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Biology, Crop Injury, and Management of Thrips (Thysanoptera: Thripidae) Infesting Cotton Seedlings in the United States

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ABSTRACT. Several species of thrips are known to infest cotton seedlings in the United States and constitute one of the most common insect pest challenges for growers. The species complex, species abundance, extent of crop injury, and impact on lint yield varies widely across the cotton states. Cotton seedlings are most susceptible to thrips injury during the first 4 to 5 weeks after plant emergence. Feeding by thrips results in distortion, malformation and tearing of seedling leaves, reduced leaf area and plant height, reduced root growth, and injury to or death of the apical meristem, the latter of which leads to excessive vegetative branching. Plant maturity (i.e., fruit production) can be delayed and in extreme cases, losses of as much a 30–50% of lint yield potential have been reported. To date, no varieties of cotton have resistance to thrips, so controls are based solely on insecticide applications. Treatment thresholds and control practices (e.g., insecticide seed treatments, in-furrow or foliar applied insecticides) vary widely across cotton states. This article provides a brief summary of the various species of thrips present in U.S. cotton, their plant host range and injury to cotton, a general description of thrips biology, and management practices currently available to growers.

Key Words: cotton; tobacco thrips; flower thrips; western flower thrips; biology

Historical Perspective

The pest status of thrips infesting cotton, *Gossypium hirsutum* (L.), seedlings in the United States has been debated for many years. This is because the impact of seedling thrips on cotton yield has been variable. Some researchers have observed decreases in yield from thrips or increases in yield when seedling thrips were controlled (Watts 1937b, Race 1961, Davis et al. 1966, Davis and Cowan 1972, Leser 1985, Carter et al. 1989, Burris et al. 1989, Almand 1995, Herbert 1998, Van Tol and Lentz 1999, Lentz and Van Tol 2000), while others have not (Newsom et al. 1953, Watson 1965, Cowan et al. 1966, Beckham 1970, Harp and Turner 1976, Terry and Barstow 1985, Ratchford et al. 1987, Ratchford et al. 1989, Lentz and Austin 1994, Roberts 1994). Delayed crop maturity because of thrips injury has also been variable (Gaines 1934, Watts 1937b, Dunham and Clark 1937, Newsom et al. 1953, Leigh 1963, Harp and Turner 1976, Parker and Huffman 1985, Carter et al. 1989, Ratchford et al. 1989, Bourland et al. 1992, Parker et al. 1992, Lentz and Austin 1994, Herbert 1998, Van Duyn et al. 1998, Faircloth et al. 1999, Van Tol and Lentz 1999, Lentz and Van Tol 2000). In the United States, thrips infesting cotton seedlings have been ranked in importance from first to seventh with regard to yield loss during 1979–2009, with yield loss estimates ranging from 0.12% to 0.88% (Hamer 1980, 1981, 1982; Head 1984, 1985, 1989, 1990, 1991, 1992, 1993; King et al. 1986, 1987, 1988; Williams 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2002a, 2002b, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010). During 1986 through 2009, 56% to 96% of the cotton acreage was infested with thrips during the seedling stage each year. Foliar insecticide applications per acre for thrips ranged from 0.19 to 1.1 during 1986–2009 (King et al. 1987, 1988; Head 1989, 1990, 1991, 1992, 1993; Williams 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2002a, 2002b, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010).

Western flower thrips, *Frankliniella occidentalis* (Pergande), have been observed in cotton flowers in the Mid-South sometimes at very high population densities. However, no impact on yield has been observed. Western flower thrips have also been observed to be opportunistic predators of spider mites (Gonzalez et al. 1982, Gonzalez and Wilson 1982).

Species Infesting Cotton Seedlings

Five thrips species commonly infest cotton seedlings in the United States. These include western flower thrips; flower thrips, *Frankliniella tritici* (Fitch); soybean thrips, *Neohydatothrips variabilis* (Beach); onion thrips, *Thrips tabaci* (Lindeman); and tobacco thrips, *Frankliniella fusca* (Hinds). Western flower thrips have been observed infesting cotton seedlings in 14 states across the cotton belt. Flower thrips have been reported infesting cotton seedlings in 10 states. Several studies have reported soybean thrips infesting cotton seedlings in five states. Onion thrips have been reported infesting cotton seedlings in six states. Tobacco thrips are widely distributed across the mid-south and southeast cotton production regions and are the predominate species in many areas. This species has been reported infesting cotton seedlings in 10 states and is the primary species in many of these areas. States where these five thrips species have been reported infesting cotton seedlings and the associated references are listed in Table 1. Adult females of flower thrips, western flower thrips, tobacco thrips, and soybean thrips are illustrated in Figs. 1A–D, respectively.

