



# Onion Thrips (Thysanoptera: Thripidae) Biology, Ecology, and Management in Onion Production Systems

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**ABSTRACT.** Onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae), is a well-known onion pest worldwide. Onion thrips cause both direct and indirect damage to onion by feeding and ovipositing on leaves that may cause green onions (scallions) to be unmarketable and dry bulb onion size to be reduced. Onion thrips can also transmit several plant pathogens that reduce onion bulb size and quality. One of the most economically damaging onion pathogens transmitted by onion thrips is Iris yellow spot virus (Bunyaviridae: *Tospovirus*). In this article, we discuss onion thrips geographical distribution, host range, biology, damage, monitoring, economic thresholds, and management in onion production.

**Key Words:** *Allium cepa*, *Thrips tabaci*, IPM, Iris yellow spot virus (IYSV), onion

Onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae), is a pest in commercially produced onion (*Allium cepa* L.) and causes significant yield loss globally (Lewis 1997). The pest status of onion thrips can be attributed to its polyphagous nature, high reproductive rate, short generation time, high survival of cryptic (nonfeeding prepupa and pupa) instars, ability to reproduce without mating (parthenogenesis), ability to transmit plant pathogens, and development of resistance to insecticides (Morse and Hoddle 2006, Diaz-Montano et al. 2011). Extensive feeding by onion thrips not only results in plant stunting and reduced bulb weight, but it also predisposes onion plants to various fungal and bacterial pathogens that further decrease yield. Onion thrips also transmits Iris yellow spot virus (IYSV) (Bunyaviridae: *Tospovirus*), which further exacerbates the damage they cause and can ultimately result in complete crop failure.

Owing to the irruptive outbreaks of onion thrips in onion fields, insecticides have been the primary mode to control this pest (Morse and Hoddle 2006, Nault and Shelton 2010). Yet, over-reliance on certain insecticides in the organophosphate, carbamate, and pyrethroid classes has led to resistance development in populations of onion thrips in New York (Shelton et al. 2003, 2006), Ontario, Canada (MacIntyre-Allen et al. 2005a), New Zealand (Martin et al. 2003), and Australia (Herron et al. 2008). The key to minimizing losses caused by onion thrips will involve the combination of cultural and chemical controls, and use of resistant and tolerant varieties that suppress onion thrips populations and reduce feeding damage.

## Geographic Distribution

Onion thrips is a global pest of onion grown between sea level and 2000 m (Lewis 1973). Onion thrips is a native of the Mediterranean region but has become a major pest of agricultural crops throughout most of the world (Mound and Walker 1982, Mound 1997). Severe damage to various crops has been reported in Africa, Asia, Europe, North and South America, and Australasia (Mound 1997, Boateng et al. 2014).

## Environmental Effects on Outbreak of Onion Thrips

Hot and dry weather can lead to an increase in onion thrips populations and the severity of thrips injury to onion. The reason behind this is likely a combination of factors including a shorter generation time and

a reduction in mortality from rain and plant pathogens. Heavy rains have been shown to wash onion thrips from plants (Harris et al. 1935, North and Shelton 1986). Additionally, water stress may impact the nutritional quality of onion plants and also increases the attractiveness of the plants to thrips (Lewis 1973).

## Reproduction

Onion thrips can reproduce asexually (parthenogenesis) and sexually. The most common reproductive mode is thelytoky, a parthenogenesis in which females are produced from unfertilized eggs. Onion thrips also reproduce via arrhenotoky, a parthenogenesis in which males are produced from unfertilized eggs; females are produced from fertilized eggs. Onion thrips that reproduce via thelytoky differ genetically from those that reproduce via arrhenotoky (Toda and Murai 2007, Kobayashi and Hasegawa 2012). In the United States and Japan, both arrhenotokous and thelytokous populations of onion thrips have been collected from onion (Nault et al. 2006, Kobayashi and Hasegawa 2012, Jacobson et al. 2013). In some instances, arrhenotokous and thelytokous onion thrips populations can occur in the same field (Nault et al. 2006, Kobayashi et al. 2013).

