

ARTHROPOD MANAGEMENT & APPLIED ECOLOGY

Effects of Simulated Threecornered Alfalfa Hopper Damage on Cotton Growth and Development

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ABSTRACT

The threecornered alfalfa hopper (TCAH), *Spissistilus festinus* (Say), is a sporadic pest in seedling cotton that has the potential to cause significant impact to cotton growth and development. Threecornered alfalfa hopper is a stem girdling pest that generally feeds on the main stem of cotton plants from the two- to eight-leaf growth stages. To better understand the potential impact of this pest on cotton growth and development, trials were conducted in Starkville and Stoneville, MS in 2023 and 2024. Experiments were implemented as a randomized complete block design with a factorial arrangement of treatments with four replications. Factor A was simulated TCAH damage at 0, 10, 20, 30, 40, and 50% increments; factor B was damage timed at the three- and six-leaf growth stage. Damage was simulated by applying low rates of glyphosate to stunt the plant to approximate TCAH damage. There were no significant impacts of simulated TCAH damage level percentage or timing on yield. Therefore, the results from this study suggest that TCAH has little economic impact on cotton seedlings.

Threecornered alfalfa hopper (TCAH), *Spissistilus festinus* (Say), is commonly recognized as a pest of soybeans (*Glycine max* [L.] Merr.) but has been observed injuring cotton (*Gossypium hirsutum* L.) seedlings in the Hills region of Mississippi (Catchot, 2019). Mississippi has two distinct geographical regions: the Hills and the Delta. The Delta region predominantly consists of large fields dedicated to monoculture, whereas the Hills region has a low

percentage of land dedicated to row crop production. The cultivated land in the Hills is characterized by smaller fields with variable field edges (Pettry, 1977). The differences in field characteristics between the Hills and Delta regions might contribute to the higher amount of TCAH damage observed in the Hills.

Threecornered alfalfa hopper adults are light green in color, with a triangular-shaped body. Males have a reddish line on the dorsum of the prothoracic shield, whereas females lack this characteristic (Wildermuth, 1915). During the nymphal stages, TCAHs lack a prothoracic shield but have a layer of hairs with prominent projections (Wildermuth, 1915). Damage caused by TCAH is referred to as girdling. Using their piercing and sucking mouthparts, these pests create a series of lateral punctures around a plant's mainstem, causing one or more knots typically below the cotyledons. This girdling can lead to stunted growth with reddish leaf venation or serve as a nutrient sink for future feeding (Rice and Drees, 1985). In cotton, girdling can occur on the main stem up until the eighth node and the insect can continue feeding on the petioles of more mature plants (Catchot, 2019). Although plant growth can be affected, a study conducted by Ewing and McGarr (1933) found that heavy infestations of TCAH and subsequent damage resulted in no significant yield losses in cotton.

Currently there is no established economic threshold for TCAH infesting Mississippi cotton. Catchot (2019) suggested that an insecticide application should be considered when cotton with fewer than six true leaves has more than 10 TCAH per 25 sweeps. However, population density is rarely high enough to warrant insecticide application. If treatment is necessary, pyrethroids or acephate provide acceptable control (Catchot, 2019). Treatment recommendations for TCAH in cotton vary by state. For example, the North Carolina State University Extension Service recommends implementing cultural practices such as destroying weedy hosts along field edges to limit adult migration (Reisig, 2021).

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In contrast, the University of Tennessee Extension Service states that uninjured plants adjacent to scattered, damaged plants will compensate for any yield loss (Stewart, 2012).

Cotton is characterized as having an indeterminate growth habit and the ability to compensate for early-season pest damage. A study conducted by Wilson et al. (2003) found that minimal early-season pest damage generally does not affect crop maturity or yield. Factors such as adequate water, proper fertilizer, temperatures, and soil type contribute to the plant's recoverability (Wilson et al., 2003). Although cotton can compensate for minor early-season damage, severe damage during early growth stages can result in delayed maturity and possible yield reductions (Crow et al., 2020). Therefore, it is important to reevaluate the impacts of early-season TCAH damage on cotton yield in Mississippi. This study evaluated the effects of simulated TCAH damage at the three- and six-leaf growth stage on cotton growth, development, and yield.

MATERIALS AND METHODS

Field studies were conducted during the 2023 and 2024 growing seasons at the Delta Research and Extension Center in Stoneville, MS and R. R. Foil Plant Science Research Center in Starkville, MS to evaluate the impact of simulated TCAH damage on cotton yields. The experiment was conducted as a randomized complete block design with a factorial arrangement of treatments with four replications. Factor A consisted of six levels of simulated TCAH damage: 0, 10, 20, 30, 40, and 50%. Factor B consisted of two levels of damage timing: three- and six-leaf growth stages. UA222 (University of Arkansas Division of Agriculture) conventional cottonseed susceptible to glyphosate herbicide was mixed at the previously specified percentages with Deltapine 2127 B3XF (Bayer CropScience, Research Triangle Park, NC), a variety tolerant of glyphosate.

