It has however, caused large economic losses in a number of ornamentals and vegetable crops in south Florida, including watermelon, snap bean, pepper, aubergine, okra, cucumber, amaranthus and squash[79,126,132].In Mexico, *T. Palmi* was first detected on watermelon in March 2004, in the state of Campeche[33], surveillance and sampling measures were put in place in an attempt to delimititspresenceintheregion[41].Cultural, physical, legal and biological control measures were also established to confine and eradicate *T. palmi* in Mexico[104]. However *T. palmi* is now reportedly present in the Yucatan of Mexico[9].

The Caribbean

T. palmi started to spread within the Caribbean region in 1985[144], had widely spread in Guadeloupe, Haiti, Martinique, Puerto Rico, St. Lucia, St. Kitts, Nevis, Trinidad and Tobago[36,43,48,83,109].

Sinceits first appearancein1985, *T. Palmi* had a major economic impact on melons, cucumbers, aubergines and capsicum in the islands of Guadeloupe and Martinique[48]. In Guadeloupe, Guyot[48] reported the disastrous economic effect that *T. palmi* had when aubergine exports fell from 5000 tonnes in 1985 to 1600 tonnes in 1986. In Martinique, 37% of the vegetable and 90% of aubergine crops of the two main cooperatives were attacked[48]. With respect to vegetable and floral crops, *T. palmi*, introduced to Guadeloupe and Martinique in 1985, was a very important pest of melon, cucumber, chili pepper and eggplant[36,44], but its populations decreased considerably during the past 15 years and its economic importance is now limited[45]. Presence of *T. palmi* has been reported from the crops belonging to various families *viz*., Amaranthaceae, Asteraceae, Capparaceae, Chenopodiaceae, Convolvulaceae, Cucurbitaceae, Cyperaceae, Euphorbiaceae, Fabaceae, Malvaceae, Mimosaceae, Piperaceae, Phyllanthaceae, Poaceae and Solanaceae from Guadeloupe and Martinique[45]. The pest was subsequently observed in Trinidad, in 1989, where severe crop losses to aubergine and cucumber occurred[34]. It is suggested that *T. palmi* might have been brought to Trinidad in the winds of a tropical depression during 1988 or might have gained entry through plant material from Martinique, where it is reported as a serious pest[34].

South America

T. palmi is distributed throughout South America, reported from Venezuela, Suriname, Guyana, Colombia, Sao Paulo and Goias[43]has a restricted distribution in Brazil[91].

In the warm humid areas of Latin America *T. palmi* has become aserious pestoflegumes, cucurbits, solanaceous crops and ornamentals[21,91,93]. The pest first appeared in South America, in Venezuela in 1990[23,24] then in Brazil and Sao Paulo, in 1995[91,93] and Colombia, in 1997[21,39,106]. InVenezuelaand Colombia, *T. palmi* is an economically important pest in pepper, cucumbers, beansandpotatoes[124]; and in Brazil, of aubergine, sweet pepper, potato, watermelon, andmelon[81,92].

In the Cauca Valley, Colombia, *T. palmi* is one of the main pests of snap beans with average yield losses of 30%[17]and the possibility of losing the entire harvest to this pest insusceptible bean genotypes[116];itisreportedly the target of excessive use of insecticides in this area[118]. In Brazil, *T. palmi* caused total croplossina 20ha field of green peppers in Goias State, and severe losses of green house melons and cucumbers in the Federal Districtin1998[101], somethreeyearsafter it was first found in the country.

T. palmi was intercepted on roses from Colombia by APHIS-PPQ in February 2000 and in January 1995, asa result of which the import of new world commercial roses into the US was identified as a new pathway by the North American Plant Protection Organisation's Phytosanitary Alert System.

Tospoviruses Vector Status

Thrips transmitted tospoviruses (genus Tospovirus, family Bunyaviridae) are a major group of plant viruses affecting at least 1,090 host plant species in 15 monocotyledonous and 69 dicotyledonous families worldwide[111]. Tospoviruses are transmitted by several species of thrips in a circulative and propagative manner[95,138,151]. While there are more than 6000 thrips species, so far only 14 are known vectors of tospoviruses, suggesting marked co-evolution for transmission specificity between tospoviruses and these thrips vector species[52,97,138]. Among all the identified thrips vector species, *T. palmi* tends to be the predominant one in tropical and sub-tropical Asia by transmitting several different tospoviruses[117]. Thus, *T. palmi*, with its ability to transmit multiple tospovirus species, appears to be the "*Frankliniella occidentalis* (Pergande)*"* of tropical and sub-tropical Asia[110].

