White-tailed Deer Damage to Cotton in Alabama

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Abstract: White-tailed deer (*Odocoileus virginianus*) damage to cotton (*Gossypium hirsutum*) was evaluated during 2 growing seasons in east-central Alabama. Deer began browsing cotton as soon as cotyledons emerged, and all plant parts were browsed during the growing season. Browsing of cotton cotyledons may kill plants and will reduce yields if it is extensive. However, browsing on cotyledons was rare in this study. Most feeding was done on cotton leaves, and occurred too late to reduce yields. Similarly, square and terminal removal after August and small boll removal after September occurred too late to impact harvestable yields. The most serious damage to cotton occurred when deer fed upon small squares and associated terminals in July and August and on small and medium (<27 days of age) bolls in August and September. Although deer browsing of cotton often was visually striking during this study, seed cotton yields were reduced ($P < 0.05$) only on the edges of lowland fields and large fields. Although white-tailed deer damage to cotton did not justify special depredation permits, some small, lowland fields were heavily damaged and were removed from cotton production.

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Cotton was the primary row-crop grown in the southeastern United States from the early 1800s until 1920. After the boll weevil (*Anthonomus grandis grandis*) invaded the region, most cotton production shifted to weevil-free areas in the West (Frisbie et al. 1989). Until 1991, most cotton in Alabama was grown in northern Alabama where boll weevil pressure was less. With the elimination of the boll weevil as an economic pest in the Southeast (Luttrell et al. 1994), cotton production in the region has increased dramatically. For example, cotton acreage in Georgia increased 144% from 1993 to 1995 (Hollis 1995). Cotton acreage in the southern third of Alabama increased 216% between 1989 and 1994 (Anon. 1995).

White-tailed deer may damage many field crops, including broccoli, cauliflower, corn, buckwheat, soybeans, and tomatoes (Matschke et al. 1984). Flyger and Thoerig (1965) reported extensive damage in Maryland to soybeans, corn, and orchard crops.

Damage to buckwheat was so severe that this crop was becoming impossible to grow economically. Palmer et al. (1982) reported extensive damage to alfalfa in Pennsylvania. In the southeastern United States, deer damage was reported to be most widespread on soybeans and corn (Moore and Folk 1978), but many other crops, including cotton, reportedly were damaged. In east-central Alabama, deer browsing on cotton is common. In response to grower complaints, the Alabama Department of Conservation, Division of Game and Fish, issued Special Depredation Permits to farmers that resulted in the killing of >500 deer in the area (Robert Seidler, Ala. Dep. Conserv., pers. commun.). However, effects of deer browsing on cotton yields are not known. As more cotton is grown in areas with high deer densities (e.g., central and southern Alabama), more apparent damage to cotton is likely.

Cotton has a remarkable ability to compensate for herbivore damage. Cotton plants may produce 3 times as many flower buds as can mature (Reynolds et al. 1975). Fruit lost to herbivore feeding may be replaced by some of these extra fruiting forms. This ability to sustain feeding damage without yield loss often makes damage assessment difficult because obvious feeding activity may result in little yield loss. Determination of economic loss of a particular crop should be made before a control permit is issued (Garrison and Lewis 1987). If repellents or mechanical scaring devices are to be used to alleviate crop damage, the timing, duration, and location of damage should be determined (DeCalesta and Schwendeman 1978). The objectives of this study were to determine: (1) the time of year deer fed upon various cotton plant structures, (2) the distribution of damage within fields, (3) effects of field size and location on damage, and (4) effects of deer feeding on cotton yields.

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Methods

Our study was conducted near Society Hill, Macon County, Alabama. The study area was chosen because it had numerous cotton fields in close proximity to each other and deer density was high. Based on population reconstruction using hunter kill data, deer density in the area was ≥0.3 deer/ha (M. K. Causey, unpubl. data). Also, the area included farms where deer damage to cotton often was visually striking. Because of the history of deer feeding on cotton in the area, we judged this study area to be representative of areas where deer browsing on bottom was likely to be heavy.

Intraplant Distribution of Damage

A single sample site was established in each of 6 fields in the first year and 5 fields in the second year of the study. Sample sites were established where a well-defined deer trail entered the study field. Plant growth and deer damage were monitored on 24 plants at each sample site. Six plants were selected randomly for monitoring at the field edge and at 5, 10, and 25 m into each field. At each distance into the fields, 2 plants were located within 3 m on each side of the entering deer trail and perpendicular to the trail, and 1 plant was located 9 m perpendicular to each side of the trail. A plant map showing all above-ground plant parts and when each structure was formed and removed was constructed for each cotton plant. Sampling was initiated 2 August in the first year of the study and 10 June in the second year. Each plant was examined at 1- to 2-week intervals, and the plant map was updated. Thus, we monitored the fate of each leaf, flower bud, and fruit on 144 cotton plants during the first year and on 120 plants during the second year.