Cotton was planted at a seeding rate of 129,865 seeds ha⁻¹ on conventionally tilled beds with irrigation on 15 May 2023 and 9 May 2024 in Stoneville and on 12 May 2023 and 9 May 2024 in Starkville, MS with no irrigation. Plots were four rows wide by 12.0 m in length on 1.01-m centers in Stoneville and 0.96-m centers in Starkville. Simulated TCAH damage was accomplished by spraying plots with glyphosate (Roundup PowerMAX®, Bayer CropScience, Research Triangle Park, NC) at a rate of

385.6 g ai ha⁻¹ at the three-leaf stage, which is a quarter of the recommended rate, and 771.3 g ai ha⁻¹ at the six-leaf stage, which is half of the recommended rate. These selected rates of herbicides successfully stunted plants to approximate TCAH damage. Herbicide applications were sprayed using a MudMaster 4WD multipurpose sprayer (Bowman Manufacturing, Newport, AR) calibrated to deliver 93.5 L ha⁻¹ at 413 kPa. All management decisions were made according to Mississippi State University Extension Service recommendations.

Plant density was determined 2 wk after planting and after the herbicide applications when cotton began squaring from a 6-m section marked in the center of row one. Stand counts were taken from the same marked location. Plant heights and node counts were measured at the first square and first bloom stages. Five damaged and five non-damaged plants were selected at random and were evaluated in all treatments, except the 0% simulated damage plots, where 10 non-damaged plants were evaluated. Plant heights were measured with a meter stick from the soil surface to the apical meristem of the plant. Node above white flower (NAWF) was assessed for 3 wk once blooms were present across all plots. The number of nodes above the uppermost first position white flower was recorded for NAWF. After cracked bolls were observed in all plots, evaluation shifted to nodes above cracked boll (NACB) for an additional 3 wk. NACB was determined by counting the number of nodes between the uppermost first position cracked boll and the uppermost first position harvestable boll. Five damaged plants were evaluated along with five undamaged plants in each plot for both NAWF and NACB. Harvestable bolls were categorized as 1.27 cm or larger in diameter.

Prior to harvest, 30 plants per replication, for a total of 120 plants per experiment, were cut at ground level for plant mapping. Three types of plants were selected at random to make up the 30 collective plants per replication: 10 non-damaged plants located next to non-damaged plants, 10 non-damaged plants located next to damaged plants, and 10 damaged plants. Plant fruiting locations were characterized similarly to studies conducted by Cook et al. (2013) (Fig. 1). Fruiting site mapping data were pooled into the following fruiting zones: zone one position one (primary fruiting locations below node nine), zone one position two (secondary fruiting locations below node nine), zone one position three (third fruiting locations below node nine), zone two position one

