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Plant agroevirons associated with cotton producing areas and the arthropod populations supported within representative plant complexes

Soybean and other alternate plant agroevirons may be potential sites for avian feeding. Arthropod populations inhabit every potential plant ecosystem. Arthropod populations vary in relative abundance and diversity by plant types and feeding habits of the individual arthropod species. While some species such as thrips, feed on a wide variety of plants and insects as a food source, other species such as tobacco budworm, are limited to a few plant species.

This summary report represents a compilation of arthropod data from published literature references from various plant ecosystems that may be associated in close proximity to cotton and represent alternative feeding areas for insectivorous avian species.

Heliothine species on wild plant hosts in the Mississippi delta

In the Mississippi delta agroevirons, most of the generation of adult *Heliothine* species that emerges from overwintering pupae and their F1 progeny is dependent on early season plant hosts for survival and reproduction. The adults of the F1 progeny migrate to cotton in mid June. From 1965 to 1977, a survey was conducted in the Mississippi delta from mid April to mid June to determine the relative abundance of overwintered *Heliothine* species on wild plant hosts (Stadelbacher, 1981). The data were summarized according to *Heliothine* species and plant host, converted from sweep net sample numbers to relative absolute numbers per hectare (Pitre *et al.* 1987), and then converted to numbers per acre, Table 1. The estimated biomass per acre was calculated by multiplying the average weight of a *Heliothine* larvae (0.6 mg) by the estimated number of *Heliothine* larvae per acre. **The estimated biomass of *Heliothine* larvae ranges from 482 to 17,288 mg/acre during mid April to mid June on the various host plants.**

Soybean

Soybean production is closely associated with cotton production. It is even common for the two crops to be grown on the same land during alternate years. Therefore, soybeans represent a cropping system which supports a large arthropod population and may be a potential feeding site for insectivorous birds.

Soybean is a crop that requires significantly less intensive crop management than cotton, thus there is much less disruption of the arthropod populations. Soybeans are typically planted one month later than cotton. Soybeans develop through vegetative growth stages (referred to as V1-Vx) and in approximately mid July (depending on maturity group), the crop enters into a reproductive phase of blooming (R1) through pod formation and maturity (R3-R6). Blooming soybeans have been shown to be more attractive than cotton to certain adult insects (Felland *et al.* 1992). Arthropod populations in soybeans were sampled in Mississippi during 1983-84 to assess sampling procedures and relative efficiencies to estimate pest and beneficial populations (Pitre *et* *al.* 1987). Insect populations from this study were used to calculate the relative abundance and biomass per acre during each of the four growth stages sampled which represent a June/July, July/August, August and September timeframe, respectively, Table 2. **The average biomass of insects sampled during the V7-V11, R1/R2, R3/R4 and R5/R6 crop stages was 10,426; 56,493; 39,145; and 39,093 grams per acre, respectively, Table 3.**

Pasture and grass lands

Pasture and grass lands are common plant agroevirons closely associated with cotton. The systems are fairly stable and support arthropod populations year round. Arthropod populations are fairly consistent throughout the year, as well as from year to year. Certain species of insects vary in numbers by season. Some epizootics of insect pests do occur such as armyworm outbreaks.

Insect pest populations in trefoil-grass mixtures were monitored from May to September in W. Virginia during 1984-85 (Mackun and Baker 1990). Although these data represent only the key pest populations monitored and do not represent either beneficial or total arthropod populations, for this exercise, they will be used to represent typical arthropod numbers and biomass per acre in pasture and grasslands.

Populations of spittlebug were reported per square meter; the leafhopper-planthopper, mirids, and aphids were reported per 5 sweeps of a standard sweep net, Table 4. Numbers of insects were converted to numbers per acre. Sweep net numbers were corrected by applying a factor of 7 to adjust for sampling inefficiencies (7X, Pitre *et al.* 1987) to represent an absolute number per acre. Average body weights, as noted in Table 4, were multiplied by the number per acre to achieve a total biomass per acre. Biomass (in mgs) per acre for spittlebugs, leafhopper-planthopper, mirids, and aphids was calculated to be 184,536; 42,042; 63,456 and 29,736. **The average total biomass was 319,770 mgs per acre.**

Summary

Comparison of the total arthropod biomass associated with wild host plants, cotton, soybean and pasture-grasslands throughout the cotton growing season is presented in Table 5. Prior to cotton emergence to pinhead square (April - early June), arthropod populations in wild hosts plants and pasture-grasslands are estimated to be 8.2 and 3209 gms/acre in total biomass. Arthropod populations develop in cotton over the season and peak in July with an estimated 5,428 gms/acre. Cotton supports an average arthropod biomass of 3,472 gms/acre. However, arthropod populations and total biomass in soybean greatly exceed that of cotton. Arthropod biomass averages a total of 36,289 gms/acre throughout the year. Populations are highest in soybean during July to September (56,493 to 39,093 gms/acre), which coincides with the major period of insect control in cotton.