There are biological differences between onion thrips populations that reproduce via arrhenotoky and thelytoky. For example, when arrhenotokous and thelytokous onion thrips populations developed on either onion or cabbage, the arrhenotokous population performed better on onion than on cabbage, whereas the opposite was true for the thelytokous population (Li et al. 2014). Arrhenotokous onion thrips that developed on onion produced more progeny and the population developed significantly faster on onion than on cabbage (Li et al. 2014). Another difference observed between arrhenotokous and thelytokous populations of onion thrips was the ability to transmit Tomato spotted wilt virus (TSWV), a *Tospovirus* closely related to IYSV (Chatzivassiliou et al. 2002). In Greece, only arrhenotokous onion thrips populations successfully transmitted TSWV (Chatzivassiliou et al. 2002). In the United States, Jacobson and Kennedy (2013) demonstrated that thelytokous populations of onion thrips also could transmit TSWV; however, populations varied in their ability to do so (range 0 to 45%). Transmission efficiency of IYSV to onion within and among populations of arrhenotokous and thelytokous onion thrips is not known.



**Fig. 1.** Adult onion thrips, *T. tabaci*. Photograph by Diane Alston, Utah State University, Bugwood.org.

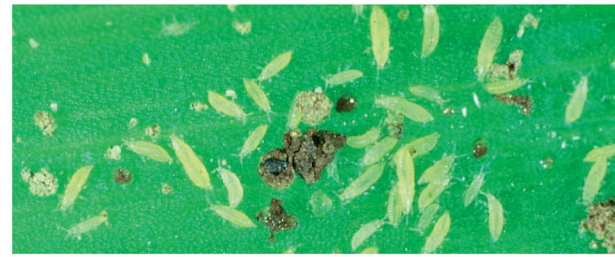
### Description of Life Stages

**Adults.** The adult stage overwinters in the soil in onion fields (Larentzaki et al. 2007) and in small grain and hay fields (Shelton and North 1987). Adults are more mobile than immature and pupal stages because they can fly (Fig. 1). Adults often fly to and land on clothes or exposed skin because of the thrips attraction to white and yellow colors (Rueda and Shelton 1995). Adults are elongated with body color varying with temperature from yellow to brown (Murai and Toda 2002). The forewings and hindwings are fringed and pale in color. Mouthparts are piercing-sucking, antennae are 7-segmented, and eyes are gray (Patel et al. 2013). Generally, adult females are 1.0–1.3 mm in length (Orloff et al. 2008), and males are 0.7 mm in length. Adult longevity varies from 16–42 d on garlic (Changela 1993) and 28–30 d on onion (Patel et al. 2013). Females exhibit a 1-wk preoviposition period and can lay eggs up to 3 wk (Alston and Drost 2008).

Onion thrips adults emerge from overwintering sites in the spring and may fly to colonize weed hosts and volunteer onion plants before subsequent generations infest onion crops (Larentzaki et al. 2007, Hsu et al. 2010, Smith et al. 2011). Winged adults are weak fliers but can fly from plant to plant or be carried long distances via wind (Carter and Sorenson 2013). In New York, there are six to eight generations per season (Hoffmann et al. 1996). In Kentucky, development time from egg to adult is estimated to be 20 d, with six to eight generations per year (Bessin 2004). Carter and Sorenson (2013) reported five to eight generations per year in North Carolina.

**Eggs.** Females lay eggs singly by inserting them into leaf tissue. Only one end of the egg is in proximity to the tissue surface to allow emergence of immatures. Eggs are microscopic, white or yellow, and kidney-shaped. As eggs mature, they develop an orange tinge and eventually reddish eye spots become evident. On onion, the average length and width of eggs are 0.23 mm and 0.08 mm, respectively (Patel et al. 2013). Incubation period is 4–5 d on onion (Fekrat et al. 2009). Hatching occurs in 2–3 d under laboratory conditions (Pourian et al. 2009), while it may take 5–10 d under cooler field conditions as reported in Utah (Alston and Drost 2008).

**Larvae.** The first and second instars are active feeding stages. The first instar is small, 0.35–0.38 mm in length, semitransparent and dull white, changing later to yellowish white (Fig. 2). The second instar is larger and yellow (Patel et al. 2013). Larvae are 0.7–0.9 mm in length with red eyes. The abdomen is divided into eight distinct segments and



**Fig. 2.** Onion thrips, *T. tabaci*, larvae on an onion leaf. Photograph by Joseph Ogradnick, Cornell University.

has a large posterior segment that is conical in shape. Duration of the first instar varies from 2 to 3 d, and the second instar can range from 3 to 4 d (Pourian et al. 2009).

**Pupae.** The prepupa and pupa (1.0–1.2 mm in length) are relatively inactive, nonfeeding stages. Pupation normally takes place at the base of the onion's apical meristem or within the soil (Rueda and Shelton 1995). The average length of the prepupa is 0.9 mm and the width is 0.23 mm. The prepupa is whitish-yellow and lasts for 1–3 d. In completely formed pupae, the antennae are folded back over the head and wing pads are well developed. The pupae are yellowish white, changing to yellow before adult emergence. The pupal period varies from 3–10 d among different geographical regions (Patel et al. 2013).