Chilli thrips, *Scirtothrips dorsalis* Hood, is an exotic thrips species that has been detected in Florida and Texas during 2005 on crops other than cotton. This species has a very large range of host plants including cotton (Holtz 2006). It has the potential to impact cotton if it becomes established.

Thrips Host Range

Thrips can be found on numerous crop and weed species, many of which are found within cotton production environment. As many as 29, 28, and 49 plant families have been documented as feeding host, reproductive hosts, or plants that thrips are transients on for tobacco thrips, western flower thrips, and flower thrips, respectively. These include Asteraceae, Brassicaceae, Convolvulaceae, Fabaceae, Poaceae, Polygonaceae, and Solanaceae.

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Table 1. List of states in which tobacco thrips, western flower thrips, flower thrips, onion thrips, and soybean thrips have been reported infesting cotton seedlings

	Tobacco thrips	Western Flower thrips	Flower thrips	Onion thrips	Soybean thrips
Alabama	18	18	18		18
Arkansas	18, 19	19	18, 19	19	18, 19
California		4, 10			
Georgia	11, 18, 19	15, 18, 19	11, 18, 19		19
Louisiana	5, 6, 18, 19	18, 19	5, 18, 19	5	9, 18, 19
Mississippi	2, 17, 18, 19	12, 18, 19	2, 17, 18, 19		2, 17, 18, 19
Missouri	19	19	19		19
New Mexico		7			
North Carolina	19	19	19		19
Oklahoma		13			
South Carolina	14, 19	14	3, 19	3	3, 19
Tennessee	18, 19	18	18, 19	19	18, 19
Texas		8, 19		19	
Virginia	16, 19	19	19	19	19

Reference for Table 1: 1. Gaines (1934), 2. Dunham and Clark (1937), 3. Watts (1937a), 4. Bailey (1938), 5. Sharp and Eddy (1938), 6. Newsom et al. (1953), 7. Race (1961), 8. Gaines (1965), 9. Burris (1980), 10. Leigh (1984), 11. Lambert (1985), 12. Reed (1988), 13. Karner and Cole (1992), 14. DuRant et al. (1994), 15. All et al. (1995), 16. Herbert (2002), 17. Reed and Jackson (2002), 18. Cook et al. (2003), 19. Reed et al. (2010).

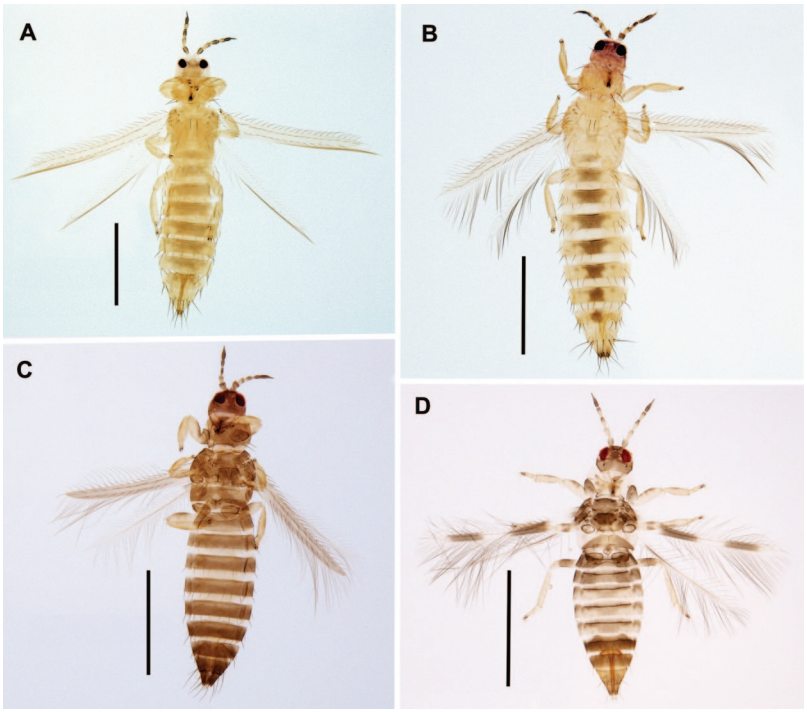

Fig. 1. (A) Flower thrips, *Frankliniella tritici* (Fitch), female. (B) Western flower thrips, *Frankliniella occidentalis* (Pergande), female. (C) Tobacco thrips, *Frankliniella fusca* (Hinds), female. (D) Soybean thrips, *Neohydatothrips variabilis* (Beach), female. Scale bars represent 0.5 mm.