Table 1. **Relative abundance and biomass of overwintered *Heliothine* species on wild plant hosts in the Mississippi delta during mid-April to mid-June, 1965-1977. (Stadelbacher 1981)**

	Crimson clover	Persian clover	Geranium dissectum	Geranium carolinianum	Vetch	Alfalfa
Maximum No. Heliothine larvae/ha (sweep net)						
H. zea	10,046	1,023	2,153	1,476	930	269
H. virescens	335	2,392	6,615	861	3,409	20
Converted to absolute No. *Heliothine* larvae/ha (6.88X)						
H. zea	69,116	7,038	14,812	10,154	6,398	1,850
H. virescens	2,304	16,456	45,511	5,923	23,453	137
TOTAL	**71,420**	**23,494**	**60,323**	**16,077**	**28,851**	**1,987**
Converted to absolute No. *Heliothine* larvae/Acre						
TOTAL	**28,814**	**9,511**	**24,422**	**6,508**	**11,680**	**804**
Converted to *Heliothine* biomass (mg/acre)						
TOTAL	**17,288**	**5,706**	**14,653**	**3,904**	**7,008**	**482**

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Table 2. **Numbers of various arthropod species in soybeans (Oktibbeha County Miss., 1983-84) relative to phenology of soybean plants. (Pitre *et al.* 1987)**

Species	Average no. arthropods/square meter*			
	V7-V11	**R1/R2**	**R3/R4**	**R6/R5**
Araneida	49.01	21.17	33.32	21.36
Coleoptera				
C. trifurcata	---**	51.9	68.25	33.6
Coccinellids	54.55	100	68.75	68.94
Lebia spp.	100	----	45.87	68.94
Hemiptera				
Geocoris spp.	100	84.47	73.1	86.05
Nabids	100	68.94	54.26	49.75
Orius insidiosus	---	100	84.3	100
Pentatomids	---	100	68.3	68.94
Homoptera				
S. fetsinus	68.94	72.93	59.48	44.15
Lepidoptera				
P. scabra				
1st -6th instar	24.2	17.24	13.78	19.38
3rd-6th instar	44.08	19.45	23.45	27.96
A. gemmatalis				30.3
P. includens				23.6

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* Average of 1983-84 sample numbers. Single number rather than average when only one year data collected.

** No data collected.

Table 3. **Biomass of various arthropod species in soybeans (Oktibbeha County Miss., 1983-84) relative to phenology of soybean plants. (Pitre *et al.* 1987)**

Species/wgt mg	Average biomass of arthropods/acre (gm)*			
	V7-V11 June/July	R1/R2 July/Aug	R3/R4 Aug	R5/R6 Sept
Araneida */14.5*	2877	1381	1954	1385
Coleoptera				
C. trifurcata/11.5	---**	2416	3176	1562
Coccinellids/31.8	2537	12869	8846	8871
Lebia spp./NA		----		
Hemiptera				
Geocoris spp./1.1	445	376	323	384
Nabids/2.4	971	667	526	481
Orius insidiosus/0.15	---	60	50	60
Pentatomids/86.5	---	35006	23909	23909
Homoptera				
S. fetsinus/12.3	3431	3630	272	2197
Lepidoptera				
P. scabra	58			
1-6th instar/ 0.6	107	41	33	47
3rd-6th instar/0./6	---	47	56	67
A. gemmatalis/0.6	---	---	---	73

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Pseudoplusia includens/0.6		---	---	57
Total biomass (gms/acre)	**10,426**	**56,493**	**39,145**	**39,093**

* Average of 1983-84 sample numbers. Single number rather than average when only one year data collected.