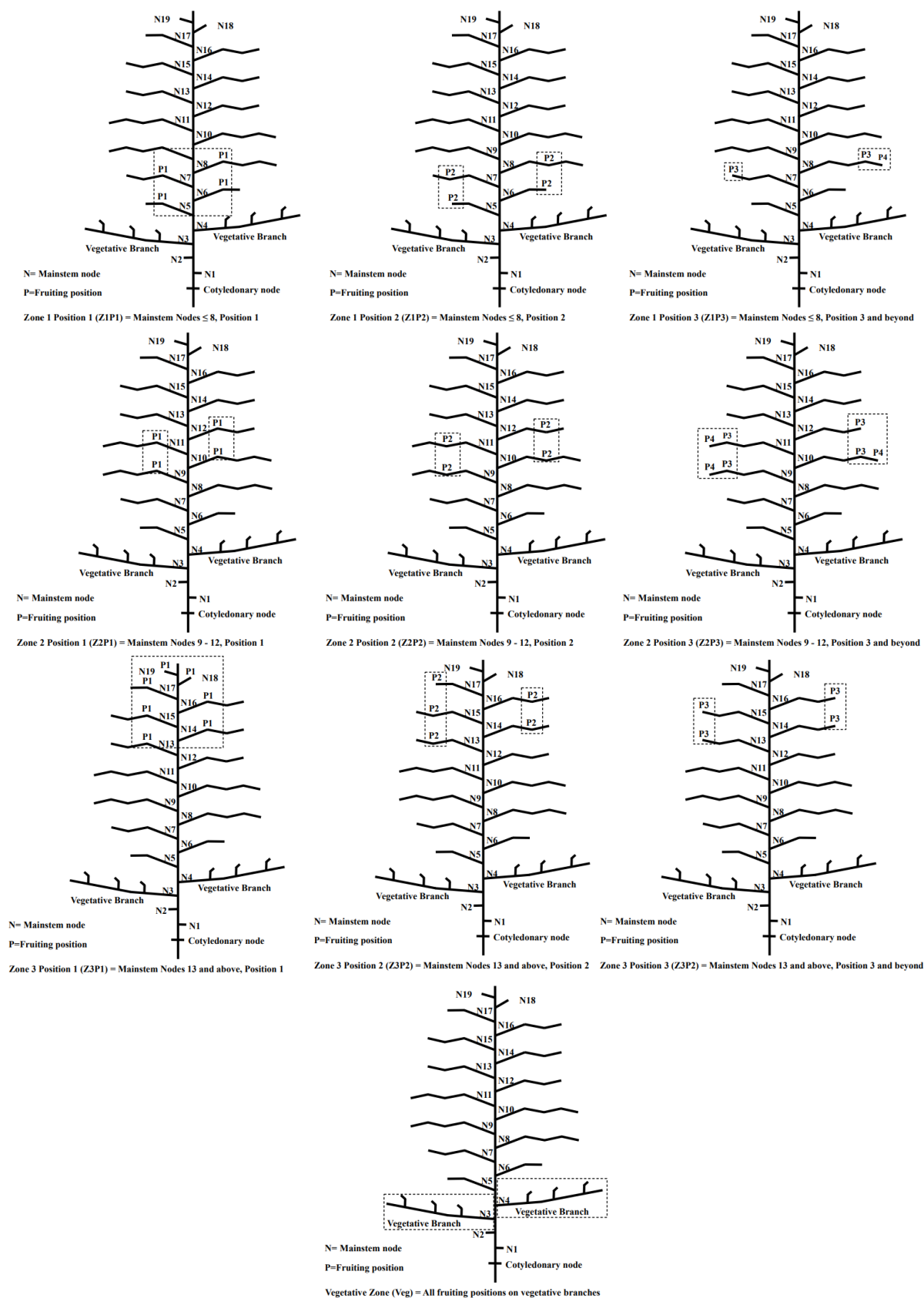


Figure 1. Visual representation of cotton fruiting zones and positions, adapted from Cook et al. (2013).

(primary fruiting location on nodes 9–12), zone two position two (secondary fruiting location on nodes 9–12), zone two position three (third fruiting location on nodes 9–12), zone three position one (primary fruiting location node 13 and beyond), zone three position two (secondary fruiting location node 13 and beyond), zone three position three (third fruiting location node 13 and beyond), and vegetative branch (all fruiting sites on vegetative branches). Cotton lint yields were collected from the center two rows of each plot using a modified cotton picker. Lint turnout was estimated at 40% to convert seed cotton weights to lint yield, expressed in kg ha⁻¹.

Statistical Analysis. Data were analyzed using Proc Glimmix in SAS 9.4 (SAS Institute, Cary, NC) and means were separated using Fisher's Protected LSD at an alpha level of 0.05. Simulated damage level and timing of damage were considered fixed effects in the model, whereas year, location, and replication were considered random effects.

RESULTS

There were no interactions among factors with respect to plant population. Simulated damage at the three- and six-leaf stage did not affect plant populations before ($F = 0.00$; $df = 1,175$; $p = 0.99$) or after ($F = 0.01$; $df = 1,175$; $p = 0.91$) damage occurred (Table 1). However, prior to herbicide application, plant populations differed among treatments with

varying damage percentages ($F = 2.89$; $df = 5,175$; $p = 0.01$) (Table 1). Although all populations resulted in acceptable stands, the highest plant populations were observed in the 10 and 40% simulated TCAH damage treatments. These populations did not differ from the 0 and 20% damage treatments but were higher than those in the 30 and 50% damage treatments. The lowest plant population was associated with 50% simulated TCAH damage treatment. By the final evaluation, no significant differences regarding plant population were observed among any treatment ($F = 1.17$; $df = 5,175$; $p = 0.32$).