### Host Range

Onion thrips have an extremely wide host range compared with other thrips species. Reports of their host range vary from more than 140 plant species in over 40 families (Ananthakrishnan 1973) to more than 355 species of flowering plants (Morison 1957). Some onion thrips populations exclusively utilize a single plant species like tobacco (Brunner et al. 2004), while other populations may establish on hosts from multiple plant families (Nault et al. 2014).

Onion thrips also can reproduce on cultivated crops and weedy plants (Diaz-Montano et al. 2011). In addition to onion, onion thrips may attack the following: alfalfa (*Medicago sativa*), asparagus (*Asparagus officinalis*), bean (*Phaseolus vulgaris*), beet (*Beta vulgaris*), blackberry (*Rubus fruticosus*), cabbage (*Brassica oleracea*), carrot (*Daucus carota*), cauliflower (*Brassica oleracea* L. var. *botrytis* L.), celery (*Apium graveolens*), cotton (*Gossypium* spp.), cucumber (*Cucumis sativus*), garlic (*Allium sativum*), kale (*Brassica alboglabra* L.H. Bailey), leek (*Allium ampeloprasum* var. *porrum*), lettuce (*Lactuca sativa*), onion, parsley (*Petroselinum crispum*), pea (*Pisum sativum*), pineapple (*Ananas comosus*), potato (*Solanum tuberosum*), pumpkin (*Cucurbita maxima*), squash (*Cucurbita* spp.), strawberry (*Fragaria ananassa*), sweet potato (*Ipomoea batatas*), turnip (*Brassica rapa* var. *rapa*), tomato (*Solanum lycopersicum*), and practically all small grains (Pergande 1895, Parella and Lewis 1997, Cranshaw 2004, Shelton et al. 2008). Notably, the extent and frequency by which onion thrips damage crops varies across plant species. Onion is its preferred host and onion is one of the crops it damages the most. In contrast, onion thrips attack potato, sweet potato, and mustard, but none are damaged to a level that would routinely cause economic damage.

In New York, 25 weed species supported reproductive populations of onion thrips, especially Brassica weed species such as *Barbarea vulgaris* Ait. f., *Sinapis arvensis* L., and *Thlaspi arvense* L. (Smith et al. 2011).

### Onion Thrips Damage to Onion

**Feeding Injury.** Onion thrips have very distinctive feeding behaviors by punching through the leaf surface and then extracting sap from plant cells. During this process, thrips release substances that help predigest the tissue. After this, they siphon off the plant contents and consume mesophyll cells, which eventually results in a loss of chlorophyll and





**Fig. 3.** Feeding damage caused by onion thrips, *T. tabaci*. Photograph by Brian A. Nault, Cornell University



**Fig. 4.** Feeding damage caused by onion thrips, *T. tabaci*. Photograph by Joseph Ogradnick, Cornell University.

reduced photosynthetic efficiency (Boateng et al. 2014). Damage appears as silvery patches or streaks on the leaves (Rueda and Shelton 1995; Figs. 3–5). Severe feeding injury by onion thrips is also associated with tiny black “tar” spots, which is excrement from thrips (Fig. 4; Cranshaw 2004). Feeding on leaves also can create an entry point for plant pathogens (Orloff et al. 2008).

**Plant and Bulb Damage.** Generally, onion is most sensitive to thrips feeding injury when plants are young and when bulbs are rapidly enlarging. Water loss from damaged leaf surfaces may cause stress and reduce plant growth and may accelerate leaf senescence, both of which may shorten the period bulbs enlarge. In New York, a 30–50% reduction in bulb yield (smaller bulb sizes) can occur due to severe thrips damage (Nault and Shelton 2008; Fig. 5). Thrips also may feed on onion bulbs following harvest and during storage, and this can cause scars that reduce the aesthetic appearance and quality of bulbs (Mayer et al. 1987).

**Pathogen Transmission.** Thrips are the only vectors of tospoviruses and onion thrips is the principal vector of the tospovirus IYSV in onion (Kritzman et al. 2001). The tobacco thrips, *Frankliniella fusca* (Hinds), also may transmit IYSV, but transmission only has been shown to lisianthus, *Eustoma russellianum* (Salisbury), and not onion (Srinivasan et al. 2012). IYSV was first detected in Idaho in 1989, and by 2000 it was confirmed in most onion-producing areas in the United States and Canada. IYSV is not transmitted via onion seeds (Gent et al. 2004),



**Fig. 5.** Onion thrips, *T. tabaci*, damaged onion plant (left) compared with a nondamaged onion plant (right). Photograph by Brian A. Nault, Cornell University.