Inter- and Intrafield Distribution of Damage

All cotton fields in the study area ($N = 26$) were classified as either large (≥5 ha) or small (<5 ha) and as either lowland or upland to determine types of fields most susceptible to deer damage. Lowland fields were in floodplains, and uplands were on first or second terraces >0.2 km from the floodplain. Thus, all fields were assigned to 1 of 4 classes: large-upland, small-upland, large-lowland, or small-lowland. In both years, 2 fields each from the large-upland, small-upland, and large-lowland groups were sampled. Four small-lowland fields were sampled initially, and 3 were sampled the second season.

We established plots 1.5 m long on single rows located on the edges of fields (0–10 m from field margins), in transition areas (25–35 m from field margins), and in the center of fields (50–60 m from field margins) to study the distribution of deer damage within cotton fields. Five replicates of each plot location were established in each large field, and 4 replicates were established in each small field. Two small fields were too small to contain center plots (<100 m across). All plants within each sampling site were examined at 1- to 2-week intervals, and numbers of leaves, squares, and bolls fed upon by deer were determined. Yields at each sample site were determined by hand-harvesting plots 0–5 days prior to commercial harvest.

Deer damage and cotton yield data were analyzed by the GLM procedure (SAS 1985) for a factorial experiment with 1 split in a completely randomized design. Field location, field size, and season were considered factors. Plot location was treated as a split-plot within each field size x field location combination. Means were separated with a LSD procedure.

In the second year, deer exclosures were used to determine cotton yields on field edges and in transition zones. Exclosures were wooden frames covered by 25-mm poultry netting that enclosed 6 m^2 areas (2 rows of cotton) to a height of 1 m. As cotton grew, the exclosures were raised to 2 m. Two exclosures were placed randomly on field edges and 2 were placed in transition zones in 5 lowland fields expected to be browsed most heavily, based on the first year's data. Exclosures were not placed in field centers because edge effect was unlikely to affect cotton yields at distances >35 m into the fields. Cotton yields in the 2 zones were compared with ANOVA (SAS 1985).

Results

No emerging cotton plants were sampled the first year, but we observed white-tailed deer feeding on terminals and leaves as soon as cotyledons emerged the following spring. Deer feeding activity on cotton terminals in June and July was light. Only

2 of the 120 plants selected for study apparently were killed in the cotyledonary stage by deer feeding.

Most deer feeding activity on cotton involved leaves (Fig. 1). Deer fed on cotton leaves all season in both years of this study, but differences were noted between seasons. The maximum mean number of leaves eaten was 12.5/plant in 1 field in October of the initial year. Squares and bolls were not present in the fields before