No interactions were observed among factors for early-season agronomic data. Plant height did not differ based on damage timing for either damaged ($F > 0.27$; $df = 1,175$; $p > 0.60$) or non-damaged ($F > 0.04$; $df = 1,175$; $p > 0.70$) plants at first square or first bloom (Table 2). Similarly, there were no differences in the number of nodes in the damaged ($F = 0.31$; $df = 1,175$; $p = 0.57$) or non-damaged ($F = 0.01$; $df = 1,175$; $p = 0.90$) plants at these same growth stages. When comparing early-season agronomic data across damage levels, differences were observed among damaged plants at first square and first bloom. At the first square stage, the 0% simulated TCAH damage treatment resulted in greater plant height and node count than all other treatments for damaged plants. There were no differences for either factor for non-damaged plants. By first bloom, 0% simulated damage treatment resulted in greater plant

Table 1. The influence of simulated TCAH damage timing and damage percentage on plant population per hectare pooled across year (2023 and 2024) and location (Stoneville and Starkville, MS)

	Plants per Hectare ($\pm$ SE) ^a	
	Pre-Damage	Post-Damage
Growth Stage		
Three Leaf	116,906 (816)	125,174 (725)
Six Leaf	117,875 (599)	125,191 (617)
<i>p</i> -value	0.9969	0.9183
Damage Percentage		
0	117,038 (904) abc	126,557 (1237)
10	123,372 (993) a	128,259 (1068)
20	119,869 (1133) ab	126,237 (1118)
30	114,072 (1634) bc	121,662 (1008)
40	120,482 (1084) a	127,142 (1197)
50	109,510 (1354) c	121,237 (1317)
<i>p</i> -value	0.0157	0.3249

^aMeans within the column followed by the same letter are not different according to Fisher's Protected LSD with an alpha of 0.05.

Table 2. The influence of simulated TCAH damage timing and damage percentage on plant height and node count of damaged and non-damaged plants pooled across year (2023 and 2024) and location (Stoneville and Starkville, MS)

Growth Stage	First Square				First Bloom			
	Plant Height (cm [$\pm$ SE]) ^a		Node Count ($\pm$ SE)		Plant Height (cm [$\pm$ SE])		Node Count ($\pm$ SE)	
	Damaged	Non-Damaged	Damaged	Non-Damaged	Damaged	Non-Damaged	Damaged	Non-Damaged
Three Leaf	22.5 (1.17)	44.3 (0.97)	5.2 (0.17)	8.2 (0.09)	36.8 (2.57)	81.0 (1.30)	6.8 (0.39)	13.1 (0.21)
Six Leaf	21.2 (0.93)	43.8 (0.54)	5.1 (0.13)	8.2 (0.09)	32.5 (2.16)	81.4 (1.22)	6.1 (0.34)	13.1 (0.20)
<i>p</i> -value	0.6053	0.8356	0.5792	0.9094	0.9722	0.7088	0.5619	0.8764
Damage (%)								
0	39.8a (1.88)	44.7 (1.06)	7.4a (0.26)	8.3 (0.14)	81.1a (2.17)	81.1 (2.39)	12.8a (0.33)	12.8 (0.36)
10	19.1b (0.90)	44.2 (0.84)	4.7b (0.21)	8.1 (0.13)	30.8b (2.59)	82.5 (2.11)	5.8b (0.52)	13.3 (0.34)
20	18.7b (0.72)	46.8 (2.54)	4.6b (0.13)	8.3 (0.18)	25.0c (1.41)	81.1 (2.10)	4.8c (0.28)	13.2 (0.36)
30	17.9b (1.19)	43.4 (1.00)	4.7b (0.18)	8.2 (0.17)	23.4c (1.72)	81.5 (2.34)	5.0c (0.40)	13.2 (0.37)
40	18.2b (1.01)	42.9 (0.94)	4.6b (0.21)	8.0 (0.17)	23.6c (1.40)	79.5 (2.19)	5.0c (0.40)	13.0 (0.38)
50	17.7b (0.92)	42.5 (0.89)	4.7b (0.17)	8.0 (0.15)	23.8c (1.27)	81.5 (2.05)	5.4c (0.36)	13.1 (0.35)
<i>p</i> -value	0.0001	0.1304	0.0001	0.5879	0.0001	0.8300	0.0001	0.4881

^aMeans within the column followed by the same letter are not different according to Fisher's Protected LSD with an alpha of 0.05.

heights than all other treatments, followed by 10% damage treatment. No differences were observed between 20 and 50% simulated TCAH damage treatments regarding plant heights of the damaged plants ($F > 55.28$; $df = 5,175$; $p < 0.01$) (Table 2). In contrast, non-damaged ($F = 1.73$; $df = 5,175$; $p = 0.13$) plants showed no difference in plant height at the first square stage. The number of nodes ($F > 32.55$; $df = 5,175$; $p < 0.01$) followed a similar trend as plant height for damaged plants: the 0% damage treatment had the greatest node count followed by the 10% damage treatment followed by all other treatments. There were no differences among treatments for non-damaged ($F > 0.75$; $df = 5,175$; $p > 0.48$) plants. Plant heights of damaged plants were reduced by approximately 50% at first square and 62 to 71% at first bloom. Node counts of damages plants were reduced by approximately 37% and 54 to 62% at first square and first bloom, respectively. Although most damage did not result in plant death, the growth and development of damaged plants was severely impacted with minimal potential to recover.