**Fig. 6.** Onions damaged by Iris yellow spot virus in a field in western New York. Photograph by Brian A. Nault, Cornell University.

nor is it successfully transmitted mechanically (Gent et al. 2006). First instars can acquire the virus from an infected plant and the acquisition rate decreases as the larva matures. Once acquired, tospoviruses can be propagated in the vector's body and transmitted in a persistent and circulative manner (Ullman et al. 1992, Wijkamp et al. 1993). Viruliferous adult thrips are capable of transmitting IYSV for life.

IYSV causes straw- to tan-colored lesions on onion leaves and spindle- to diamond-shaped lesions on the scapes. In severe cases, IYSV may cause leaves to become necrotic and plants to mature prematurely (Fig. 6). In such situations, bulb size (Gent et al. 2006) and yield losses in individual fields can range from insignificant to 60% (Mohan and Wilson 1989) and even up to 100% (Pozzer et al. 1999). Onion thrips is also known to transmit TSWV (Wijkamp et al. 1996), tomato yellow fruit ring virus (TYFRV; Golnaraghi et al. 2007), and impatiens necrotic spot virus (INSV) in other crops.

Onion thrips may serve as a vector of *Alternaria porri*, the fungus that causes purple blotch. *A. porri* typically enters onion leaves through



stomata and the epidermal cell layer, but fungal penetration becomes easier when the leaf surface has been damaged by onion thrips. Therefore, measures against onion thrips should also be considered while planning control of *A. porri* (Thind and Jhoo 1982). Recently, onion thrips was shown to transmit a bacterial pathogen, *Pantoea ananatis*, to onion (Dutta et al. 2014). *P. ananatis* causes center rot in onion and has caused substantial economic losses in the United States. Feeding by onion thrips did not result in the increased incidences of the fungal pathogen *Botrytis allii* Munn in stored onions (Mayer et al. 1987).

## Monitoring

Early detection of a pest problem is a key element for designing integrated pest management strategies. In many cases, infestation of onion thrips begins along field edges rather than other parts of the field (Nault and Shelton 2012). The density of onion thrips in onion fields can be assessed in multiple ways.

**Field Inspection.** To make management decisions for onion thrips, in situ examination of the onion plant is required. Onion thrips adults and larvae can be visually identified and counted more easily after opening the neck of the onion plants (Shelton et al. 1987; Fig. 7). Inspection should primarily be concentrated on the youngest leaves in the lowest center part of the neck, which is a preferred feeding site for thrips (Rueda and Shelton 1995). Older leaves that have been folded over may also be a preferred feeding site for the pest (Paibomesai et al. 2013). Scouting onion fields for onion thrips should start at an early phenological stage such as the 4–5 leaf stage, as the thrips population may increase rapidly at this time under ideal weather conditions (Rueda and Shelton 1995).

Recommended number of sampling sites within an onion field varies in accordance with field size. For large onion fields (>2 ha), 10 sampling sites with five plants per site (total of 50 plants per field) has been recommended (Rueda and Shelton 1995). Additionally, thrips infestations tend to be higher near the field borders early to mid-season, and then they eventually disperse within the field. Early in the season, control measures can target crop borders, which may slow spread of the pest to the entire field and save money because the entire field is not treated (Shelton et al. 1987).

**Laboratory-Based Methods.** Thrips activity can be monitored using sticky cards (Kuepper 2004, Trdan et al. 2005). Sticky cards are collected from the field after a certain period and then examined under a microscope to assess the presence and species of thrips (Mo 2006). Thrips densities on onion plants can be determined by removing plants from the field and taking them to the laboratory where plants can be immersed in ethanol or soapy water for a few minutes followed by

filtering the contents through a fine mesh sieve. Thrips on the mesh are visualized using a hand lens or a microscope and then counted. Alternatively, the onion leaves can be cut into pieces and then placed in a funnel connected with a collection vial (Mo 2006). A cotton wick containing a few drops of turpentine can be placed on the top of plant material (Mo 2006). Turpentine will repel the thrips into the collection vial, where they can be counted. These methods are more accurate for determining the number of immatures in a sample because adults may have flown away during collection.