** No data collected.

Table 4. **Average insect populations in trefoil-grass mixtures, W. Virginia 1984-85. (Mackun and Baker 1990)**

	Spittlebug	Leafhopper-planthopper	Mirids	Aphids
Average number/sq. meter Average number/5 sweeps	3.8	1.325	2.28	4.06
Average number/acre*	15378	2310	3976	7080
Average number/acre corrected sweep net**		16170	27832	49560
Average body wgt (mg)	12	2.6	2.28	0.6
Biomass/acre (mg)	184,536	42,042	63,456	29,736
Total biomass (mgs/acre)	**319,770**			

* 5 sweeps of 38 cm net = 2.32 square meters

** Number corrected for sweep net sampling efficiency 7X factor (Pitre *et al.* 1987)

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Table5. **Average arthropod biomass per acre in wild plant hosts, cotton, soybean, pasture-grasslands plant ecosystem during the cotton growing season.**

Plant hosts	**Arthropod Biomass gms/acre**						
	April - early June	**Early - mid June**	**Early - mid July**	**July/ August**	**August/ September**	**September/ October**	**Season average**
Wild plant hosts	8.2	8.2					NA
Cotton - pests		68	4,380	2524	580	1,389	2,218
Cotton - beneficials		139	1,048	890	926	1,077	985
Cotton total		207	5,428	3,414	1,505	2,465	3,472
Soybean			10,426	56,493	39,145	39,093	36,289
Pasture-grasslands	320	320	320	320	320	320	320

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References cited

Mackun, I.R., and B.S. Baker. *1990*. Insect populations and feeding damage among birdsfoot trefoil-grass mixtures under different cutting schedules. J. Econ. Entomol. 83(1) 260-267.

Pitre, H.N., L.G. Thead, and J.L. Hamer. 1987.Predcition of field populations of soybean insects from sweep-net samples in narrow-row soybean plantings. J. Econ. Entomol. 80:848-853.

Stadelbacher, E.A. 1981. Role of early-season wild and naturalized host plants in the buildup of the F1 generation of Heliothis zea and H. virescens in the delta of Mississippi. Environ. Entomol. 10:766-770.

Biomass in Treated Fields

Detailed information on insect pest management in cotton, timing, and biomass of avian food items follows.

Cotton culture has a relatively short history in the US. Wild cottons were discovered in what are now LA and TX in 1528 (Lambert *et al.* 1996). The first commercial production occurred in the Jamestown settlement of VA in about 1621 (Lambert *et al.* 1996). More than 100 species of insects and mites are pests of cotton in the US (Leigh *et al.* 1996). However, less than 2 dozen species are common on a yearly basis and will cause crop damage if not controlled. The remaining species can cause severe losses, but usually only in limited geographic areas during occasional years (Leigh *et al.* 1996).

Cotton insect control only started in earnest with the invasion of the boll weevil in the early 1900's. This devastating pest dominated insect control practices through the 1970's. Now, however, boll weevil eradication programs have been successful and the priorities and procedures of cotton insect control are in flux.

A common practice in cotton insect control since 1940's has been "scouting" by trained entomologists to measure pest population levels and damage, and beneficial insect population levels. Treatments are recommended based on stage of the cotton and insect population levels. Some Extension Services have routinely published these thresholds in bulletins since the early 1940's (see Leser *et al.* 1996). It is estimated that over 95% of the cotton acres planted are currently "scouted" for insect pests by trained entomologists (Lambert *et al.* 1996).

Chlorfenapyr will have 2 distinct use patterns in cotton, as roughly reflected by the separate PIRATE and ALERT labels. The first is for control of budworm, bollworm, and the armyworm complex across the Cotton Belt. Budworm and bollworm moths lay eggs in the terminals of the plant and larvae burrow into developing squares and bolls. Thus budworm and bollworm larvae are often concealed from view. Armyworm moths lay eggs on the leaf surfaces throughout the plant. Larvae of the armyworm complex attack cotton leaves and remain exposed on the leaf surface to a greater degree than budworm and bollworm larvae. They will also attack developing squares and bolls, but do not burrow in them. Because these pests have the theoretical potential of being bird food items, they will be discussed first. The second use pattern will be for control of mites in Western Cotton, primarily AZ and CA. Because these pests are microscopic and have very little potential of being bird food items, they will be discussed second.

There are numerous thresholds that state Extension Entomologists have developed for cotton pests (see for example, Laws (1993), Lambert *et al.* (1996), Johnson *et al.* (1996), Leser *et al.* (1996), Moore *et al.* (1996), Western Integrated Pest Management Project (1984)). The following information is drawn primarily from Laws (1993) for pest management procedures control of budworm, bollworm, and armyworms in Arkansas, Louisiana, and Mississippi, from Leser *et al.* (1996) for Texas, Oklahoma, and New Mexico, and from the Western Integrated Pest Management Project (1984) for California and Arizona.