When evaluating late-season agronomic data, there were no interactions between damage timing and percentage levels for NAWF or NACB. Damage timing had no effect on NAWF ($F > 0.21$; $df = 1,80$; $p > 0.45$) or NACB ($F > 0.10$; $df = 1,80$; $p > 0.09$) at any sampling period (Table 3). Similarly, the simu-

lated damage percentage did not impact NAWF ($F > 1.34$; $df = 1,80$; $p > 0.06$) at any sample interval. For NACB, no differences were observed among treatments at the first ($F = 1.76$; $df = 5,80$; $p = 0.13$) or third ($F = 1.34$; $df = 5,80$; $p = 0.25$) sample periods (Table 3). However, at the second sample timing ($F = 3.60$; $df = 5,80$; $p < 0.01$), 0% simulated TCAH damage treatment had fewer NACB than any other plots. Although some differences in plant maturity were observed, the overall impact of simulated damage on plant maturity was minimal. Damaged plants exhibited reduced plant height and node counts early in the season with minimal late-season response to early-season damage. Additionally, cotton yield was not affected by damage timing ($F = 0.83$; $df = 1,175$; $p = 0.36$) or percentage of simulated damage ($F = 0.57$; $df = 5,175$; $p = 0.72$) (Table 3).

The type of plant and location of the plant within the field did not affect the number of fruiting sites in zone one for any position ($F > 0.53$; $df = 2,14$; $p > 0.31$) (Table 4). However, the type of plant and its adjacent plant exhibited differences at all positions in zone two ($F > 19.44$; $df = 2,14$; $p < 0.01$), with damaged plants having fewer fruiting sites compared to non-damaged plants next to either non-damaged or damaged plants. Differences were observed in zone three ($F > 13.41$; $df = 2,14$; $p < 0.01$) at positions one, two, and three, where damaged plants

Table 3. The influence of simulated TCAH damage timing and damage percentage on nodes above white flower, node above cracked boll, and lint yield pooled across year (2023 and 2024) and location (Stoneville and Starkville, MS)

	Node Above White Flower ($\pm$ SE) ^z			Node Above Cracked Boll ($\pm$ SE)			Lint
	Sample One	Sample Two	Sample Three	Sample One	Sample Two	Sample Three	kg ha ⁻¹ ($\pm$ SE)
Growth Stage							
Three Leaf	4.2 (0.16)	3.1 (0.14)	2.3 (0.11)	7.2 (0.25)	5.2 (0.14)	5.4 (0.15)	867.5 (72.97)
Six Leaf	4.3 (0.15)	3.0 (0.12)	2.4 (0.12)	7.1 (0.24)	5.0 (0.14)	5.4 (0.14)	781.8 (37.78)
<i>p</i> -Value	0.4584	0.6446	0.4982	0.5449	0.0959	0.7490	0.3644
Damage (%)							
0	3.9 (0.18)	2.9 (0.19)	2.0 (0.13)	6.4 (0.32)	4.4b (0.22)	5.0 (0.28)	798.8 (57.07)
10	3.8 (0.27)	2.9 (0.20)	2.2 (0.15)	6.8 (0.37)	5.2a (0.28)	5.3 (0.28)	821.1 (70.22)
20	4.2 (0.22)	3.0 (0.28)	2.4 (0.23)	7.5 (0.44)	5.4a (0.22)	5.6 (0.23)	787.1 (58.24)
30	4.2 (0.25)	3.0 (0.18)	2.2 (0.19)	7.4 (0.40)	5.2a (0.20)	5.2 (0.20)	764.5 (61.92)
40	4.5 (0.30)	3.2 (0.22)	2.4 (0.27)	7.2 (0.48)	5.4a (0.24)	5.4 (0.24)	774.5 (57.41)
50	4.6(0.33)	3.5 (0.30)	2.9 (0.15)	7.6 (0.51)	5.1a (0.28)	6.0 (0.26)	1013.2 (205.64)
<i>p</i> -Value	0.1106	0.2547	0.0630	0.1307	0.0045	0.2578	0.7250

^zMeans within the column followed by the same letter are not different according to Fisher's Protected LSD with an alpha of 0.05.

