BIOLOGY AND DAMAGE OF THE TARNISHED PLANT BUG, *LYGUS LINEOLARIS*, IN COTTON [1]

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ABSTRACT

Tarnished plant bug (TPB), *Lygus lineolaris* (Palisot de Beauvois), is a key pest of cotton in many states. Although this pest can damage cotton throughout most of the growing season, economic damage is most likely to occur during the period from first square through early bloom due to feeding on small squares and subsequent abscission of these squares. During this period, excessive damage by high TPB populations may result in reduced yields or delayed maturity. However, current research suggests that cotton can tolerate low levels of TPB damage without sustaining yield loss. Most states recommend monitoring both numbers of insects and percent square retention in order to obtain information on which to base TPB management decisions. The relative importance of TPB as a key pest of cotton is increasing due to a number of changes in cotton insect management systems. These include: development of insecticide resistance in TPB, boll weevil eradication, transgenic Bt cotton, and the development and availability of more target-specific foliar-applied insecticides.

INTRODUCTION

The tarnished plant bug (TPB), *Lygus lineolaris* (Palisot de Beauvois), is one of several plant bugs that attack cotton in the U.S. Other members of this group include: western tarnished plant bug(WTPB), *Lygus hesperus* Knight; cotton fleahopper, *Pseudotomoscelis seriatus* (Reuter); clouded plant bug, *Neurocolpus nubilus* (Say); and several less common species. Of these, TPB is the most widely distributed and is the predominant species in the Southeast, Mid-South, and parts of Texas. However, the cotton fleahopper is the more important pest in some areas of Texas. TPB damages cotton primarily by feeding on squares (immature flower buds), which causes abscission. In western production areas, WTPB is the primary plant bug species, although TPB also occurs there. However, the biology of WTPB and the damage it causes are similar to that of TPB, and much of the literature on WTPB has some relevance to TPB.

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BIOLOGY OF THE TARNISHED PLANT BUG

TPB , a true bug belonging to the family Miridae, is the most widely distributed species of Lygus in North America, occurring from central Alaska and Newfoundland to southern Mexico (Schwartz and Foottit 1992). It has an extremely wide range of host plants and is recognized as a pest of many cultivated crops, ranging from alfalfa to peaches, as well as many vegetables and a variety of row crops, including cotton (Bariola 1969). Crosby and Leonard (1914) describe the injury caused to a large number of cultivated crops. In addition to cultivated crops, TPB also feeds on a wide variety of weeds. Because of the type of host plants preferred by TPB, it is often particularly abundant in disturbed or early successional type habitats. Both nymphs and adults feed preferentially on developing floral buds, often causing "blasting" or abscission from the plant, and on meristematic areas of plant terminals. Strong (1968) noted that this blasting of floral buds often associated with plant bug feeding may offer a selective advantage due to the stimulation of additional flower bud production in affected hosts.

Womack and Schuster (1987) sampled 56 plant species in the northern blackland prairies of Texas and found that 33 of these supported reproducing populations of TPB. Snodgrass et al. (1984) collected TPB from 169 different species of wild hosts in the Arkansas-Louisiana-Mississippi Delta. Young (1986) listed a total of 385 recorded host plants of TPB and suggested that this insect may have the broadest documented host range of any insect. In addition to feeding on plants, TPB is also known to prey on other insects (Young 1986).

Like all true bugs, TPB undergoes a gradual life cycle and has piercing-sucking mouthparts. In cotton, eggs are usually inserted into plant tissue with most eggs being deposited in squares and terminals (Fleischer and Gaylor 1988). The nymphs molt 5 times before becoming adults, and there is a rather lengthy pre-oviposition period during which new adults feed, mate, and mature eggs. There are several generations per year.