Asia

Of the 20 tospovirus species recorded worldwide, the Asian continent has by far the greatest diversity. At least 15 have been identified so far infecting a wide range of crop plants in Asia[52,110]. *Cerathripoides claratris* (Shumsher), *Frankliniella cephalica* (Crawford), *F. occidentalis*, *F. schultzei* Trybom, *Scirtothrips dorsalis* Hood, *Thrips tabaci* (Lindeman) and *T. palmi* are the known vectors of tospoviruses in Asia[47]. Among all the identified thrips vector species, *T. palmi* tends to be the predominant one in tropical and sub-tropical Asia by transmitting several different tospoviruses[117]. *T. palmi* populations in Asia are competent vectors of six known tospoviruses[110].

In India, *T. palmi* (misidentified as *F. schultzei*) was initially reported as the main vector of tomato spotted wilt disease on groundnut by Palmer *et al*[108]. Later, the vector status was confirmed by transmission studies with various active stages of *T. palmi* and subsequently reported as the main vector of Groundnut Bud Necrosis Virus (GBNV) in India[114]. *T. palmi*, *T. tabaci*, *F. schultzei* and *S. dorsalis*are the known thrips vectoring tospoviruses from India; predominated by *T. palmi* and *S. dorsalis*[94,113]. *T. palmi*is the principal vector of peanut bud necrosis virus on ground nut[40,78,88,110,117,141], mung bean[131] and potato[11]. *T. palmi*is also known for transmitting Watermelon Bud Necrosis Virus (WBNV) to various crops[110,115].

In Japan, Iwaki *et al*[58]., first reported *T. palmi* transmits Watermelon Silver Mottle Virus (WSMoV).*T. palmi* is the main vector of Tomato Spotted Wilt Virus (TSWV) on watermelon[56,69,136], Melon Yellow Spot Virus (MYSV) on melon and cucumber[71,72,110,117], WSMoV[69,110,117] and GBNV[40].

A total of 5 tospoviruses are known to occur in China[28,37,38,132,133,158]; *T. palmi* is known for transmitting WBNV[110,132], TSWV[133]. *T. palmi* along with *C. claratris* is known to transmit Capsicum Chlorosis Virus (CaCV)[31,110,132], whereas GBNV is being transmitted to crops by *T. palmi*, *F. schultzei* and *S. dorsalis* in China[110,132].

At present, total 8 tospoviruses are known to be present in Taiwan[132]. *T. palmi* has been reported to transmit TSWV on watermelon[29,156], WSMoV on watermelon[40,110,132,156,157] and MYSV[132]. Recently, it is also known for transmitting Calla Lily Chlorotic Spot Virus on Calla lilies in Taiwan[30,110,117,132]. In Indonesia, *T. palmi* transmits WSMoV[69,110].

Australia

Frankliniella intosa (Trybom), *F. occidentalis*, *F. schultzei*, *S. dorsalis*, *T. palmi* and T. *tabaci* are the known vectors of tospoviruses in Australia[64,86,97,112]. *T. palmi* populations in Australia arecompetent vectors of two known tospoviruses. CaCV was initially found infecting capsicum and tomato crops in Queensland in north east Australia in 1999[85], but may have been detected seven years earlier without being conclusively identified[112]. Australian isolates of CaCV have been reported to be successfully transmitted by *T. palmi* along with *F. schultzei*[64,86,110,112]. *T. palmi* along with *F. occidentalis*, *F. schultzei* and *T. tabaci* is known to transmit Australian isolates of TSWV[110,112].

Natural Enemies for Biological Control

Predators

Anthocorid bugs play the most significant role in the natural control of *T. palmi* in many areas where it is a pest[144]. CABI (2015)[19] listed numerous predators that have been found associated with *T. palmi* round the globe.