Table 4. The influence of simulated TCAH damage on the number of fruiting sites, number of bolls present, and percentage boll retention for each position in each zone for each plant group pooled across year (2023 and 2024) and location (Stoneville and Starkville, MS)

	Zone One ^z ($\pm$ SE)			Zone Two ^y ($\pm$ SE)			Zone Three ^x ($\pm$ SE)		
	Pos. 1 ^w	Pos. 2	Pos. 3	Pos. 1	Pos. 2	Pos. 3	Pos. 1	Pos. 2	Pos. 3
Number of Fruiting Sites									
Non-damaged by non-damaged	13.1 (1.51)	12.7 (1.81)	14.1 (1.78)	20.1a (2.05)	21.1a (1.32)	24.8a (1.77)	47.1a (5.88)	48.3a (5.30)	30.1a (3.11)
Non-damaged by damaged	10.5 (1.50)	10.1 (1.71)	9.2 (1.49)	18.0a (1.42)	19.8a (0.91)	23.2a (1.01)	48.7a (5.31)	46.7a (5.14)	30.3a (2.78)
All damaged	13.8(1.72)	11.6 (1.88)	11.3 (1.73)	8.7b (0.83)	8.8b (0.83)	10.1b (0.83)	20.7b (2.44)	22.7b (2.90)	13.0b (1.28)
<i>p</i> -Value	0.3163	0.5991	0.1563	0.0001	0.0001	0.0012	0.0006	0.0004	0.0001
Number of Bolls Present									
Non-damaged by non-damaged	7.1a (0.54)	5.6a(0.82)	5.3a (0.49)	8.6a (0.82)	8.5a (0.80)	9.8a (1.27)	11.1a (1.76)	13.6a (2.54)	7.8a (1.36)
Non-damaged by damaged	5.1b (0.95)	4.0a (1.21)	3.8a (0.87)	7.5a (1.01)	8.3a (0.94)	9.5a (1.58)	12.6a (2.11)	14.1a (2.24)	7.7a (1.96)
All damaged	0.1c (0.12)	0.3b (0.18)	0.2b (0.25)	0.1b (0.12)	0.2b (0.16)	0.7b (0.36)	1.3b (0.53)	0.6b (0.26)	0.6a (0.26)
<i>p</i> -Value	0.0001	0.0019	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0004
Boll Retention (%)									
Non-damaged by non-damaged	57.6a (5.40)	45.4a (5.67)	40.4a (3.81)	44.3a (3.80)	40.9a (4.34)	42.5a (8.00)	25.3a (4.50)	30.5a (6.97)	27.3a (4.24)
Non-damaged by damaged	48.8a (6.64)	39.5a (8.31)	39.8a (4.37)	40.9a (3.30)	43.2a (5.80)	41.2a (7.20)	25.5a (3.92)	30.2a (4.37)	24.0a (5.55)
All damaged	1.7b (1.78)	5.5b (3.19)	2.0b (2.08)	1.5b (1.56)	2.2b (1.48)	7.6b (3.35)	6.3b (2.38)	2.9b (1.43)	4.6b (1.83)
<i>p</i> -Value	0.0001	0.0002	0.0001	0.0001	0.0001	0.0012	0.0018	0.0003	0.0006

^zNodes ≤ 8 (excluding monopodial branches)

^yNodes 9 through 12

^xNodes ≥ 13

^wMeans within the column followed by the same letter are not different according to Fisher's Protected LSD with an alpha of 0.05

had fewer fruiting sites. In contrast, plant type and location did not result in differences in the number of fruiting sites found on vegetative branches ($F = 1.40$; $df = 2, 14$; $p = 0.27$) or in zone one ($F = 1.09$;

$df = 2, 14$; $p = 0.36$) (Table 5). However, type of plant and location of the plant did influence the number of fruiting sites in zone two and three ($F > 15.82$; $df = 2, 14$; $p < 0.01$), with non-damaged plants adjacent

Table 5. The influence of simulated TCAH damage on the number of fruiting sites, number of bolls present, and percentage boll retention for vegetative branches, each zone, each position, and total sites for each plant group pooled across year (2023 and 2024) and location (Stoneville and Starkville, MS)