Bariola (1969) found the average time required to complete one generation on cotton at 80°F to be approximately 33 days, with the approximate number of days required for each stage as follows: egg - 8, nymph - 17, pre-ovipositional period - 8. Fleischer and Gaylor (1988) reported a nymphal development time of 18 days on cotton at 78°F and found cotton to be a less favorable host than the fleabane, *Erigeron annuus* (L.). Ridgway and Gyrisco (1960) reported similar results using pods of green beans (*Phaseolus vulgaris* L.) as the host. In their study, the preoviposition period was approximately 8 days; the egg incubation period was approximately 7.6 days, and the total nymphal development period was approximately 19.7 days at 77°F. They also reported that first instar nymphs failed to survive at 95°F.

Although there is evidence that virgin female TPB release a pheromone that is attractive to males (Scales 1968; Snodgrass and Scott 1999), this pheromone has not yet been isolated. Snodgrass and Scott (1999) also reported results that suggest the presence of a male produced aggregation pheromone that is attractive to both sexes.

Diapausing adults spend the winter in ground trash and other protected sites (Bariola 1969; Crosby and Leonard 1914). Their distribution into northern Canada and Alaska (Schwartz and Foottit 1992) is evidence of their winter hardiness.

TPB usually completes one or more generations on alternate hosts and then moves into cotton fields once plants become attractive due to the initiation of squaring. Intensity and duration of movement into cotton varies considerably from year to year and appears to be related to abundance of alternate hosts and availability of flower buds on these hosts. Large numbers of TPB are often noted moving into cotton fields when dry conditions or natural senescence causes a decline in blooms on alternate hosts, or when mowing or tillage operations destroy such hosts.

Work by Stewart and Gaylor (1994) indicates that older females with chorionated eggs are more likely than either males or females less than 8 days old to engage in the type of long-duration flight that would result in migration into cotton. Based on results of sticky trap captures, approximately 90% of TPB flight occurs within 6 feet of ground level (Stewart and Gaylor 1991; Ridgway and Gyrisco 1960), a height which corresponds to that of many of the early successional type hosts of TPB. This tendency of TPB to fly near the ground may be one reason that higher TPB numbers often are observed near the periphery of cotton fields, especially where cotton adjoins areas of taller vegetation such as ditch banks or corn fields.

In Mississippi, seasons with above normal rainfall have been noted to be favorable to development of high TPB populations in cotton, presumably because alternate hosts remain in bloom longer, allowing TPB to build to higher populations and move into cotton fields over an extended period. Interestingly, yields also tend to be better than average in such years.

Although TPB is a common pest of cotton throughout the Mid-South and Southeast, it historically occurs at higher numbers and causes greater concern in delta environments. Annual yield losses attributed to TPB are often notably higher in the delta region of Mississippi than in the hill region of the state (Williams, 1995; 1997). This greater abundance of TPB on cotton in delta environments is attributed primarily to the relative ecological simplicity or lower host diversity that is typical of heavily cropped delta areas during the growing season. However, it must also be noted that boll weevil historically has been a greater problem in the hill region of Mississippi, and coincidental control of TPB with treatments primarily targeted to control boll weevils may also have contributed to the relatively lower TPB problems in the hill region of the state.

DAMAGE AND YIELD EFFECTS

Types of Damage. TPB has the capacity to cause damage to cotton from emergence through the early lint development stage of the last harvestable bolls. However, it is during the period between square initiation and early bloom that cotton is most susceptible to economic damage by TPB (Black 1973; Tugwell et al. 1976). Feeding is accompanied by injection of salivary enzymes into the plant, and it is the disruptive effects of these digestive enzymes on the plant tissue, rather than the amount of tissue consumed, that is responsible for most of the damage inflicted by TPB. However, the effects of this injected saliva are localized and there appears to be no systemic effect expressed at other locations in the plant.

Although pre-squaring cotton is not particularly attractive to TPB, terminals can be killed when fed upon by adults, causing a loss of apical dominance and development of numerous secondary terminals, a condition referred to as 'crazy cotton' (Scales and Furr 1968; Hanny et al. 1977). This condition also can result from damage inflicted to the terminal area by other pest species or by injury from abiotic factors. The economic impact of such damage is questionable, especially when only a small percentage of plants are affected, as some studies have found no effects on yield from this type injury (Hanny et al. 1977; Tugwell et al. 1976). However, because such damage potentially can delay crop maturity, cotton should be scouted for TPB before squaring to avoid any problems that could result from unusually high populations.