## Action Thresholds

An action threshold for onion thrips is defined as the average thrips number per plant that will cause economic yield loss if the infestation is not controlled (Nault and Shelton 2010). Knowledge of action thresholds for onion thrips can help onion growers optimize insecticide applications and other management tactics. Benefits include making fewer applications, saving time and money, and potentially mitigating insecticide resistance development. Action thresholds for onion thrips may vary depending on geographic region, cultivar, plant stage, plant architecture, and insecticide efficacy. For example, an action threshold of 30 thrips per plant during mid-season has been effective in California for dry bulb, fresh-market onion (Kuepper 2004). This threshold value is adjusted based on plant age in that fewer thrips are tolerated on young plants and more thrips are tolerated on mature plants (Kuepper 2004). The recommended action threshold is higher for tolerant varieties as compared with susceptible ones. For instance, an action threshold level of 30 or more thrips per plant is suggested for the thrips-tolerant varieties, whereas a lower level of 15–30 thrips per plant is suggested for susceptible cultivars (Cranshaw 2004). Plant architecture (e.g., cultivars with flat sided leaves and compact growth habits harbor more thrips as compared with cultivars with openly spaced leaves) may also impact thresholds.

In New York, action thresholds for onion thrips on onion vary from one to three thrips larvae per leaf depending on insecticide efficacy (Nault and Shelton 2010). For example, spinetoram (Radiant SC) can effectively manage onion thrips using a threshold level of three thrips larvae per leaf. In contrast spirotetramat (Movento), methomyl (Lannate LV), and abamectin (Agri-Mek SC) need to be applied at one thrips larva per leaf (a more conservative threshold) to manage infestations (Nault and Shelton 2010, 2012; Table 1). Thus, it is important to consider all influential factors before selecting an action threshold to use in making onion thrips control decisions.

## Management Tactics

The use of insecticides is the most common management tactic for onion thrips infestations in commercial onion production. Host plant



**Fig. 7.** Onion thrips, *T. tabaci*, are easier to observe and count after opening the neck of an onion plant. Photograph by Brian A. Nault, Cornell University.

**Table 1.** Action thresholds suggested for onion thrips, *T. tabaci*, management in dry bulb onion production systems

Location	Insecticide	Action threshold	Reference
New York	Spinetoram	3 thrips/leaf	Nault and Shelton 2012
	Abamectin	1 thrips/leaf	
	Spirotetramat	1 thrips/leaf	
	Methomyl	<1 thrips/leaf	
California	n/a	30 thrips/plant	Kuepper 2004
Texas	n/a	1 thrips/leaf	Edelson et al. 1989
Auckland, New Zealand	n/a	5 thrips/50 onions	Jamieson et al. 2012
Canada	n/a	0.9 thrips/leaf under severe drought; 2.2 thrips/leaf during mild drought	Fournier et al. 1995
Honduras	n/a	0.5 and 1.6 thrips/leaf in dry seasons	Rueda et al. 2007

resistance is another tactic that has received attention, but no onion cultivars that have a high level of thrips resistance are commercially available. Cultural and biological control practices have been examined in commercial onion fields to manage thrips, but many are not used because they may be less effective than insecticides and are more expensive and labor intensive. Below we describe tactics that have been evaluated for thrips management in commercial onion fields.

**Insecticides.** Insecticides vary in their toxicity to different life stages of thrips. Larvae are often more likely to be killed by insecticides compared with other stages. Spirotetramat (Movento) is a good example of an insecticide that is effective against larvae, but much less so against adults (Guillen et al. 2014). Adults can fly quickly when disturbed and also have a thicker cuticle (external covering) than larvae, which makes them more difficult to kill. Prepupae and pupae seek protection in the soil or at the base of onion plants, escaping contact by most insecticides.

Despite their availability and ease of use, insecticide resistance has been a historical problem (Gill and Garg 2014). The inability to control onion thrips infestations in onion using organophosphate (e.g., azinphosmethyl, diazinon, and methyl parathion) and synthetic pyrethroid (e.g., cypermethrin, and permethrin) insecticides has been observed across the United States (Cranshaw 1989, Davis et al. 1995, Shelton et al. 2003, 2006). In New York, onion thrips collected from commercial onion fields were shown to be resistant to methomyl (Lannate LV) and  $\lambda$ -cyhalothrin (Warrior T; Shelton et al. 2003, 2006). In Ontario (Canada), insecticide resistance in onion thrips populations from onion fields was reported for  $\lambda$ -cyhalothrin, deltamethrin, and diazinon (MacIntyre-Allen et al. 2005b). In Auckland (New Zealand), onion thrips tested resistant to diazinon, deltamethrin, and dichlorvos (Martin et al. 2003). In Australia, onion thrips from onion fields were resistant to  $\alpha$ -cypermethrin (164-fold),  $\lambda$ -cyhalothrin (606-fold), diazinon (27-fold), dimethoate (5.2-fold), although no resistance was reported to omethoate, malathion, and methidathion (Herron et al. 2008).