	Veg ^z (±SE)	Zone One ^y (±SE)	Zone Two ^x (±SE)	Zone Three ^w (±SE)	Pos. One (±SE)	Pos. Two (±SE)	Pos. Three (±SE)	Total Sites (±SE)
Number of Fruiting Sites								
Non- damaged by non-damaged	4.2v (1.25)	40.0 (5.06)	66.1a (4.94)	125.6a (14.19)	80.3a (8.00)	82.2a (6.78)	69.1a (5.37)	236.0a (20.98)
Non-damaged by damaged	4.2 (1.38)	29.9 (4.61)	61.1a (3.25)	125.8a (13.06)	77.2a (5.94)	76.7a (5.50)	62.8a (3.40)	221.1a (15.86)
All damaged	2.3 (0.98)	36.9 (5.23)	27.7b (2.27)	56.5b (6.45)	43.3b (3.75)	43.2b (3.53)	34.5b (2.37)	123.5b (9.86)
<i>p</i> -Value	0.2797	0.3647	0.0001	0.0003	0.0003	0.0001	0.0001	0.0001
Number of Bolls Present								
Non-damaged by non-damaged	1.0a (0.32)	18.1a (1.60)	27.0a (2.15)	32.6a (5.21)	26.8a (2.55)	27.7a (2.98)	23.1a (2.15)	78.7a (7.20)
Non-damaged by damaged	1.1a (0.39)	13.0a (2.67)	25.3a (2.91)	34.5a (6.12)	25.2a (2.88)	26.5a (3.68)	21.1a (3.43)	74.0a (9.63)
All damaged	0.0b (0.00)	0.7b (0.36)	1.1b (0.47)	2.6b (0.92)	1.6b (0.67)	1.2b (0.36)	1.6b (0.56)	4.5b (1.43)
<i>p</i> -Value	0.0291	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Boll Retention (%)								
Non-damaged by non-damaged	29.5 (12.92)	47.9a (4.18)	42.5a (4.94)	27.7a (4.89)	35.3a (4.08)	35.4a (4.99)	35.7a (5.17)	35.3a (4.56)
Non-damaged by damaged	44.3 (15.89)	42.9a (4.90)	41.8a (5.02)	26.8a (4.30)	32.6a (2.83)	34.6a (4.47)	33.3a (4.89)	33.5a (3.93)
All damaged	0.0 (0.00)	2.8b (1.17)	4.3b (1.80)	4.5b (1.58)	4.1b (1.74)	3.1b (1.07)	5.1b (1.85)	3.9b (1.34)
<i>p</i> -Value	0.1295	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001

^zAll fruiting positions on monopodial branches.^yNodes ≤ 8 (excluding monopodial branches).^xNodes 9–12.^wNodes ≥ 13.^vMeans within the column followed by the same letter are not different according to Fisher's Protected LSD with an alpha of 0.05.

to damage and non-damaged plants exhibiting an increase in the number of sites compared to damaged plants. All three fruiting positions ($F > 15.46$; $df = 2, 14$; $p < 0.01$) showed that non-damaged plants next to other non-damaged plants or damaged plants were similar, whereas damaged plants continued to have the fewest number of fruiting sites. Lastly, the total number of fruiting sites ($F = 21.14$; $df = 2, 24$; $p < 0.01$) on non-damaged plants adjacent to either non-damaged or damaged plants were greater than the number of fruiting sites on damaged plants alone.

Differences in the number of bolls were observed when evaluating the plant type and their location within the field for zone one position one ($F = 44.57$; $df = 2, 14$; $p < 0.01$) (Table 4). Non-damaged plants adjacent to other non-damaged plants produced more bolls than those next to damaged plants. Furthermore, non-damaged plants next to damaged ones produced significantly more bolls than damaged plants. Damaged plants consistently had fewer bolls than both non-damaged plants next to either damaged or non-damaged plants. In zone one, positions two and three, the type of plant and its neighboring plant influenced the number of bolls ($F > 10.18$; $df = 2, 14$; $p < 0.01$),

with non-damaged plants producing more bolls at these positions than damaged plants. Similarly, in zone two, positions one, two, and three ($F > 18.45$; $df = 2, 14$; $p < 0.01$), no differences were observed between non-damaged plants adjacent to either damaged or non-damaged plants, whereas damaged plants had fewer bolls. In zone three, positions one, two, and three showed differences in boll numbers ($F > 14.24$; $df = 2, 14$; $p < 0.01$), with non-damaged plants producing more bolls than damaged plants. The number of bolls on vegetative branches showed similar results ($F = 4.60$; $df = 2, 14$; $p = 0.02$) (Table 5), with non-damaged plants producing more bolls than damaged plants. Across all three fruiting zones, damaged plants consistently produced fewer bolls compared to non-damaged plants ($F > 23.62$; $df = 2, 14$; $p < 0.01$). Additionally, plant type and location within the field influenced the number of bolls across positions one, two, and three ($F > 42.65$; $df = 2, 14$; $p < 0.01$), with damaged plants producing fewer bolls than their non-damaged counterparts. Lastly, the total number of bolls ($F = 56.87$; $df = 2, 14$; $p < 0.01$) indicated that non-damaged plants were similar in their production levels regardless of damage

to the neighboring plant, whereas damaged plants had fewer bolls. Notably, damaged plants rarely reached a total of five bolls, whereas both groups of non-damaged plants produced a total of more than 70 bolls, underscoring the minimal contribution of damaged plants.