As soon as squares begin to form on the plants, TPB tends to feed on these preferentially. Squares smaller than approximately 1/8 inch in diameter are preferred over larger squares and bolls (Tugwell et al. 1976). Feeding on small squares usually results in 'blasted squares' that abscise within a few days, leaving an abscission scar at the point where the square was attached to the fruiting branch. Results of several studies with plant bugs (TPB or *L. hesperus*) caged on plants have shown that the rate of square shed per insect is in the range of 0.6 to 2.1 squares per insect per day in trials where the insects remained on plants for several days (Gutierrez and

Leigh 1977; Mauney and Henneberry 1979; Wilson 1984). Thus, there is a significant negative relationship between TPB numbers and percent early square retention (Andrews et. al. 1997; Phelps et. al. 1996; Ruscoe et. al. 1998), and excessive early square loss resulting from high, sustained TPB populations can affect fruiting patterns and delay crop maturity or result in yield loss. However, it is important to recognize that TPB damage is not the only cause of early square shed. Environmental factors, such as shading or drought stress, and injury by other pests, such as thrips or caterpillars, may also cause square shed (Guinn 1998).

Feeding on larger squares results in damage to developing anthers. Depending on intensity of damage, larger squares may abort but more commonly remain on the plant and develop into a bloom. Damage inflicted during the square stage is obvious on the open bloom as brown or darkened anthers. According to Pack and Tugwell (1976), the effect of this type of damage depends on the percent of anthers that are damaged. When less than 30% of the anthers are damaged there is little or no effect. However, as the level of anther damage increases, there is an increase in the percent of malformed bolls and an increase in percent of bolls shed, presumably due to inadequate pollination.

TPB will also feed directly on small bolls, resulting in a dull, dark colored slightly sunken lesion on the outer boll wall. Close examination of such lesions often will reveal a glossy, pin-point sized black spot at the site where the boll wall was punctured (Pack and Tugwell 1976). Again, the effect of such damage appears to depend on the age of the boll when damaged and the intensity of feeding. Small to medium sized bolls that have been heavily damaged contain a translucent, jelly-like material in affected locks that can be observed by slicing bolls. This is tissue that has been disrupted by the salivary enzymes that are injected into the plant. Bolls damaged in such a way may eventually abscise or fail to open. On larger bolls with more developed lint, feeding by TPB rarely destroys the entire boll, but may result in damaged seed, discolored lint, and reduced weight of harvestable lint (Pack and Tugwell, 1976). Recent research (Horn et al. 1999; Russell et al. 1999) indicates that bolls are relatively safe from damage by TPB once they have accumulated approximately 250 to 300 DD60s after flowering.

Effects on Yield. As indicated previously, cotton is most susceptible to delays in fruiting and yield reductions due to plant bug injury during the period from first square to early bloom. Before square initiation and during late season, cotton is much less likely to sustain damage from TPB. In studies with pre-squaring cotton, Tugwell et al. (1976) found no effects on yield as a result of 100% artificial terminal removal. Likewise, Hanny et al. (1977) measured no yield decrease as a result of terminal abortion due to TPB damage inflicted at or before the 6th node stage.

Although TPB has the capacity to damage bolls and high levels of this type of damage will obviously affect yield, most studies have shown no yield effects due to infestations during late season. Black (1973) found no significant yield loss in caged plots infested after first bloom, even at populations as high as 148,616 insects per acre. Tugwell et al. (1976) found no significant yield loss in plots infested at levels as high as 12 insects per plant during the 7th-9th week of squaring. Jubb and Carruth (1971) reported similar results but did note reductions in lint quality, and hence monetary value, due to late infestations of WTPB.