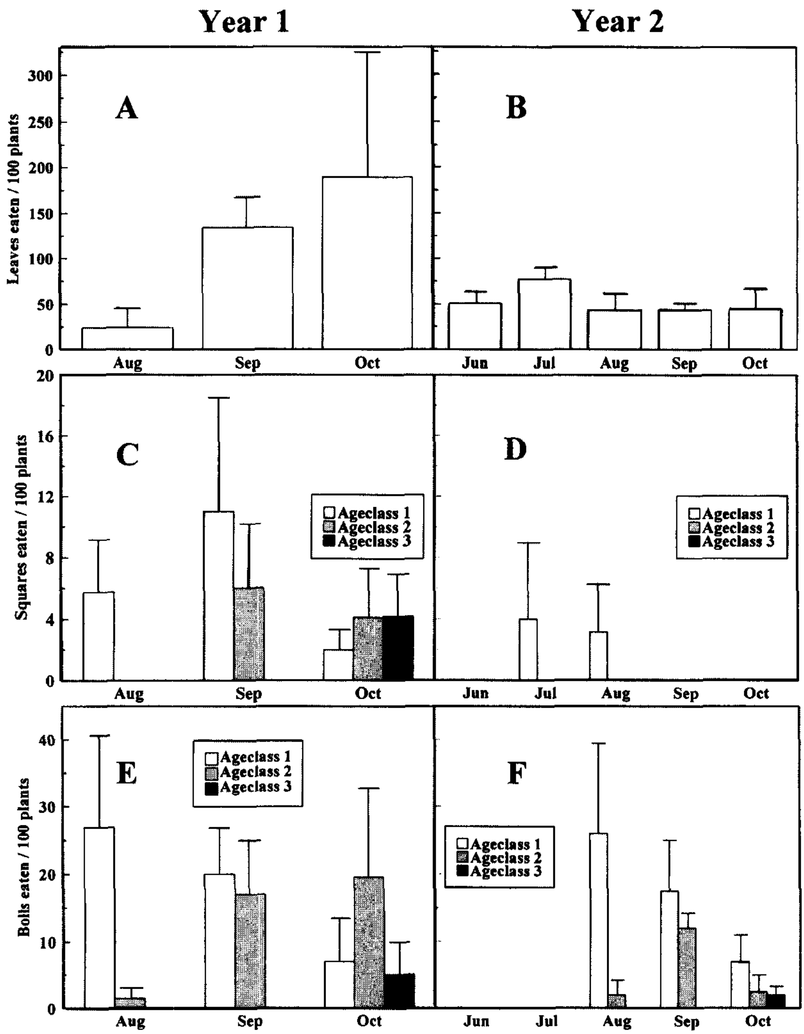

Figure 1. Mean numbers of cotton leaves (A and B), squares (C and D), and bolls (E and F) eaten by white-tailed deer per 24 plants in year 1 and 2. Structures in age classes 1, 2, and 3 are 1–4 days, 15–27 days, and >27 days, respectively. Vertical bars represent standard errors of the means.

July and August, respectively. Thus, feeding on these structures apparently began as soon as they became available, but observations were initiated too late to determine the level of damage to young squares in July of the first year. Feeding on squares was greater and continued longer the first season than the second (Fig. 1). No squares were removed by deer after August during our second study season. Most feeding on young squares appeared to occur when deer removed terminals. Most white-tailed deer feeding on cotton fruit was confined to young- (1–14 days old) and mid- (15–27 days old) aged bolls (Fig. 1).

Inter- and Intrafield Distribution of Damage

Because of significant differences ($P < 0.05$) between years for effects of field sizes, field locations, and plot locations on cotton yields, we analyzed all data on deer damage for each year separately. During the second field season, there were significant ($P < 0.05$) interactions between plot location and field location for damage to bolls and terminals (Table 1) and between plot location and field size for damage to terminals (Table 2). These interactions were not significant ($P > 0.05$) during our initial study season. Neither the plot location x field size interaction nor field size main effects were significant ($P > 0.5$) for numbers of bolls fed upon in either year of this study (Table 2).

In lowland fields, significantly more feeding on bolls and terminals occurred on field edges than in other parts of the fields during the second growing season (Table 1). In the first season, there were no significant ($P > 0.05$) differences detected due to plot location, but the trend for plot location effects on numbers of bolls and termi-

Table 1. Effects of plot and field locations on mean (±S.E.) number of cotton structures eaten by white-tailed deer and on cotton yields.

Variable	Plot location within fields	Field location			
		Field season 1		Field season 2	
		Upland	Lowland	Upland	Lowland
Bolls eaten (*N*/1.5 row-m)					
	Edge	0.8+0.3a[a]	5.9±1.8a	0.1±0.1a	2.3±0.9a
	Transition	0.7±0.3a	2.6±0.8a	0.3±0.2a	0.6±0.3b
	Center	0.1±0.1a	1.1±0.4a	0.0±0.0a	0.4±0.2b
Terminals eaten (*N*/1.5 row-m)					
	Edge	0.4±0.4a	5.0±4.0a	1.1±0.7a	3.1±1.3a
	Transition	0.0±0.0a	0.6±0.5a	0.7±0.3a	1.4±0.5b
	Center	0.0±0.0a	0.0±0.0a	0.0±0.0a	0.5±0.2b
Seed cotton (g/1.5 row-m)					
	Edge	226.7±19.0a	292.4±42.3a	327.9±17.1a	227.7±20.5b
	Transition	331.3±19.4a	322.1±34.5a	326.1±17.7a	331.2±23.9a
	Center	303.6±26.5a	377.6±35.1a	358.7±28.0a	349.2±23.4a

[a]Means within columns and structures followed by the same letter are not significantly different ($P > 0.05$) according to a LSD test.