Across all fruiting zones and positions, non-damaged plants retained more bolls than damaged plants ($F > 10.20$; $df = 2, 14$; $p < 0.01$) (Table 4). In contrast, no differences in boll retention were observed for vegetative branches based on plant group and location ($F = 2.52$; $df = 2, 14$; $p = 0.12$) (Table 5). The overall boll retention percentage ($F = 34.31$; $df = 2, 14$; $p < 0.01$) confirmed that non-damaged plants retained significantly more bolls than damaged plants. Notably, boll retention percentage was higher in the lower portions of the plants than the upper portions, suggesting that bolls located lower on the plant play a critical role in compensating for losses incurred by damaged plants.

DISCUSSION

A study conducted by Miller et al. (2004) looked at low rates of glyphosate in non-glyphosate-resistant cotton, applied at different growth stages. The results showed a reduction in plant height and plant maturity. With the reduction of height being a symptom of both glyphosate and TCAH damage, the use of glyphosate to simulate TCAH damage is justified to evaluate the growth and development of injured plants. Plant populations in this study remained consistent across treatments even after sustaining damage. Injury caused by TCAH rarely results in mortality, but can impact growth and development, indicating that the simulated damage method produced injury similar to that of TCAH. Feeding injury from TCAH or other insect pests like the tarnished plant bug (*Lygus lineolaris* [Palisot de Beauvois]) can cause plants to redirect resources toward recovery rather than reproductive growth, leading to extended flowering periods, delayed boll set, and uneven crop development (Wilson et al., 2003). These factors can affect harvest timing and management decisions. However, the extent of maturity delay is often influenced by pest pressure, plant populations, and environmental conditions (Wilson et al., 2009). Although some differences in maturity were observed in this study, no major delays in plant development occurred. In high planting populations, simulated damage of up to 50% resulted in minimal-to-no maturity delays or yield

loss, indicating that these populations can withstand TCAH damage without significant consequences. However, in lower plant populations, the impact of damage can be more pronounced.

In the absence of insect damage, Hall et al. (2024) evaluated the growth, development, and yield of several cotton varieties differing in seed size and seeding rates of 49,400, 98,900, and 148,200 seeds ha^{-1} . This study found that seeding density had no significant impact on cotton lint yield. Similarly, Kimura et al. (2024) evaluated the effects of high and low seeding rates in both irrigated and non-irrigated fields. Their results showed that increasing the seeding rate did not improve yield, suggesting no economic benefit to planting at higher populations. Although lower seeding rates can yield comparable-to-higher planting populations, damage can have a greater impact on plant recovery and increase the likelihood of delayed maturity (Wilson et al., 2003). Further research is needed to evaluate the effects of early-season plant damage on growth and development with variable seeding rates.

Cotton is able to recover from early-season damage due to its indeterminate growth habit, which enables it to continue producing new vegetative and reproductive structures throughout the growing season (Wilson et al., 2003). When plants incur early damage from factors such as insect feeding, weather events, or mechanical injury, they can compensate by increasing boll retention, producing additional fruiting sites, or adjusting boll size (Sharma et al., 2015). The extent of recovery depends on various factors, including the timing of the injury (Chaudhry and Guitchouts, 2003). Sapkota et al. (2023) found that cotton plants can compensate for yield loss when population density is less than ideal or when plant stands are uneven. In our study, non-damaged plants showed no significant differences in boll production or retention, regardless of neighboring plants. However, damaged plants produced fewer bolls. Given the irregular distribution of damaged plants and the lack of impact on yield, it is likely that compensation occurred through increased boll size.

Lastly, in high plant populations, neighboring plants can compensate for losses, mitigating the overall impact on yield. However, in lower plant populations, individual plant recovery becomes crucial, and damage can have a more pronounced effect on maturity and yield potential (Wilson et al., 2009). Wilson et al. (2009) examined the effects of plant damage on neighboring plants and their

responses in growth, development, and yield. Their study found that in non-uniformly damaged populations, undamaged plants exhibited increased yield. Similarly, Ramsey (2015) reported that cotton plants girdled by TCAH were less productive, producing less seed cotton per plant when compared to non-girdled plants. Based on these data, the impacts of elevated levels of TCAH damage on higher plant populations are less likely to cause delays in plant maturity or yield losses. Therefore, with no established economic threshold in the Mississippi insect control guide for TCAH in cotton and this study showing minimal impact on maturity and yield from simulated damage, it remains justifiable to continue without implementing an economic threshold for this pest in Mississippi cotton.

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