Newsom et al. (1953) identified 13 plant species as important alternate hosts of tobacco thrips in Louisiana. During 1968–1970, 16 winter hosts of tobacco thrips were identified in Georgia (Beckham et al. 1971). Chamberlin et al. (1992) listed 24 plant species as winter and spring hosts in Georgia and north Florida. Tobacco thrips were collected in Florida from 11 and three winter plant species by Chellemi et al. (1994) and Toapanta et al. (1996), respectively. Tobacco thrips were collected from five plant species in South Carolina (DuRant et al. 1994). Groves et al. (2001) reported overwintering tobacco thrips on common chickweed (*Stellaria media* (L.) Cyrillo), knawel weed (*Scleranthus annuus* (L.), and spiny leaved sowthistle (*Sonchus asper* L.). Groves et al. (2002) collected tobacco thrips from 21 plant species in North Carolina; also larvae were collected from these plant species indicating that they were reproductive hosts for tobacco thrips. Paini et al. (2007) collected tobacco thrips from 20 plant species in north Florida, 12 of which were reproductive host plants.

Beshear (1983) reported collections of western flower thrips from four plant species in Georgia. Western flower thrips were collected from 19 plant species by Graves et al. (1987) in Louisiana. Chellemi et al. (1994), Toapanta et al. (1996), and Paini et al. (2007) reported collections from 23, 3, and 7 plant species, respectively, in Florida. Two of the species that Paini et al. (2007) collected western flower thrips from were considered reproductive hosts because of the presence of larvae. Also, DuRant et al. (1994) collected western flower thrips from five plant species in South Carolina.

Watts (1936) identified 109 plant species as hosts for flower thrips in South Carolina. In addition, DuRant et al. (1994) collected flower thrips from four plant species in South Carolina, while Beckham et al.

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(1971) reported collections of flower thrips from nine plant species in Georgia. Flower thrips was collected in Florida from 27, 3, and 48 species of plants by Chellimi et al. (1994), Toapanta et al. (1996), and Paini et al. (2007), respectively. Eighteen of the plant species on which Paini et al. (2007) collected flower thrips were reproductive hosts.

The host range of the onion thrips is fairly large, encompassing several hundred plant species. The major crop hosts include onions, garlic, cotton, carrots, cucumbers, melons, peas, tobacco, roses, carnations, beans, gladiolus, and hops (Bailey 1938). Beckham et al. (1971) collected onion thrips from mouse-ear chickweed and daisy fleabane in Georgia. Soybean thrips are known to infest soybean, other legumes, and cotton (Vance 1974, Burris et al. 1989).

Thrips Biology

Females of most thrips species in the suborder Terebrantia oviposit within the leaf tissue of host plants. Incubation and developmental periods vary with species and environmental conditions (Watts 1934, Bailey 1938, Lublinkhof and Foster 1977, Lowry et al. 1992). Several of these studies do not list the temperatures at which observations were taken.

Egg. Eggs hatch after 2–26 days (Quaintance 1898; Hinds 1903; Horsfall and Fenton 1922; MacGill 1927; Eddy and Clarke 1930; Eddy and Livingstone 1931; Bailey 1933, 1938; Watts 1934, Watts 1936; Lublinkhof and Foster 1977; Lowry et al. 1992). MacGill (1927) reported that onion thrips eggs hatched after 8 days on average at 19°C, while Eddy and Clarke (1930) observed onion thrips eggs hatched at 4.7 on average at 24.7°C.

Larva. Following eclosion, two plant-feeding larval stages occur. Larval development periods range from 2 to 13 days (Quaintance 1898; Hinds 1903; Horsfall and Fenton 1922; MacGill 1927; Eddy and Clarke 1930; Eddy and Livingstone 1931; Bailey 1933, 1938; Watts 1934, 1936; Vance 1974; Lowry et al. 1992). MacGill (1927) reported that onion thrips progressed through both larval instars in 10–14 days at 19°C. Eddy and Clarke (1930) observed in onion thrips required 2.3 and 2.9 days for the first and second larval instar stages, respectively, at 24.7°C. Lublinkhoff and Foster (1977) observed that western flower thrips required 1.9, 2.3, and 1.1 days to complete the first instar stage at 15, 20, and 30°C, respectively. Western flower thrips also required 9.8, 5.2, and 4.3 days to complete the second larval instar at 15, 20, and 30°C, respectively (Lublinkhoff and Foster 1977).