Several studies have examined the ability of TPB to adversely affect both yield and date of maturity when infestations occur during the first 6 weeks of squaring. In examining the results of these studies it is important to note both the degree of yield loss sustained as well as the level and duration of infestation. Laster and Meredith (1974) reported a yield reduction of 15.5% averaged across 16 varieties of cotton when initial populations averaged 0.9 nymphs per plant. Scott et al. (1986), working in relatively large field plots, reported a 21% yield reduction in untreated check plots compared to yields from plots treated with 4 weekly applications of commercial insecticides before bloom. Although the insecticides used in this study also had activity against other pests, most of this yield reduction was attributed to extremely high populations of TPB combined with damaging levels of cotton fleahoppers. Tugwell et al. (1976) reported a 42% yield reduction in plots infested with 3 TPB per plant during the first 2 weeks of squaring and a 55% yield reduction in plants infested at the same level during the 4th-6th week of squaring. All of the above mentioned studies involved populations in excess of 1 TPB per foot of row. Black (1973) observed no yield reductions in caged plants infested from first square to first bloom at a level of 9,017 TPB per acre (approximately 0.7 per row foot), but infestations of 18,949 TPB per acre caused a 31.4% yield loss and 148,616 TPB per acre caused in excess of 90% yield loss.

However, not all studies have shown yield reductions in response to infestations during this time. Wilson (1984) examined effects of infestations of 1 TPB per plant for periods of 1, 3, or 7 days at various times during the first 6 weeks of squaring. Although he noted delays in maturity of up to 2 weeks, yields were not significantly reduced, except in one case of late planted (June 11) cotton. Jubb and Carruth (1971) also found no effects on yield due to artificial infestations of 1 *L. hesperus* per plant, even though they noted that this was approximately 10-fold the normal field infestation level. In addition, there have been several studies involving artificial de-fruiting that show that cotton can tolerate partial or even complete loss of squares during the early square set period without suffering yield loss (Hamner 1941; Mann et al. 1994; Montez and Goodell 1994; Phelps et. al., 1997; Stewart 1997; Tugwell et al. 1976,). Many of these studies have shown a slight increase in yield due to low to moderate levels of de-fruiting. The ability to compensate or overcompensate for insect-induced injury is well documented in cotton (Brook et. al., 1992; Easton 1931; Stewart and Sterling 1988; Terry 1992) and has also been reported in other crops (Harris 1974; Russin et. al. 1987). There also are reports for some animal species showing increased rates of regeneration of body parts in response to increased levels of certain types of non-lethal injury (Zeleny 1905).

Although excessive square loss due to injury by plant bugs or other factors may cause significant delays in maturity, these delays do not necessarily result from low to moderate levels of square loss (Brook et. al. 1992; Montez and Goodell 1994; Stewart 1997). This is because harvest maturity is more influenced by the date of opening of the last harvestable bolls than by date of initial boll opening.

While studies involving caged plants with introduced insect infestations or artificial fruit removal have limitations, they do serve to illustrate that cotton can tolerate some square loss without suffering adverse yield effects or maturity delays. Results of a field study involving 12 cotton lines (Jenkins and McCarty 1995) help show why this is so. In this two-year study, in which average yield was in excess of 3 bales/Acre, average end of season boll retention did not exceed 66% at any fruiting position and averaged approximately 56% for first position bolls located at nodes 6 through 16.

PLANT BUG AS A KEY PEST OF COTTON

Throughout the Mid South, TPB ranks well behind bollworm/budworm (*Helicoverpa zea* (Boddie) and *Heliothis virescens* (Fabricius), respectively) in terms of damage caused or cost of control. However, TPB, along with boll weevil where it still occurs, is recognized as a key pest of cotton because it often colonizes fields and requires treatment during the early part of the growing season when insecticides would not otherwise be required. Treatment at this time destroys beneficial insects that would aid in suppressing populations of budworm/bollworm, aphids, and other pests and reduce the likelihood of having to treat for these pests, at least until later in the season. Therefore, early season treatments for TPB can result in increased numbers of treatments for pests, such as budworm and bollworm, and this can in turn contribute to increased levels of insecticide resistance in these secondary pests, resulting in a "pesticide treadmill" effect that increases production costs. On the other hand, failure to treat for damaging levels of TPB can result in significant yield losses or delays in maturity. Maturity delays also can result in increased exposure of the crop to damage from secondary pests by prolonging the cropping season during that portion of the season when many pest populations typically are highest.