Managing resistance to insecticides is critical given that this is the principal tactic used to manage thrips. Resistance can be mitigated by limiting the frequency of insecticide applications, rotating insecticides used in a sequence (based on groups or modes of action), and maintaining thorough coverage to prolong the effectiveness of insecticides (Gill and Garg 2014). Applying insecticides to onion using a high spray volume will provide better coverage of the foliage and better thrips control. Inclusion of a penetrating surfactant is critical for improving the efficacy of insecticides that have systemic and translaminar movement within onion plants to control onion thrips (Nault et al. 2013).

**Synthetics.** A number of synthetic insecticides are registered for control of onion thrips in the United States (Table 2). Of these products, only five active ingredients have consistently demonstrated excellent onion thrips control in New York field trials: abamectin,

cyantraniliprole, spinetoram, spinosad, and spirotetramat (Nault and Hessney 2008, 2010, 2011).

Spinetoram is highly effective against larvae and adults with residual activity of more than seven days. Spinosad is similar to spinetoram except the residual activity is shorter. Abamectin and cyantraniliprole have provided moderate to excellent control of onion thrips larvae and adults, and had a residual activity of 5–7 d. Spirotetramat is systemic with a residual activity of >10 d, but it does not work well against adult onion thrips or late in the season when plants are maturing. Spirotetramat is suggested for use early in the season when it can easily move systematically in the plant and also adult populations are often lower than they are in late season. Abamectin, cyantraniliprole, spinetoram, and spirotetramat must penetrate the leaves for maximum effectiveness (Nault and Shelton 2012).

**Botanicals.** Botanicals may offer protection against onion thrips, especially when combined with other management tactics. Efficacy of some botanical products tends to be lower than efficacy of synthetic products (Nault and Hessney 2010, 2011), so their use may be more practical in situations where onion thrips infestations are low to moderate. In a field experiment in India, efficacy of neem seed powder extract, neem soap, essential oils from basil or tulsi (*Ocimum tenuiflorum* syn. *O. sanctum*), and scented *Geranium* (*Pelargonium graveolens*) was compared with the efficacy of commonly used synthetic insecticides such as dimethoate, acephate, and fipronil for onion thrips control (Krishna Moorthy et al. 2013). The lowest mean thrips population and the highest marketable yield were achieved by applying fipronil, while neem-based formulations were less effective relative to untreated control (Pandey et al. 2013).

**Host Plant Resistance.** There are no onion cultivars that are highly resistant to thrips, but some onion cultivars have low levels of resistance or can tolerate feeding damage by onion thrips. These cultivars require fewer insecticide applications, which not only lower the control costs, but they might delay the development of insecticide resistance and may enhance biological control by protecting biocontrol agents (Panda and Khush 1995, Diaz-Montano et al. 2011). A study in New York identified a number of cultivars considered partially thrips-resistant (OLYS05N5, Tioga, Peso, Calibra, Vaquero, Cometa, Medeo, NMSU 03-52-1, Delgado, T-433, Colorado 6, Arcero, Mesquite, White Wing, and Granero; Diaz-Montano et al. 2012a). Onion cultivars with yellow-green, glossy to semi-glossy leaf surfaces and an open neck were less attractive to onion thrips compared with cultivars with blue-green, waxy leaves, and tight necks (Diaz-Montano et al. 2012b). Onion cultivars with glossy and semi-glossy leaves have lower levels of epicuticular waxes, especially the wax ketone hentriacontanone-16, compared with standard nonglossy cultivars (Damon et al. 2014). Thus, glossy to semiglossy onion cultivars with low levels of epicuticular waxes should be integrated into onion thrips management strategies.

**Cultural Control. Field Location.** Adult thrips may overwinter in crops like alfalfa and small grains, and their proximity to onion could increase their likelihood to disperse into onion fields. Similarly, onion thrips populations can build up rapidly on other hosts like carnations, crucifers, cucurbits, roses, and strawberries. Therefore, onions grown near other hosts for onion thrips will be more vulnerable to attack (Carter and Sorenson 2013).