Budworm and Bollworm – General for the Mississippi Delta: Plant between April 15 and May 15. From planting to June 30, control budworms and bollworms only if economic damage is occurring. Use *Bacillus thuringiensis* or carbamates (as ovicides or larvicides). Do not use pyrethroids or organophosphates during this time period. From July 1 to August 16, scout fields at least twice weekly. Time insecticide applications to eggs or 1-2 day old larvae (1/16" to 1/8" long). Use pyrethroids plus ovicidal rates of carbamates. From August 16 to boll maturation, do not use pyrethroids, use organophosphates or organophosphates plus ovicidal rates of carbamates. General for California and Arizona: Older larvae do most of the damage, but treatments must be aimed at young larvae because large larvae are hard to kill. Losses are greatest where natural enemies have been destroyed by applications for other pests. Severe outbreaks are most common in the deserts following repeated applications for pink bollworm. Damaging outbreaks rarely occur in central New Mexico or the San Joaquin Valley.

The following thresholds are recommended:

Arkansas: Treat when 7000 small larvae (less than ¼ ") are present per acre. If larvae begin to develop treat when 3500 medium or large larvae (greater than ¼ ") are present. When damage to squares occurs, treat when 14,000 squares are damaged per acre and eggs and small larvae are present. Time to egg hatch.

Louisiana: Start applications when squares are 1/3 grown or larger and 5 live worms per 100 plants, plus eggs are present. After August 1, or when terminal growth has ceased, eggs and small larvae may be found in squares and dried blooms. It is especially important to apply insecticides before the larvae attack the bolls.

Mississippi: From first square to first bloom, the objective should be to manage the egg stage using an ovicidal rate of a carbamate. If beneficial populations are low, treat when egg counts exceed 20 eggs per 100 plants. After first bloom, treat when there are 4 or more 0 - 5 day old larvae per 100 plants. Use a pyrethroid until August 16.

Texas: Treat at 5000 small larvae per acre.

Oklahoma: Treat when there are 10 small larvae per 100 terminals plus eggs.

New Mexico: Treat at 5000 small larvae per acre or 10 small larvae per 100 plants.

California and Arizona desert valleys: Treat when there are 10 - 12 small larvae per 100 plants.

Beet and Fall Armyworms – Leaves, squares, and bolls are occasionally damaged by armyworms. Apply insecticides while the worms are small.

Arkansas: Treat when fall or beet armyworms are present. More effective control can be obtained when applications are timed to egg hatch and small larvae and when infestation is comparable to bollworm treatment levels, i.e., 7000 small larvae per acre or 3500 large larvae per acre.

Louisiana: Treat when egg masses and worms appear.

Mississippi: Treat when 3 to 5 egg masses (at an estimated 175 eggs per egg mass) and live larvae are found per 100 plants or when 4 or more worms are found in 100 blooms and bolls or when one small larva is found per four row-feet. Time applications to treat young larvae.

Texas has established a threshold of 20,000 larvae per acre, with the proviso that at least 10% of the plants must be checked in order to compensate for the clumped distribution of larvae.

It is apparent from the above that Extension Service recommendations for economic thresholds are expressed as numbers of a particular insect life stage per 100 terminals, per 100 feet of row, or per acre. It is possible to convert the units per 100 terminals or per 100 feet of row to per acre values, as the table below shows.

Calculations for Insect Population Density in Cotton [1]
Spatial Characteristics of Single Row Cotton Fields

Row Spacing (in.)	Rows per 210 ft	# Row ft of plants	# Plants per acre
30	84	17640	70560
38	66	13860	55440
40	63	13230	52920

(1) Assumptions
1 acre is 43650 square feet
It can be treated as a square 210 feet on an edge
Cotton plants in a row are 3" apart at their bases, or 4 plants per row foot
Cotton single row spacings can vary from 30" to 40"

The above table can be used to convert the various recommendations to a per acre basis. By knowing estimated population densities of the life stages per acre and their weights, one can estimate the biomass of insects in a cotton field at application. Data on insect weights follow.

Weights (mg) of the Various Larval Stages of Important Pest Lepidoptera

Species	Egg	1st Instar	2nd Instar	3rd Instar	4th Instar	5th Instar
Bollworm		0.61	4.44	23.24	154.94	237.88
Budworm		0.73	4.56	22.93	98.99	158.85
Fall Armyworm	0.07					
Beet Armyworm		0.2	1.48	10.9		

The information for bollworm, budworm, beet armyworm was obtained by C. Kukel and M. Treacy of American Cyanamid Company. The weights for 5th instar bollworms are somewhat lower than those reported by Wiseman *et al.* (1991) for colonies originating in Georgia. The mean weights of 5th instar bollworms in their study were about 400 mg. It is not clear how much of the difference is due to inherent weight differences and how much of the difference is due to nutrition from the artificial diet. Laboratory-reared insects tend to be better nourished, and are often larger, than insects occurring in nature (Lynch *et al.* 1983). The weights for 3rd instar budworm larvae are comparable to those obtained by Mullins and Pieters (1982). The fall armyworm information is from Lynch *et al.* (1983).