Thus, early season TPB treatment decisions can have season long consequences of significant economic importance. Before treating for TPB, growers should carefully assess whether the risk of economic loss is sufficient to justify risking the long term consequences associated with treatment. Automatic or scheduled treatments should be avoided for several reasons. Residual activity of foliar TPB materials is relatively short, and it is difficult to predict when TPB will migrate into cotton from alternate hosts in numbers sufficient to cause economic loss. Automatically scheduled treatments may, by chance, be applied when damaging infestations are occurring, but more likely they will be applied: 1) too early - before TPB has moved into the field; 2) too late - after damaging populations have been present for an extended period of time and caused excessive square loss; or 3) when not needed - where TPB never reach damaging levels.

Head et al. (1985) compared the results of automatic, prophylactic control (4 weekly insecticide treatments beginning at the pin-head square stage) to scouting and treating only as needed. This large plot study was conducted in five Mississippi counties and was replicated at each site. Results showed that fewer sprays were required for the scout and spray as needed approach than for the automatic approach (average of 0.8 vs 4 insecticide applications), yet yields were essentially the same (average of 1019 lb. lint in the spray as needed vs 989 lb. in the automatic). In a similar large plot study conducted in Mississippi from 1995-1997 attempts to prophylactically control TPB did not provide a significant benefit (Stewart et. al. 1998).

EVOLVING PEST STATUS OF TARNISHED PLANT BUG

Historically, the boll weevil has been considered the primary key pest of cotton in the Mid-South and Southeast. However, with the success of the boll weevil eradication effort in much of the Southeast and the ongoing expansion of the program through the Mid-South, the key pest status of TPB likely will increase. Similarly, increased adoption of transgenic Bt cotton and the accompanying decrease in coincidental control of TPB due to the reduction in foliar treatments applied to control caterpillar pests is expected to allow TPB to become more prominent (Layton 1996, 1997). Recent surveys comparing Bt cotton and non-Bt cotton (Layton et. al. 1997, 1998, 1999) have shown that fields planted to transgenic Bt varieties often require additional treatments specifically to control TPB and/or sustain more TPB induced boll damage. Also, the recent development of more caterpillar-specific foliar insecticides will reduce coincidental control of TPB where these products are used on non-Bt cotton.

Another factor that has caused TPB to increase in prominence as a pest, especially during mid and late season, in recent years is the development of resistance to many of the organophosphate and pyrethroid insecticides traditionally used for its control (Snodgrass 1994; Snodgrass and Elzen 1995; Snodgrass 1996). In addition to reduced control from insecticide applications specifically targeted toward TPB, this resistance also results in less coincidental control of TPB from treatments targeting other pests, allowing TPB populations to build in cotton fields during a time of the season when they historically were controlled coincidentally by treatments targeting boll weevils and caterpillar pests. Collectively, these changes in cotton insect management systems, combined with the development of insecticide resistance in TPB, likely will allow the relative importance of TPB to increase. Consequently, the importance of proper sampling and management of TPB also is expected to increase.

SAMPLING AND THRESHOLDS

Sampling. As indicated in the previous section, there are certain adverse economic consequences associated with treating for plant bugs. Thus, it is important that populations be sampled properly and that treatments be applied only when populations exceed economic thresholds. TPB is much more mobile than most other cotton pests, and as a result is in some respects more difficult to sample. However, there are techniques which can be used effectively to sample TPB populations, provided the sampler is familiar with the mobile nature of this insect.