Pre-Pupa and Pupa. The larval stages are followed by a mobile, but nonfeeding prepupal stage. After 1–5 days, the insect drops to the soil and enters a pupal stage (Quaintance 1898; Hinds 1903; Horsfall and Fenton 1922; MacGill 1927; Eddy and Clarke 1930; Eddy and Livingstone 1931; Bailey 1933, 1938; Watts 1934, 1936; Vance 1974; Lublinkhof and Foster 1977; Lowry et al. 1992). Thrips adults emerge from the soil after 1–10 days (Quaintance 1898; Hinds 1903; Horsfall and Fenton 1922; MacGill 1927; Eddy and Clarke 1930; Eddy and Livingstone 1931; Bailey 1933, 1938; Watts 1934, 1936; Vance 1974; Lublinkhof and Foster 1977; Lowry et al. 1992). MacGill (1927) reported that onion thrips required 1–2 days and 4–7 days to complete the prepupal and pupal stages, respectively, at 19°C. While, Eddy and Clarke (1930) observed that onion thrips required 1.4 and 3.2 days to complete the prepupal and pupal stages at 24.7°C, respectively. Lublinkhoff and Foster (1977) observed that western flower thrips required 2.9, 2.2, and 1.4 days to complete the prepupal stage at 15, 20, and 30°C, respectively, and 5.6, 2.9, and 1.6 days to complete the pupal stage at 15, 20, and 30°C, respectively.

Adult. Adult longevity varies somewhat among species. Watts (1934) reported tobacco thrips females lived 29.1 days on average (temperature not specified). Flower thrips female average lifespan has been reported as 21.4 days (Watts 1934) and 25.3 days (Watts 1936), with males having a shorter average lifespan of 14.7 days (Watts 1936). Adult longevity of female onion thrips has been observed as 14.5 days (Eddy and Clarke 1930) and 18.3 days (Watts 1934). Bailey (1933, 1938) reported average adult longevity of western flower thrips as 20–21 days. While Lublinkhoff and Foster (1977) observed an average life span for western flower thrips females of 27.5 days at 30°C up to 70.8 days at 15°C.

Tobacco thrips, western flower thrips, flower thrips, and onion thrips are capable of reproducing by means of both sexual reproduction and parthenogensis (Eddy and Clarke 1930; Eddy and Livingstone 1931; Bailey 1933, 1938; Watts 1936; Newsom et al. 1953; Higgins and Myers 1992; Lowry et al. 1992). Soybean thrips are known to reproduce sexually, but parthenogensis has not been observed.

Most species of thrips overwinter as adults (Bailey 1938, Stannard 1968, Beckham et al. 1971, Vance 1974, Chamberlin et al. 1992, Toapanta et al. 1996). Western flower thrips, flower thrips, soybean thrips, and onion thrips are macropterous (Stannard 1968). Tobacco thrips may be either macropterous or brachypterous (Eddy and Livingstone 1931, Burns 1951, Newsom et al. 1953, Stannard 1968, Chamberlin et al. 1992).

Thrips Injury to Cotton Seedlings

Adults and larvae of thrips species infesting cotton seedlings feed on the contents of plant epidermal cells. Thrips injured plant tissue appears as areas of damaged cells. Cell surface damage is usually minimal, but cells appear wrinkled or depressed because of removal of the cellular contents. The silvery appearance of plant tissue injured by thrips occurs after cell fluids are replaced by air (Telford and Hopkins 1957, Reed and Reinecke 1990). Damaged areas of leaves do not develop in a normal manner causing leaves to twist. Distortion, malformation, and tearing of leaves occurs at the site of injury as leaf size increases. In addition, leaf margin areas curl upward and inward toward the mainstem (Telford and Hopkins 1957). Severe infestations may result in injury to or death of the apical meristem (Telford and Hopkins 1957, Reed 1988). Examples of the injury described above are illustrated in Figs. 2 through 4. Thrips injured seedlings sometimes display excessive vegetative branching. The development of an unusual growth pattern, commonly referred to as "crazy cotton," results from the loss of apical dominance caused by injury to the apical meristem (Gaines 1934). Several studies have indicated that thrips injury to seedling cotton can negatively impacted root growth and development (Roberts and Rechel 1996, Sadras and Wilson 1998, Brown et al. 2008). Thrips injury that adversely affects root growth may potentially off-set positive effects of nematicides in terms of early root development (Roberts, Toews, and Kemerait 2009).