Estimates of Pest Biomass per Acre at the Treatment Thresholds

Pest	State	Life Stage	Biomass (gr)	Life Stage	Biomass (gr)
Bollworm/Budworm	AR	Small Larvae	31.5	Large Larvae	80.5
Bollworm/Budworm	LA	Larvae	70.6	--	--
Bollworm/Budworm	MS	Eggs	98.8	0 - 5 Day Larvae	324.5
Bollworm/Budworm	TX	Small Larvae	22.5	--	--
Bollworm/Budworm	OK	Small Larvae	141	--	--
Bollworm/Budworm	NM	Small Larvae	22.5	Small Larvae	352
Beet Armyworm	AR	Small Larvae	21.0	Large Larvae	38.2
Beet Armyworm	MS	Eggs	432	Small Larvae	13.2
Beet Armyworm	TX	Small Larvae	60	Large Larvae	218

Assumptions:
Bollworm/Budworm
AR: 7000 small larvae per acre. Small larvae are less than ¼" and weigh 4.5 mg each. 3500 large larvae per acre. Large larvae are late 3rd instars weighing 23 mg.
LA: 5 small larvae per 100 plants. Small larvae are 1 - 2 days old and weigh 2 mg each. There are 70560 plants per acre in the densest *cotton planting. (Typical plantings have about 55000 plants).*
MS: 20 eggs per 100 plants. Eggs weigh 0.7 mg each. There are 70560 plants per acre in the densest cotton planting. (Typical plantings have about 55000 plants). Four 0 - 5 day old larvae per 100 plants. 5 day old larvae weigh 11.5 mg each. There are 70560 plants per acre.
TX: 5000 small larvae per acre. Small larvae are less than ¼" and weigh 4.5 mg each.
OK: 10 small larvae per 100 plants. Small larvae weigh 2 mg. There are 70560 plants per acre.
NM: 5000 small larvae per acre. Small larvae are less than ¼" and weigh 4.5 mg each. 10 small larvae per 100 plants. Small larvae are less than ¼" and weigh 4.5 mg each.
Beet Armyworm
AR: 7000 small larvae per acre. Small larvae are less than ¼" and weigh 3.0 mg each. 3500 large larvae per acre. Large larvae are late 3rd instars weighing 10.9 mg each.
MS: 5 egg masses per 100 plants, at 175 eggs per egg mass with eggs weighing 0.07 mg each. One small worm per 4 row feet. Small worms are less than ¼" and weigh 3.0 mg. The maximum row feet per acre is 17640.
TX: *20,000 small larvae per acre. Small larvae are less than ¼" and weigh 3.0 mg each. 20,000 large larvae per acre. Large larvae are* late 3rd instars weighing 10.9 mg each.

The egg biomasses are included for completeness. It is not expected that either the bollworm/budworm eggs or the beet armyworm eggs will be food items for birds. Larval *biomass per acre ranges from 13.2 to 352 grams. The low biomass available suggests that it* is not efficient for birds to forage for insects in cotton. This theoretical calculation is supported by avian censuses and observations of bird usage of cotton.

A Life Table for Bollworm/Budworm and Beet Armyworm in Cotton

Pest	Life Stage	Plant Density	Life Stage per Acre	Grams per Acre per Life Stage
Bollworm/Budworm	Eggs (0.7 mg each)	70560	14,112	9.9
	Early instar larvae (4.5 mg 90% control)	70560	1,411	6.3
	Mid instar larvae (23 mg/larva, 50% survival)	70560	706	16.3
Beet Armyworm	Eggs (0.07 mg/egg)	70560	154,350	10.8
	Early instar larvae (3.0 mg per larva, 90% control)	70560	15,435	46.3
	Mid-instar larvae(10.9 mg/larva, 50 % survival)	70560	7718	84.1

The above life table sets forth a reasonable treatment scenario for bollworm/budworm and beet armyworm in cotton. Egg densities per acre were set using treatment thresholds. An insecticide application is made, timed to eggs, and results in commercial control, a 90% reduction. The larvae that survive treatment continue to feed and develop and 50% of these survive. This scenario again suggests reasons why bird foraging in treated fields would be inefficient.