During the early square setting period when cotton is most susceptible to damage by TPB, it is the migrating adults that initially are of greatest concern. Adult TPB are very 'flighty' and will often flush while a scout is still some distance away. For this reason, adults are difficult to sample at this time using visual methods, and most states recommend using a 15-inch diameter sweep net. Although other methods of sampling using clam shell devices, whole plant sample bags, or D-vac machines have been shown to provide more accurate estimates of absolute adult populations (Byerly et. al. 1978; Ellington et. al. 1984; Fleisher et. al. 1985), these are cumbersome and impractical for routine commercial scouting. Ellington et. al. (1984) found the results of sweep net sampling for adults to be lower than, but significantly correlated with, results from an absolute sampling method. Young and Tugwell (1975) found the sweep net to be the most time efficient method of sampling adults and Byerly et. al. (1978) found it to be an effective method of monitoring relative populations, particularly before plants begin to bloom. Because the sweep net provides a relative estimate of populations, it is necessary to express thresholds in relative terms as well, such as number of TPB per 100 sweeps.

Proper sweeping technique is very important to obtaining a meaningful sample. The sweep net is swung through the upper part of the plant canopy to capture dislodged adults and nymphs. A sample usually consist of 25 sweeps along a single row. Samples are usually collected from several areas of the field, and counts are expressed as average number of TPB per 100 sweeps. Each sweep, one pass of the net through the row, should be several feet away from the previous sweep, to avoid sampling areas from which bugs have already flushed, and the sampler should move quickly down the row. Care should also be taken to hold the net at such an angle that the lower part of the net rim strikes the plants first, creating a scooping action as the net passes through the row. It is also important to keep the net moving during the entire time that the sample is being taken to prevent the quick moving adults from escaping before the sample is counted.

Although the sweep net is an effective method of sampling adults, the drop cloth is more effective in sampling nymphs, which spend more time hidden underneath the bracts of fruiting structures (Snodgrass 1993). The drop cloth consists of a 3-ft wide piece of strong white cloth, usually mounted on 2 wooden dowels for easier handling. It is spread between two rows of cotton and the 3 row ft of plants from one or both sides of the cloth are vigorously beaten over the cloth. Then the plants are moved aside and the number of dislodged nymphs are counted. Numbers are usually expressed as number per 6 row ft or number per ft of row. Because most adults are flushed while the cloth is being positioned, the drop cloth is less effective for sampling adults.

Both nymphs and adults can be sampled visually, and this is the recommended method of sampling once plants begin to bloom and effective use of the sweep net or ground cloth becomes more difficult (Layton 1999). Again, it is important to keep the 'flighty' nature of adult

TPB in mind when sampling visually. Select a plant terminal from a distance and observe closely for any adults that may flush as the plant is being approached and initially handled. Also, examine inside bracts of large squares and/or small bolls on the upper 5 to 8 nodes and count any nymphs or adults that are found. Counts and treatment thresholds are expressed as number of TPB per 100 plants. Snodgrass (1998) reported that nymphs, which are often more abundant than adults at this time, are most commonly found on fruiting structures, and that approximately 75% of the adults and nymphs are found in the upper 6 nodes of the plant.

In addition to information on populations of TPB present, information of percent square retention is extremely useful in making treatment decisions, particularly during the period from square initiation to early bloom. Such counts are usually taken by examining a predetermined number of potential square sites, counting the number of sites where a square has been lost, as evidenced by an abscission scar, and determining the percent of squares being retained on the plants. Usually, such counts are taken only from the uppermost five fruiting branches (less on young cotton with less than five fruiting branches) on a number of plants and only first, or first and second position square sites are examined. Results are expressed as percent square retention. Although plant bugs are not the only cause of early square loss, information on percent square retention is useful in making treatment decisions before bloom, and many states adjust plant bug treatment thresholds based on square retention levels (Bagwell 1999; Layton 1999; Seward and Lentz 1999).