**Transplanting and Early Maturing Cultivars.** Transplanting onions (Kisha 1977), selecting early-maturing cultivars, or both should expedite the period between planting and harvest, thereby truncating the period that thrips are able to infest the crop. In New York, transplanted onion fields are often colonized by onion thrips before direct-seeded onion fields (Hsu et al. 2010). However, onion fields transplanted with early-maturing cultivars are harvested much earlier than direct-seeded fields and often require few to no insecticide applications (B.A.N., unpublished).

**Table 2. List of insecticides registered for onion thrips, *T. tabaci*, management in onion fields in the United States**

Trade name	Active ingredient	Insecticide class	IRAC MoA <sup>a</sup>
Agri-Mek SC	Abamectin	Avermectin	6
Ambush	Permethrin	Pyrethroid	3A
Assail 30SG	Acetamiprid	Neonicotinoid	4A
Entrust	Spinosad	Spinosyn	5
Exirel	Cyantraniliprole	Anthranilic diamide	28
Lannate LV	Methomyl	Carbamate	1A
Movento	Spirotetramat	Tetramic acid	23
Mustang Max	zeta-Cypermethrin	Pyrethroid	3A
PennCap-M	Methyl parathion	Organophosphate	1B
Pounce	Permethrin	Pyrethroid	3A
Radiant SC	Spinetoram	Spinosyn	5
Warrior	lambda-Cyhalothrin	Pyrethroid	3A

<sup>a</sup> IRAC MoA, Insecticide Resistance Action Committee mode of action classification (<http://www.irac-online.org/>).

**Mulches.** Mulches have many benefits including weed suppression, conserving soil moisture, increasing soil temperature, and reducing soil erosion. Some synthetic mulches also may repel insects. For example, in Taiwan, silver mulch was shown to repel thrips in seedling-stage shallots (Lu 1990). Some organic mulches also may decrease pest populations by promoting populations of biocontrol agents (Gill et al. 2011, Gill and McSorley 2012, Gill and Goyal 2014). Straw mulch has been used to reduce thrips infestations in onion (Larentzaki et al. 2008, Schwartz et al. 2009). Field experiments in Colorado showed that straw mulch application to the center of onion beds at early to mid-bulb growth reduced thrips densities to 33% compared with nontreated plots of transplanted onions. Cumulative thrips-days suggested that straw mulch significantly reduced season-long abundance of thrips by 10 to 20% compared with bare soil plots. Field studies in New York produced similar results, showing that colonization of adult onion thrips was delayed one to two weeks and fewer thrips larvae developed in straw-covered plots of onions compared with those with no mulch (Larentzaki et al. 2008).

**Intercropping and Trap Crops.** In Egypt, intercropping of onions and garlic with tomato reduced the onion thrips infestation by 80% (Afifi and Haydar 1990). In England, mixed plantings or intercropping of carrots and onions effectively decreased onion thrips populations by 50% (Uvah and Coaker 1984). In this case, both crops can be harvested because thrips injury to carrots is not economically damaging. Other crops such as carrot, crucifers, cucurbits, and some flowers (carnation, chrysanthemum) are highly attractive to onion thrips. Attractive crops can be planted in strips or patches to attract onion thrips. This approach might only work if the trap crops are large and more attractive than the onion plants. When thrips populations reach a certain threshold level, then the trap crop could be sprayed with an insecticide or disked under (Alston and Drost 2008). Additionally, modification of planting date of onion and trap crops, and different cultivars of onions could help reduce onion thrips populations.

**Nitrogen Reduction.** Reductions in nitrogen levels in plants have reduced populations of insects (Mattson 1980), and this has been shown to be true for onion thrips in onion. For example in Utah, adult thrips populations in a reduced nitrogen treatment (one-third the standard rate) were 23 to 31% lower than in a standard nitrogen rate treatment (402 kg N ha<sup>-1</sup>; Buckland et al. 2013). In the same study, onions grown following corn rather than wheat in a 1-yr rotation reduced the thrips population because corn removed more nitrogen from the soil than wheat and the lower levels of nitrogen were shown to reduce thrips densities (Buckland et al. 2013).

In Pakistan, six rates of nitrogen (50 to 250 kg/ha) were applied to onion to evaluate the effect it had on onion thrips populations. Application of the lowest (50 kg N/ha) and optimum level (150 kg N/ha) had no effect on thrips abundance. However, thrips abundance increased 74% in the highest nitrogen level treatments (200 and 250 kg/ha) and thrips damage led to reductions in onion yield (Malik et al. 2009).