Thrips injury to cotton seedlings may result in reductions in plant height (Parencia et al. 1957; Burris et al. 1989, 1994, 1995), and leaf area (Harp and Turner 1976, Rummel and Quisenberry 1979, Leser 1985, Burris et al. 1989, Ratchford et al. 1989, Roberts and Rechel 1996). Injury resulting from thrips feeding also may delay production of fruiting forms (Race 1961, Davis et al. 1966, Leser 1985, Lentz and Austin 1994). The impact on these plant growth parameters results in boll development and maturation periods extending into the latter part of the growing season, thus delaying crop maturity and timely harvest.

Fig. 2. Light-moderate thrips injury to cotton.

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Fig. 3. Moderate-severe thrips injury to cotton.

Fig. 4. Severe thrips injury to cotton.

Significant delays in maturity because of thrips injury have been observed by many researchers (Gaines 1934, Watts 1937b, Dunham and Clark 1937, Carter et al. 1989, Bourland et al. 1992, Parker et al. 1992, Herbert 1998, Van Duyn et al. 1998, Faircloth et al. 1999, Van Tol and Lentz 1999, Lentz and Van Tol 2000). Heavy infestations of thrips have delayed crop maturity to harvest ≥ two weeks (Gaines 1934, Dunham and Clark 1937, Watts 1937b, Carter et al. 1989, Bourland et al. 1992, Parker et al. 1992). However, other studies have shown that thrips infestations had no effect on crop maturity (Newsom et al. 1953, Leigh 1963, Harp and Turner 1976, Parker and Huffman 1985, Ratchford et al. 1989, Lentz and Austin 1994). Delayed crop maturity can extend the period in which the crop is susceptible to injury from other insect pests that can lead to higher production costs. By extending the crop growing period, cool temperatures that further delays crop maturity may be encountered before defoliation and harvest (Morris 1963, Gipson and Joham 1968, Hesketh and Low 1968, Yfoulis and Fasoulas 1978, Young et al. 1980). Some harvest aid chemicals are sensitive to low temperatures, thus making defoliation practices less effective and more costly. In addition, adverse environmental conditions such as rainfall (Williford et al. 1995) can reduce lint quality and yield (Barker et al. 1976), and shorten the period in which soil conditions are favorable for conducting fall tillage operations. Optimum utilization of stale seedbed practices also may be inhibited.

The effect of seedling thrips on yields has been variable. Some researchers have reported an increase in yields when seedling thrips were controlled (Watts 1937b, Race 1961, Davis et al. 1966, Davis and Cowan 1972, Leser 1985, Carter et al. 1989, Burris et al. 1989, Almand 1995, Herbert 1998, Van Tol and Lentz 1999, Lentz and Van Tol 2000). Other studies showed no significant improvement in yields associated with thrips control on seedling cotton (Newsom et al. 1953; Watson 1965; Cowan et al. 1966; Beckham 1970; Harp and Turner 1976; Terry and Barstow 1985; Ratchford et al. 1987, 1989; Lentz and Austin 1994; Roberts 1994). Some studies have reported mixed results with significant yield responses to thrips control with at-planting insecticides at some locations or during some years and no differences at or during others (Leigh 1963; Parker and Huffman 1985; Burris et al. 1994, 1995; Van Duyn et al. 1998; Faircloth et al. 1999). More consistent yield responses are reported from Virginia where 220 insecticide treatments (including foliar, in-furrow and seed applied) tested over a 5 year period from 1997 to 2001 showed an average yield increase of 339 lb lint/acre over nontreated controls (Herbert 2002). More recently in North Carolina and Virginia, treatments with in-furrow applications of aldicarb and seed treatments with imidacloprid resulted in average increases of 431 and 547 lb lint/acre, respectively (Herbert et al. 2007).