Thresholds. Plant bug treatment thresholds for the period from first square through early bloom are presented in Table 1 for most U.S. cotton producing states. There are many similarities in thresholds among the various states. All states recommend a method of sampling, such as sweep net or ground cloth, which provides estimates of relative TPB populations, rather than absolute numbers of TPB per acre. Most states utilize information on both TPB populations and percent square retention in making TPB treatment decisions. In most cases, number of TPB is the primary trigger for treatment, but lower thresholds are used and/or sampling efforts are intensified when square retention drops below a specified amount, usually in the range of 70 to 85%.

By timely, effective scouting and monitoring of percent square retention during early square set, growers should be able to optimize plant bug management decisions by avoiding both unnecessary treatments and excessive damage due to high TPB infestations. However, it is important to stress that in order to achieve this goal sampling must be adequate and timely.

During the early square setting period, sampling for TPB and taking percent square retention counts are two of the most important insect scouting operations. Because large numbers of adults can migrate into cotton fields in a relatively short period of time, sweep net samples should be taken every 3 to 5 days. It is important that enough samples be taken to provide a reliable indication of the population, and samples should be taken from several areas of the field. Ideally, percent square retention counts also should also be made every 3 to 5 days until the crop begins to bloom. Such sampling is quite labor intensive, and growers should expect scouting fees and time spent in the field to reflect this investment of labor.

TABLE 1. Plant Bug Treatment Thresholds for Various Cotton Producing States for the Period from First Square to First Bloom (Thresholds are for TPB Unless Otherwise Noted).

State	Minimum % Square Retention[a]	Threshold[b]
Alabama	80%	1 per row ft. 1 per 2 row ft., if square set < 80%.
Arizona (L. hesperus)	(25% damaged squares)	15-20 bugs/ 100 sweeps or if damage exceeds 25% and nymphs present, (4-6 nymphs per 100 sweeps)
Arkansas	75%	1 per row ft. 1 per 3 row ft., if square set < 75%.
California (L. hesperus)	(25% damaged squares)	1st 3 weeks of squaring - treat if square damage exceeds 25%. Dynamic threshold based on number of squares present.
Florida	80%	7 per 100 sweeps, or 1 per row ft.
Georgia	85%	Treat if square set < 85% and numerous plant bugs present.
Louisiana	70%	10-25 per 100 sweeps.
Mississippi	80%	8 per 100 sweeps -; 2 weeks of squaring. 15 per 100 sweeps – 3rd week to 1st bloom. if square set < 80%, reduce threshold. 6-8 per 100 row ft. – 1st week of squaring.
Missouri	80%	8-10 per 100 row ft. – 2nd week of squaring. 12-15 per 100 row ft. – 3rd week of squaring.
North Carolina	80%	7.5/ 1 00 sweeps – 1st 2 weeks of squaring. 151100 sweeps – 3rd week till bloom.
Oklahoma (cotton fleahoppers)		40 fleahoppers per 100 terminals.
South Carolina	75%	1 per row ft if square set < 75%.
Tennessee	80%	1 per 6 row ft. - 1st 2 wks of squaring. 2 per 6 row ft. – 3rd week to 1st bloom.

TABLE 1. Continued.

State	Minimum % Square Retention[a]	Threshold[b]
Texas: High Plains Rolling Plains and Trans Pecos	75%	20 lygus per 100 sweeps - on 2 successive dates. 25-30 fleahoppers per 100 terminals.
Texas: Southern, Eastern and Blacklands		20 lygus per 100 sweeps - on 2 successive dates. 10-15 fleahoppers per 100 terminals-Blacklands). 15-25 fleahoppers per 100 terminals-(other areas).

[a] Most states recommend intensifying sampling and/or lowering threshold if percent square retention drops below this level.

[b] Condensed from cotton insect control recommendations of respective states (Alabama Cooperative Extension Service 1999; Bagwell 1999; Bacheler 1996; Ellsworth et. al. 1994; Georgia Cooperative Extension Service 1999; Godfrey et. al. 1994; Johnson 1999; Karner 1997; Layton 1999; Nabors and Jones 1994; Parker et. al. 1999; Roof, 1999; Sansone et. al. 1999; Seward and Lentz 1999; Sprenkel et. al. 1997).

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