The question remains as to whether the information on treatment thresholds for the bollworm/budworm and beet armyworm is representative of likely biomass levels when other insects that could be in the crop are considered. It is suggested that these biomass levels are representative for the following reasons. First, as mentioned above (Leigh *et al.* 1996), there are about 2 dozen major pests of cotton; the other pests are sporadic and highly localized. Some of the major pests and many of the minor pests are not on the chlorfenapyr label, so economic levels of them should not be exposed to chlorfenapyr. Second, it seems reasonable that biomasses of pest insects would be at least as large and as predictable as biomasses of sporadic or non-pest species. Yet the biomasses of major pests like the bollworm or budworm are low.

Knowing the toxicity and residue levels of chlorfenapyr is instructive in assessing potential risk, but the likelihood of an individual being capable of acquiring sufficient residues from the cotton agroecosystem completes the picture. Nagy (1987) determined the metabolic requirements for many taxonomic groups of free-ranging animals. He developed allometric equations based on body weight that allow calculation of the daily requirements for birds, among other groups. Passerines have higher metabolic requirements than other birds. The table below lists the species of birds found to be common during the census work performed across the cotton belt in 1993 and 1995 along with their metabolic requirements and the amounts of insects or seeds required to satisfy those requirements.

Species	Body Wt (g)	Group	Metabolic Requirement (kcal/day)[a]	Dry Wt. Insects (g/day)[b]	Wet wt. Insects (g/day)[c]	Dry Wt. Seeds (g/day)[d]	Wet Wt. Seeds (g/day)[e]
Abert's towhee	46	passerine	37.36	8.69	24.82	7.32	8.05
barn swallow	16	passerine	16.94	3.94	11.25		
blue grosbeak	28	passerine	25.76	5.99	17.11	5.05	5.55
blue jay	87	passerine	60.21	14.00	40.00	11.81	12.97
brown thrashers	64	passerine	47.84	11.13	31.79	9.38	10.31
brown-headed cowbird	39	passerine	33.01	7.68	21.93	6.47	7.11
Carolina chickadee	10	passerine	11.91	2.77	7.91	2.34	2.57
Carolina wren	20	passerine	20.02	4.66	13.30	3.93	4.31
chimney swift	24	non-passerine	19.95	4.64	13.26		
cliff swallow	22	passerine	21.50	5.00	14.29		
common yellowthroat	10	passerine	11.91	2.77	7.91	2.34	2.57
Gambel's quail	166	non-passerine	68.79	16.00	45.71	13.49	14.82
horned lark	37	passerine	31.73	7.38	21.09	6.22	6.84
indigo bunting	15	passerine	16.14	3.75	10.72	3.16	3.48
lark sparrow	28	passerine	25.76	5.99	17.11	5.05	5.55
mourning dove	122	non-passerine	56.48			11.07	12.17
northern bobwhite	180	non-passerine	72.45	16.85	48.14	14.21	15.61
northern cardinal	46	passerine	37.36	8.69	24.82	7.32	8.05
northern mockingbird	49	passerine	39.17	9.11	26.02	7.68	8.44
painted bunting	14	passerine	15.32	3.56	10.18	3.00	3.30
red-winged blackbird	58	passerine	44.44	10.33	29.53	8.71	9.58
scissor-tailed flycatcher	43	passerine	35.52	8.26	23.60	6.96	7.65

[a] kcal/day = 2.61 x body weight$^{0.640}$ for non-passerines and kcal/day = 2.123 x body weight$^{0.749}$ for passerines from Nagy (1987)
[b] insect dry wt. = kcal/day ÷ 4.3 kcal/g (EPA 1993)
[c] insect wet wt. = dry wt. ÷ 0.35 since insects are on average 65% water (EPA 1993)
[d] seed dry wt. = kcal/day ÷ 5.1 kcal/g (EPA 1993)
[e] seed wet wt. = dry wt. ÷ 0.91 since seeds are on average 9% water (EPA 1993)

If we assume an average of 143 g of beneficial insects and 143 g of pests, per acre (from the above life table), then a single bird the size of a brown thrasher would have to consume approximately 10% of all insects present in an acre. Should a bird consume all its insect food from a treated field, it could conceivably consume insects with residues exceeding the LC_{50} value. The acute toxicity value of 2 to 34 mg/kg body weight is the only toxicity value available to assess this issue, but extrapolating from that laboratory number must be done with caution, since in LD_{50} tests, the entire dose if provided in a single bolus with no other stomach or intestinal contents to slow or block rapid absorption. With those considerations, it is more likely that a "field lethal dose" would exceed the "laboratory lethal dose". Again using the brown thrasher as an example, one can ask whether it would be possible for a bird to consume a sufficient amount of insects to acquire a "field lethal dose". At a maximum of 5 ppm (μg/g) in insects, and a diet of 32 g of insects, an adult brown thrasher would encounter 160 μg chlorfenapyr. This would translate to a dose of 2.5 mg/kg spread throughout the day with absorption possibly blocked by the insect matter consumed simultaneously. The metabolic requirements indicate that a bird could, depending on its sensitivity, consume sufficient insect matter to receive what could be interpreted as exceeding levels of concern. However, if birds eat the majority of their insect diet from off the treated field, their risk is much lower. Insect residues off the field have been measured to be negligible.