Table 2. Effects of plot location and field size on mean (±S.E.) number of cotton structures eaten by white-tailed deer and on cotton yields

Variable	Plot location within fields	Field size			
		Field season 1		Field season 2	
		<5 ha	≥5 ha	<5 ha	≥5 ha
Bolls eaten (N/1.5 row-m)					
	Edge	4.0±2.0a[a]	3.6±1.3a	1.1±0.7a	1.4±0.7a
	Transition	2.3±1.0a	1.5±0.6a	0.8±0.4a	0.4±0.2a
	Center	0.6±0.4a	0.8±0.3a	0.2±0.2a	0.3±0.2a
Terminals eaten (N/1.5 row-m)					
	Edge	6.8±5.2a	0.1±0.1a	4.4±1.8a	0.7±0.4a
	Transition	0.0±0.0a	0.7±0.5a	0.5±0.2b	1.5±0.5a
	Center	0.0±0.0a	0.0±0.0a	0.6±0.3b	0.2±0.1a
Seed cotton (g/1.5 row-m)					
	Edge	250.6±40.4a	277.8±35.4a	320.4±21.2a	289.1±18.3b
	Transition	321.0±22.8a	315.2±35.5a	319.0±25.0a	336.1±19.4a
	Center	360.2±28.6a	344.5±33.9a	324.2±30.8a	370.8±21.1a

[a]Means within columns and structures followed by the same letter are not significantly different ($P > 0.05$) according to a LSD test.

nals eaten in lowland fields was the same as in the second season. In upland fields, there were no plot location effects for bolls or terminals eaten during either season.

Significantly more feeding on bolls occurred in the lowland fields than in the upland fields during both years of this study. Numbers of terminals eaten did not differ ($P > 0.05$) between lowland (x ± SE = 2.0 ± 1.4 and 1.6 ± 0.5 for the first and second seasons, respectively) and upland fields (x ± SE = 0.2 ± 0.2 and 0.7 ± 0.3 for first and second seasons, respectively) during either season.

More cotton terminals were fed upon in small (x ± SE = 2.0 ± 0.7) than in large fields (x ± SE = 0.8 ± 0.2) the second season. Most of this difference could be attributed to more feeding on the edges of small fields (Table 2) than in other parts of these fields. Terminal damage during the first year was not different ($P > 0.05$) for plot locations or field sizes, but the trend also was for more damage on the edges of small fields. Thus, we concluded that most deer feeding damage to cotton occurred on the edges of small-lowland fields.

In our first study season, there were no differences in yields for any factor studied (Tables 1, 2). However, significant interactions ($P < 0.5$) for yields among plot locations and field locations and among plot locations and field sizes were detected the following year. Yields were lower on field edges than in other plot locations in lowland fields, but there were no differences among plot locations in upland fields (Table 1). Yields also were lower on the edges of large fields than in other plot locations in these fields (Table 2). Plot location had no significant effect in small fields. There were no differences between zones ($P > 0.05$) in yields of cotton grown within deer exclosures in large, lowland fields (x ± SE = 265.6 ± 128.6 and 281.7 ± 134.4 g/plot in edge and transition zones, respectively) or in small, lowland fields (x ± SE = 226.8 ± 98.8 and 246.3 ± 145.4 g/plot in edge and transition zones, respectively). Thus, lower yields on the edges of large, lowland fields were attributed to deer browsing.

Discussion

When evaluating the economic impact of white-tailed deer feeding on cotton, the wildlife manager first must determine if the plant structures being fed upon will contribute to harvestable yield. Cotton plants fed upon in the cotyledon stage usually die if the apical meristem is removed. However, the 2 young plants killed in this study were in an area of the field where a deer trail entered the field and where damage might be expected to be greatest. Because cotton yields normally are unaffected by a wide range of stand densities (Martin et al. 1976), we concluded that little economic damage due to deer feeding on cotton in the cotyledonary stage occurred during this study. However, deer feeding on plants in this growth stage has the potential of reducing yields if feeding pressure is heavy.

Removal of leaves after cotton had reached the first true leaf stage probably did not reduce yields significantly except where virtually all leaves were removed. This level of defoliation was rare during this study. The maximum level of leaf feeding (12.5/plant) would be obvious to a casual observer, but removal of leaves during this time (October) was not economically damaging because the crop was mature. In 2 of our study fields, the farmers applied defoliants in mid-October to accelerate leaf shedding and boll opening.