In Japan, the predatory effect of *Orius* sp. on the density of *T. palmi* was investigated on potted aubergine in a screen house[100] and on aubergine in the field[68,99]. It was concluded that the introduction of *Orius* sp. lowered the population density of *T. palmi* on aubergine. Conversely, the population densities of *T. palmi* (together with *Tetranychus kanzawai* Kishida and *Tetranychus urticae* Koch) were greater when populations of *Orius* sp had been eliminated by insecticides[66]. The dispersal of *Orius* spp. was evaluated by Kawai[67] on greenhouse grown aubergine infested with *T. palmi*. The population density of *T. palmi* decreased on nine plants adjacent to the plant where the predator was released within a few days after release, and remained low until the end of the examination. It was concluded that the dispersal ability of early instar nymphs is low while that of late-instar nymphs and adults is high. *O. sauteri* was registered as a biological control agent in Japan in1998, and on peppers reduced *T. palmi* population five fold, two months after planting[77,136]. However, *Orius strigicollis* (Poppius) is now preferred to *O. sauteri* for commercial use because of its low erincidence of diapauseandeaseofmassproduction[127,153]. *O. strigicollis* was registered as a biological control agent in Japan in2001and is widely used for controlling *T. palmi* on aubergines and sweet peppers[152]. The predatory mites, *Amblyseius mckenziei* Schuster & Pritchard and *A.okinawanus* Ehara, and *Orius* sp., were investigated by Kajita[65] in Japan. Adult females of the two species of mites preferred first instar larvae as prey to second instar larvae and adult thrips, whereas the numbers of first and second instar larvae consumed by second instar *Orius* sp. did not differ greatly. *Orius* sp. did not differ significantly in the number of prey consumed from the two species of mites.

In China, Wei *et al*[150]., studied the biology and predatory behaviour of *Orius similis* Zheng. They found that in the laboratory, one individual of *O. similis* could prey on 440 individuals of *T. palmi* during its lifetime (both as a nymph and adult).

The predatory efficiency of *Orius tantillus* (Motschulsky) against *T. palmi* was studied under laboratory conditions in the Philippines by Mituda and Calilung[89]. Adult *O. tantillus* consumed up to 20 thrips per day and thus the studies have demonstrated the great potential of the anthocorid as a biological control agent against *T. palmi*. Bernardo[10] listed numerous predators that have been found associated with *T. palmi* in the Philippines.

In India Kumar and Ananthakrishnan[75]studied the predatory efficacy of anthocorids, *Orius maxidentex* Ghauri and *Carayonocoris indicus* Muraleedharan in the laboratory and field near Madras. *O. maxidentex* fed on *T. palmi* on the young foliage of sesame and, after the crop was harvested, was abundant on the weed *Croton sparsiflorus*L., preying on *T. palmi* until prey populations died out in September.

In Taiwan, Wang[148]evaluated the mirid bug, *Campylomma chinensis*Suhch and the anthocorid, *O. sauteri* in aubergine fields. Population densities of the mirids were higher than those of the anthocorids. Chang *et al*.[26]., recorded *O. sauteri, C. livida, C. ochropterus, Arthrocnodax longispinosus* Evans, *A. occidental s*and *Paraphytoseius multidentatus* Swirski and Shechter as predators of *T. palmi* from eggplant fields of Taiwan. Nymphs and adults of *O. sauteri* consumed up to 15 larvae of thrips per day and thus the studies have demonstrated the great potential of the anthocorid as a biological control agent against *T. palmi.*

In Trinidad, the only predator discovered was the coccinellid beetle, *Coleomegilla maculate* (DeGeer)[34]. In Hawaii, Mau *et al*[84]., recorded *Orius insidiosus* (Say) and *Franklinothrips vespiformis* (D.L. Crawford) as predators of *T. palmi*, and in Florida, Seal[126], evaluated *O. insidiosus* in cucumber and eggplant fields. *O. strigicollis* was reported as an efficient predator of *T. palmi* in cucumber fields of Korea which can be utilized for its biological control[74]. Hirose[53] explored the possibilities of using natural enemies against *T. palmi* in South-East Asia and Japan. The anthocorid predator *Bilia* sp. from Thailand was suggested to control *T. palmi* in Japan[68,99,100].

Yasunaga and Miyamoto[155] reported *Wollastoniella rotunda* Yasunaga and Miyamoto, O. *minutus* and *O. tantillus* associated with *T. palmi* in aubergine gardens in Thailand. Two species, *Wollastoniella parvicuneis*Yasunaga and Miyamoto and *W. rotunda*, were noted by Yasunaga[154]preying on *T. palmi* in northern Thailand. Hirose *et al*[55]., reported anthocorids, *Bilia* sp. and *O. sauteri*; mirid, *Campylomma* sp; thrips, *F. vespiformis*; predatory mites, *Amblyseius* sp. and *Phytoseius* sp. as predators of *T. palmi* in Thailand and the studies have demonstrated the great potential of *Bilia* sp. and *O. sauteri* as efficient biological control agents of *T. palmi*.