A similar process can be followed for a seed-eater such as the mourning dove. If a dove consumed all its seeds from within a cotton field, or an area that received 100% of three applications at weekly intervals and a rate of 0.35 lb. a.i./acre (a frequency exceeding the current proposed label) residues could reach up to 42 ppm. More realistically, the maximum would likely be less than 35 ppm, the maximum immediately after two treatments. Should a bird consume all its seed from an area receiving direct overspray, it could conceivably consume seeds with residues exceeding the LC_{50} value. Again, the residues on seeds diminish over time, reducing that likelihood that the individual would consume seeds with a sufficiently high concentration to cause lethality. The question remains whether a dove could consume a sufficient dose rapidly enough to cause lethality. At a maximum of 35 ppm (μg/g) in seeds, and a diet of 12 g of seeds, an adult mourning dove would encounter 420 μg chlorfenapyr. This would translate to a dose of 3.4 mg/kg. With the likely mitigating factors, this dose is not likely to cause lethality. Consumption of a portion of the seed diet from off the field would greatly diminish the risk. Even as close to the treated field as 25 ft, the residues are less than 25% that measured from a directly oversprayed area.

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Arthropod Populations in Cotton:

Numbers and Biomass of Pests and Natural Enemies

A Report Prepared for American Cyanamid

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Introduction

Cotton supports a substantial complex of arthropods, many of which are beneficial species (Whitcomb & Bell 1964, van den Bosch & Hagen 1966, Knutson & Ruberson 1997). Although a variety of studies have surveyed species in cotton, or have attempted to quantify the numbers of selected species, there is no comprehensive database on the numbers and species of arthropods present in cotton during the growing season. Three factors limit our ability to develop such a database. First, sampling methodologies in cotton are labor-intensive and can yield inaccurate results (see below). Second, because of the diversity of organisms that can inhabit a cotton field and the variability of the field itself, a variety of sampling means would have to be employed intensively to increase the likelihood of sampling all species, and of sampling all species in a manner that would provide meaningful information on population dynamics. Third, conditions within the crop (degree of canopy closure, surface residue, temperature, moisture, plant variety, plant and row spacing, tillage practices, soil type, and plant growth stage) and around the field (adjacent plantings and production practices), as well as regiona0l influences, have profound effects on the arthropod poulations within a given field, making generalizations challenging.

This report represents an effort to amalgamate various studies, both published and unpublished, into a database representative of typical arthropod abundance and biomass in cotton at several points during the growing season. There are limitations to such an approach, as noted above, but the findings can provide a useful baseline for discourse and decision-making. As observed above, the conclusions presented here must be tempered by an awareness of the field-to-field variability that can occur in arthropod numbers and diversity..

Methods and Limitations

The data presented here represent a "best guess" of arthropod numbers in cotton. Data were collected from several published sources (Gonzalez et al. 1977, Byerly et al. 1978, Smith & Stadelbacher 1978, Pyke at al. 1980, Wilson & Gutierrez 1980, Butler et al. 1982, Fleischer et al. 1985, Dean & Sterling 1992), as well as two of my own studies (conducted in 1996 and 1997, in untreated cotton fields). In the various studies, multiple sampling methods were employed to evaluate arthropod abundance. All sampling methods have drawbacks, and are often difficult to extrapolate to actual numbers (Wilson 1994); regardless, these methods can provide insights into population dynamics of the arthropods and are valuable for research purposes. The numbers presented in the accompanying tables are an amalgamation of numbers from various studies (with a predominant number from the Midsouth and Southeast), but for the most part are comprised of my own data augmented by others' work. Data are presented for 5 key periods during the cotton production season: pinhead square, first bloom, peak bloom, boll maturation, and when 5 nodes are present above the uppermost white flower (abbreviated 5 NAWF).