Destruction of cotton terminals may be economically damaging because it may cause a delay in harvest (Heilman et al. 1981, Wilson, 1982). Delayed harvest results in economic loss to the farmer because of lint loss, decreased crop quality, and increased insect problems while the cotton remains in the field. Terminal removal was not monitored on the mapped plants, but because most small squares removed were in plant terminals and these squares were too small to be removed without damage to the terminals, the number of young squares eaten may be an indication of the number of terminals destroyed. A worst-case situation would occur if the loss of each square also involved the destruction of the plant terminal. The timing of deer feeding on different cotton structures also is critical in evaluating damage. Square and boll development average about 22 and 50 days, respectively (Stewart 1986). Bolls produced in late season require 65–90 days for maturation (Smith and Falcon 1973). Thus, squares removed in August may reduce yield, but squares produced after August probably would not have enough time remaining in the growing season to reach the open boll stage. Although apparent deer damage to squares was striking in September, little economic damage resulted. Removal of the lower number of small squares (and terminals) in August probably was more economically damaging.

Deer feeding on young bolls may not be a serious loss to cotton farmers if losses from other causes do not occur. Even in the absence of damage from external sources, ≥50% of the small bolls produced by a cotton plant normally are shed for physiological reasons (Hall 1958). If young bolls or squares are lost to herbivores, cotton plants usually compensate by retaining more of their excess fruits (Stewart et al. 1989, Montez and Goodell 1994). Loss of many small bolls, however, makes the cotton crop vulnerable to subsequent fruit loss or to adverse weather. Removal of mid-aged and old (>28 days old) bolls (age classes 2 and 3, respectively) is more serious than the loss of young bolls because these older fruits normally are not shed. However, removal of these older fruits is economically damaging only if sufficient time remains for these bolls to mature before harvest. Assuming 65 days for maturation (Smith and Falcon 1973), bolls harvested during the first week of November formed no later than the first week of September and would reach the mid-age stage during mid- to late-September. Under cooler temperature conditions and longer boll maturation times, or assuming an earlier harvest, harvestable bolls have to be formed even earlier than September. Most of the mid-aged bolls eaten by deer in September (Fig. 1) were formed in mid-August to mid-September. Thus, these bolls could have contributed to harvestable yields and their loss probably was economically damaging. Young bolls removed in October probably would not have had time to mature before harvest. Thus, most economic damage by deer feeding on fruiting structures was due primarily to feeding on bolls in September.

Reduction of cotton yields on edges of lowland fields was consistent with greater feeding activity observed on field edges and observations of deer frequenting bottomlands in the warm season. This behavior is consistent with previous deer crop damage studies, where heaviest damage occurred at edges and declined as distance into fields increased (Flyger and Thoerig 1965, Hartman 1972, DeCalesta and Schwendeman 1978). Reduced yields on edges of large fields and equal yields among plot locations in small fields might be expected if deer were feeding throughout the small fields and primarily on the edges of large fields. However, because deer fed primarily on terminals on the edges of small fields and equally throughout large fields, white-tailed deer browsing on terminals cannot be used to explain yield differences in this study.

After the wildlife manager determines that deer are feeding on plant structures that would contribute to harvestable yield, he/she must determine the proportion of each field that is being damaged and the proportion of fields in the area that are being damaged. In our study, feeding activity on the edges of some fields was visually striking in both years of this study. Casual observers might conclude farmers were suffering great economic losses to deer. However, the amount of actual loss, even in fields heavily utilized by deer, was related directly to the proportion of field area within 10 m of the field edge. Little feeding occurred in plots located >50 m from field margins. Few fields in the area were both lowland and so small that a large part of the field was within 50 m of the field margin. Thus, the level of deer damage to cotton in the study area probably did not justify special deer population reduction. However, a few small fields located on bottomland suffered significant deer damage. For example, during the first study season in field 11, a small narrow (<100 m wide) lowland field, deer damage to terminals and leaves averaged 28.8 and 62.8, respectively on the field edge and 0 and 10.2 m in the transition zone. Mean yields were 45.1 g and 202.4 g/1.5 row-m on the edge and in the transition zone, respectively. Because the edge zone was a large portion of the field, the productivity of the field was reduced drastically. The best method of preventing damage to cotton in this area may be to avoid planting these particular fields with cotton, as the grower did with field 11 in the second year of this study. It might be more prudent to plant these small, lowland fields with deer forage and lease the hunting rights. Since most economic damage appeared to occur when deer fed on terminals or small bolls during short time spans, the use of repellents or scaring devices should be investigated.

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