Etienne *et a*l[45].,recorded 17 species of predators of thrips including insects, mites and spiders from Guadeloupe and Martinique. Anthocorid bugs, *O. insidiosus* and *Lasiochilus pallidulus* Reuter; thrips, *F. vespiformis* found to be predating on *T. palmi* from eggplant and cucurbit fields. Both larvae and adults of *O. insidiosus* are very efficient in the management of *T. palmi*. Adults of *Trypticus violaceus* Van Duzee and *Chrysotus* sp were observed capturing larvae of *T. palmi* on leaves of eggplant. Adults and larvae of *Cycloneda sanguinea* (Linnaeus) are efficient predators of all developmental stages of *T. palmi*. Three predatory mite species, *Aceodromus convolvuli* (Muma), *Cunaxa* sp, *Amblyseius herbicolus* (Chant) were reported from the region predating *T. palmi.*

Parasitoids

A few attempts have been made to utilize parasitoids for the biological control of *T. palmi*; only two parasitoids have been reported, mainly from Southeast Asia[19,136,144]. Hirose[53]suggested the introduction of an eulophid larval parasitoid, *Ceranisus* sp. to control *T. palmi* in Japan. Hirose[54]offered a convincing argument to explore further the biological control of *T. palmi* using *Ceranisus menes* (Walker), a species native to Japan. Two parasitoids, *Megaphragma* sp. (egg parasitoid) and *C. menes* (larval parasitoid) have been reported parasitizing *T. palmi* in Thailand on aubergine fields; 40-60 per cent parasitism by *C. menes* in home gardens and parasitism was almost negligible where insecticides are regularly sprayed, whereas parasitism was comparatively low in case of *Megaphragma* sp.[19,55].

Fungal pathogens

Saito *et al*[120]., recorded the entomopathogenic fungus, *Neozygites parvispora* for the first time on *T. palmi* on melon in a greenhouse in Japan with an infection of 10% of adults and nymphs, but the fungus did not effectively managed the pest population.

In Japan, Kurogi *et al*[76]., studied the pathogenicity of the fungus, *Beauveria bassiana*, against *T. palmi*. The fungus can be highly effective in controlling *T. palmi* under certain conditions[22,121], although there are reports of antagonism with some chemical insecticides[59,76].

Hall[49]reported *Hirsutella* sp. on *T. palmi* on aubergine field in Trinidad; approximately 80% population of *T. palmi* was found to be infected by the fungus. This appeared to be the first deuteromycete pathogen found on *T. palmi* and isolated in pure culture.

Saito[122] reported that preparations of *Lecanicillium muscarium* (Petch) (formerly *Verticilliumlecanii* (Zimm.) (Viegas) were highly effective against *T. palmi*, and Visalakshy *et al*[142]., recorded the natural epizootics of *L. Muscarium* on *T. palmi* under field conditions. Smith*et al*[128]., recorded significant mortalities against *T. palmi* larva eon chrysanthemum leaves, following treatment with *L. Muscarium* together with a wetting agent, 0.1% Agral, and however, North *et al.*[105]., found that *L. muscarium* had a more significant impact on adult *T. palmi*, than on juvenile stages.

CONCLUSION

T. palmi is still spreading rapidly around the world and it is probably only a matter of time before it invades the whole African and North American continents. The higher population density of *T. palmi* increased its chances to expand into other areas and in Europe special care and attention should be paid to block its introduction. Considering the economic importance of *T. palmi* both as a pest and a vector, it is essential to keep a vigil on the further spread and infestation of the species.

T. palmi tends to be the predominant thrips vector in tropical and sub-tropical Asia and transmits several different tospoviruses; has a wide host range infesting tobacco, cotton, cucurbits, eggplant, soybean, peanut and mango. It is the main vector of GBNV in India, MSMoV in Japan and Indonesia and MYSV in Japan. Thus, *T. palmi*, with its ability to transmit multiple tospovirus species, appears to be the "*F. occidentalis*" of tropical and sub-tropical Asia. The increased incidence of *T. palmi* in Southeast Asia could be the result of increased insecticide applications in some areas of this region for the past 20 years. The mechanism of the resurgence of *T. palmi* involves destruction of its effective natural enemies. In Southeast Asia, most of the insecticides used for the control of pests other than *T. palmi* in fact contribute to its resurgence. This shows the importance of naturally occurring biological control agents of *T. palmi* in Southeast Asia. It is consistent with the fact that *T. palmi* is native to Southeast Asia and thus has effective natural enemies native to this region. Neither classical biological control of *T. palmi* nor inundative release of its natural enemies is necessary for Southeast Asia. Sustainable, biologically based pestc ontrol programmes against *T. palmi* willneed to depend on a suite of natural enemies with complementary lifestyles. Strategies for controlling *T. palmi* in this region should be explored, based on its naturally occurring biological control.

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