**Sanitation.** Removing or destroying debris and volunteer onion plants after harvesting eliminates potential overwintering sites (Larentzaki et al. 2007). If left on the soil surface, onion plant matter can harbor thrips that might successfully overwinter and infest the crop the following year. Inspection of onion transplants for presence of thrips and discarding the infested ones may also be useful (Larentzaki et al. 2007).

**Irrigation.** Overhead irrigation and rainfall may reduce thrips populations on onion plants (Harris et al. 1935, Passlow 1957). The physical action of water washing thrips off the plants and water droplets standing on leaf surfaces are inhibitory to thrips. In addition, sprinklers used for

water application may promote a crust on the soil surface, which reduces the access of pre-pupae and pupae to seek shelter in the soil.

**Biological Control. Predators.** Predators of onion thrips are usually not in abundance until late summer when the majority of thrips feeding injury has already occurred (Fok et al. 2014). Some of the predators of onion thrips include *Aelothrips* spp., green lacewing (*Chrysoperla* spp.) larvae, minute pirate bug (*Orius* spp.), coccinellids (*Coleomegilla maculata*), and big-eyed bug (*Geocoris* spp.) (Fok et al. 2014).

**Parasitoids.** In India, the major natural enemies of onion thrips in onion and garlic were parasitoids (>80%) rather than predators (16%). The parasitoid population was solely composed of *Ceranisus menes* (Eulophidae: Hymenoptera) (Jayanthi Mala and Nighot 2013). Another study in India showed that *C. menes* parasitized onion thrips, but the range of parasitism varied from 2 to 18% during the season (Saxena 1981).

**Predaceous Mites.** In Denmark, biological control of onion thrips was investigated on greenhouse-grown cucumbers (*Cucumis sativa*) by two species of phytoseiid mites *Amblyseius cucumeris* and *Amblyseius barkeri*. *A. cucumeris* had a better numerical response compared with *A. barkeri* when feeding on onion thrips (Brødsgaard and Hansen 1992). To our knowledge, research has not been conducted with these mite species for managing onion thrips on onion.

**Entomopathogenic Nematodes.** Different species of entomopathogenic nematodes (*Steinernema carpocapsae*, *S. feltiae*, *Heterorhabditis bacteriophora*) were evaluated for control of onion thrips in a laboratory study and one with onion and green bean plants grown in a controlled environment. While onion thrips prepupal and pupal mortality was high (>90%) in the high nematode concentration treatments in the laboratory, there was no effect of nematodes on thrips mortality on plants grown in the controlled environment (Kashkouli et al. 2014).

**Entomopathogenic Fungi.** In India, entomopathogenic fungi (*Beauveria bassiana*) were successful in reducing onion thrips populations and increasing onion yield (Singh et al. 2011, Ganga Visalakshy and Krishnamoorthy 2012). In China, the SZ-26 strain of *B. bassiana* significantly lowered the population of larval and adult stages of onion thrips under greenhouse conditions (Wu et al. 2013). Studies conducted in Germany reported that out of 41 isolates, 36 isolates of entomopathogenic fungi were found pathogenic against onion thrips. However, the pathogenicity varied among fungal species, genera and isolates (Thungrabeab et al. 2006). A study in western Kenya documented that the entomogenous fungus, *Metarhizium anisopliae*, has the potential to control onion thrips in onion (Maniania et al. 2003).

In Jordan, integration of entomopathogenic fungi and sublethal doses of neem tree extracts (botanicals) effectively controlled onion thrips (Almazra awi et al. 2009). In Ethiopia, a study concluded that some botanicals (*Nicotiana* spp., *Phytolacca dodecandra*, *Securidaca longepedunculata*, *Nicotiana tabacum*) and entomopathogenic fungi (*B. bassiana*) applied at recommended rates were significantly effective against onion thrips in the field (Shiberu et al. 2013). Combinations of entomopathogenic fungus *Paecilomyces lilacinus* with nonconventional agents such as *Azadirachta indica* and diatomaceous earth formulations may be effective for controlling onion thrips (Wakil et al. 2012).

## Summary

Onion thrips is one of the most economically important pests of onion. Its high reproductive rate, short generation time, and ability to damage onion plants throughout the onion-growing season pose challenges to developing effective management plans. A combination of preventative and curative control measures outlined above should not only help in reducing damage caused by onion thrips, but can reduce



the spread of plant pathogens and mitigate the development of pesticide resistance.

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