Environmental conditions during the growing season vary between years. Depending on locale, favorable environmental conditions that allow cotton to compensate for thrips injury that occurred during the seedling stage may occur in some years but not in others. More northern portions of the cotton belt have shorter growing seasons, which provide less time and heat unit accumulation to mature bolls set later in the growing season because of stresses that occur before flowering (i.e., thrips injury) or direct fruit loss. This would help explain the variability in response to thrips infestations on cotton seedlings.

Impact of Cultural Practices Thrips Populations

Recently, considerable interest has arisen on stale seed bed and conservation tillage production practices for cotton. However, the impact of these practices on early season thrips populations has been a concern. Several researchers have reported that tillage practices did not affect seedling thrips populations (DeSpain et al. 1990, 1992; Leonard et al. 1994). All et al. (1992) reported that tobacco thrips densities were significantly lower in no-till treatments than in conventional till treatments. Toews et al. (2010) observed that thrips densities were lower in plots managed using strip till practices compared with plots managed using conventional tillage practices. In addition, All et al. (1993) reported cotton seedlings had higher thrips densities in areas that had native winter vegetation compared with areas that had winter wheat as a cover crop. Toews et al. (2010) found no differences in thrips densities between three cover crops (rye, *Secale cereale* L.; wheat, *Triticum aestivum* L.; and crimson clover, *Trifolium incarnatum* L.).

Thrips Management in Cotton

There are many natural enemies of thrips including predators, parasitoids, and pathogens (Butt and Brownbridge 1997, Loomans et al. 1997, Sabelis and Van Rijin 1997). The insidious flower bug, *Orius insidiosis* (Say), has been shown to be an effective predators of several thrips species including western flower thrips and flower thrips in field grown peppers (Funderburk et al. 2000). Several species of *Orius* have been shown to suppress western flower thrips populations (Chambers

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et al. 1993, Higgins 1992). Others have reported that natural enemies play a small role in suppressing thrips populations in field crops and that biological control of thrips is difficult in field crops and success varies among crops (Parrella and Lewis 1997, Hulshof et al. 2003). Osekre et al. (2008) indicated that the insidious flower bug was not effective in suppressing flower thrips populations in cotton flowers. There is little information on the impact of natural enemies on thrips populations occurring on cotton seedlings.

Control of thrips on cotton seedlings is generally achieved with use of prophylactic at-planting insecticide treatments. This practice has been widely adopted because damage can occur quickly after seedling emergence. This is achieved through the use of in-furrow granular or liquid insecticides such as aldicarb or acephate sprayed in-furrow or seed treatments such as acephate, imidacloprid, and thiamethoxam (Kerns et al. 2009a, Kerns and Cattaneo 2009a, Parker et al. 2009a, Bacheler and Reisig 2010, Catchot et al. 2010, Greene 2010, Herbert 2010, Pollet et al. 2010, T. Reed et al. 2010, Roberts et al. 2010, Stewart et al. 2010, Studebaker et al. 2010). California recommends the use of a seed treatment for thrips and other seedling pests based upon field history (Godfrey et al. 2009). The newer neonicitinoid seed treatments (imidacloprid and thiamethoxam) have been widely adopted by growers in many areas. Residual activity of at-planting insecticides ranges from 2 to 4 weeks after planting. Researchers have reported that aldicarb provided control of thrips for 28–41 days after planting (Hopkins and Taft 1965; Leser 1985, Ratchford et al. 1987, 1989; Burris et al. 1989; Lentz and Austin 1994, Graham et al. 1995). Acephate, used as a seed treatment, provided control for 20–23 days after planting (Leser 1985, Burris et al. 1989, Ratchford et al. 1989), and in one study for 33 days after planting (Lentz and Austin 1994). Variable results have been reported with imidacloprid, used as a seed treatment. The imidacloprid seed treatment provided consistent thrips control to 11 d after planting (Lentz and Austin 1994) and 29 DAP (Graham et al. 1995). However, thrips control was variable to 33 days after planting (Lentz and Austin 1994) and 37 days after planting (Graham et al. 1995). Supplemental foliar treatments are sometimes required following seed treatments and in-furrow applications when environmental conditions that slow the growth rate of cotton seedlings (cool temperatures) occur. Rummel et al. (1988) reported an interaction between thrips injury and environmental conditions during the seedling development stage. Immigration of large numbers of thrips from maturing crops such as wheat or native vegetation also may warrant foliar insecticide applications. Treatment thresholds for foliar applications against thrips vary somewhat between states. All of these thresholds include the presence of plant injury (Boyd and Phipps 2005, Sprenkel 2008, Bacheler 2009, Godfrey et al. 2009, Kerns et al. 2009b, Kerns and Cattaneo 2009b, Parker et al. 2009b, Catchot et al. 2010, Greene 2010, Herbert 2010, Pollet et al. 2010, T. Reed et al. 2010, Roberts et al. 2010, Stewart et al. 2010, Studebaker et al. 2010). Foliar treatment thresholds for Alabama, Arizona, California, Florida, Georgia, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, and Virginia are detailed in Table 2.

Most states recommend acephate, dicrotophos, or dimethoate for foliar applications (Kerns et al. 2009a, Kerns and Cattaneo 2009a, Parker et al. 2009a, Bacheler and Reisig 2010, Catchot et al. 2010, Greene 2010, Herbert 2010, Pollet et al. 2010, T. Reed et al. 2010, Roberts et al. 2010, Stewart et al. 2010, Studebaker et al. 2010). Some states recommend additional insecticides for thrips control such as methamidophos: Louisiana (Pollet et al. 2010), North Carolina (Bacheler and Reisig 2010), and South Carolina (Greene 2010); thiamethoxam: Alabama (T. Reed et al. 2010); oxydemeton-methyl: North Carolina (Bacheler and Reisig 2010); methyl parathion: Texas (Kerns et al. 2009a, Kerns and Cattaneo 2009a, Parker et al. 2009a). Virginia also recommends spinetoram, gamma-cyhalothrin plus chlorpyrifos, and the pyrethroids bifenthren, lambda-cyhalothrin, gamma-cyhalothrin, and beta-cyfluthrin (Herbert 2010). Most states do not recommend pyrethroids to avoid the potential of flaring spider mites and cotton aphid, *Aphis gossypii* L., and some states recommend not to use acephate when spider mites are present (Catchot et al. 2010, Pollet et al. 2010). Western flower thrips are considered to be more difficult to control than other species that commonly occur on cotton seedlings. Worldwide including the United States, there is resistance to one or more classes of insecticides in some populations of western flower thrips, many of these were collected from greenhouses (Immaraju et al. 1992, Brødsgaard 1994, Robb et al. 1995, Zhao et al. 1995, Broadbent and Pree 1997, Kontsedalov et al. 1998, Jensen 2000, Loughner et al. 2005).

Table 2. Foliar treatment thresholds for thrips infesting cotton seedlings

State	Threshold	References
Alabama	Presence of injury	12
Arkansas	Presence of injury up to two true leaf stage and presence of injury and 5 thrips per plant after two true leaf stage	15
California	When terminals of cotton seedlings are being destroyed	4
Florida	Evidence of feeding and 2 or more thrips per plant	2
Georgia	Presence of injury and 2–3 thrips per plant with larvae present	13
Louisiana	Presence of injury and thrips larvae	11
Missouri	Presence of 1 or more thrips per plant and before noticeable foliar damage has occurred on seedling plants.	1
Mississippi	Presence of injury and 1 thrips per plant	8
North Carolina	Presence of injury and 1 thrips larvae per plant times the no. of true leaves up to the four true leaf stage	3
South Carolina	Presence of injury and thrips larvae	9
Tennessee	Presence of injury and 1 thrips per plant	14
Texas	Presence of injury and 1 thrips per plant times the no. of true leaves up to the four true leaf stage	5, 6, 7
Virginia	Presence of injury and thrips larvae	10

Reference for Table 2: 1. Boyd and Phipps (2005), 2. Sprenkel (2008), 3. Bacheler (2009), 4. Godfrey et al. (2009), 5. Kerns et al. (2009b), 6. Kerns and Cattaneo (2009b), 7. Parker et al. (2009b), 8. Catchot et al. (2010), 9. Greene (2010), 10. Herbert (2010), 11. Pollet et al. (2010), 12. T. Reed et al. (2010), 13. Roberts et al. (2010), 14. Stewart et al. (2010), 15. Studebaker et al. (2010).

The impact of thrips infestations during the seedling stage of cotton is likely to remain variable in many locations because of variations in environmental conditions from one year to the next. Foliar treatment thresholds for thrips on seedling cotton are somewhat vague. The interactions between thrips density, amount of thrips injury, and environmental conditions during the seedling stage have not been fully investigated. These interactions need to be understood before foliar treatment thresholds can be further refined.

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