In my studies, I used four different sampling methods: sweep net (50 sweeps per plot), drop cloth (4 1-row-meter samples per plot), whole plant visual observation (8 plants per plot), and pitfall trapping (2 10-cm diameter cups per plot, spaced 40 feet apart). The first study, conducted in a 30-acre field in 1996 and 1997, incorporated all four sampling methods. The second study, conducted in a 4- and and 8-acre field in 1997, used only the first three methods. Each of these methods, with its pros and cons, is discussed briefly below.

Sweep Net. This sampling method is rather straightforward, and is widely used. It entails use of a heavy net with a 38.1-cm opening. The net is swung through the crop in a pendular motion, with the base of the net opening striking the upper edge of the plant canopy. While relatively efficient early in the season, while the cotton is quite small, the efficiency of sweep net samples rapidly degrades as the cotton grows. As a result, sweep sample data are notoriously variable and often poorly describe the targeted populations. My sweep net data are not presented here for the reasons mentioned.

Drop cloth. In this method, a square sheet (1x1 meter) of rugged material (e.g., muslin) is spread on the ground between the cotton rows. All of the plants on in a 1-meter section of one row adjacent to the cloth are then vigorously shaken over the cloth. This method dislodges numerous arthropods, allowing the sampler to count those arthropods that fall onto the sheet. This method provides reasonably good data for some species, such as *Geocoris* spp. (Fleischer et al. 1985), but many arthropods are not readily dislodged. The efficiency of drop cloth sampling versus absolute sampling was studied by Fleischer et al. (1985), who found good correlations between the two methods for some species, but not others. Some of the data presented below were obtained with drop cloth samples. Where deemed appropriate, the regression equations of Fleischer et al. (1985) were applied to the data in an effort to correct for reduced efficiency of the drop cloth method relative to absolute methods.

Whole plant observation. This method involves a detailed examination of the entire plant for the presence of arthropods, and is suitable for more sedentary species or life stages (e.g., Gonzalez et al. 1977). For example, heliothine eggs and cotton aphids are sampled most effectively this way, as are *Scymnus* lady beetles and *Orius* spp. When sampling for aphids, two fully-expanded leaves on each plant were selected for aphid census -- one in the upper third, and one in the middle third of the plant. This was done by necessity, as aphid numbers could become prohibitively large for counting on entire plants. The total number of aphids per plant was extrapolated by multiplying the total aphid count by one-half of the estimated number of leaves on plants at that point in the season (for numbers of leaves, see footnote to Table 1). Whole plant observations are a valuable means of sampling arthropod populations, but efficiency and accuracy of samples vary from one sampler to the next.

For this report I will assume that the whole-plant counts represent 80-90% of the absolute number present on the plant. This reflects some of the variability observed by Fleischer et al. (1985) between whole-plant observations in the field and plants that were bagged and returned to the laboratory for more careful counting. When examining entire plants in the field, several factors can influence the accuracy of the count. First, some species tend to move away from the plant as the observer approaches. For example, adult *Geocoris punctipes* may fly from a plant if the observer disturbs the plant while examining. Second, observer fatigue can become a problem over time -- efficiency tends to decline toward the latter end of a long sampling period (3-4 hours). Finally, time of day, with its accompanying temperature and moisture variables, can alter dramatically numbers and species of arthropods observed. It is generally accepted that samples should be taken in the morning, before 11 am, although this is not always logistically feasible. Given these variables, I have chosen a "correction" value of 80-90%. This is probably an overestimate for some species, and an underestimate for others, but, as we lack sufficient data to make a proper estimate for each species, I feel that it provides a good general estimate.

Pitfall trapping. Pitfall traps generally provide tolerable presence-absence information, but are of limited value in evaluating population sizes (Southwood 1978, Jervis & Kidd 1995). In contrast to other sampling methods, pitfall trapping removes individuals irreplaceably from the population, and can diminish local populations of over time (although sweep sampling can also remove individuals if samples are removed from the field for examination). The occurrence of individuals in a trap is dependent on numerous factors, including weather conditions, availability of food resources, dispersal ability of the arthropod, and wariness and sex of the individuals and species to be sampled. Nevertheless, pitfall traps are a widely-used and proven means of surveying the ground-dwelling fauna, and so provide important information. For this report, I am making the general assumption that each trap effectively trapped a roughly 1260 ft^2 area around the trap. Given this assumption, the numbers collected in each trap would comprise the population present in 0.029 acres of land. This is a rather arbitrary value, and most certainly underestimated the foraging range of some species, while certainly overestimating that of others. This value was chosen because of the 40-foot distance between traps in each plot (i.e., 20 ft. radius), and because the numbers and species composition collected in the two traps were quite similar, suggesting that each trap was independently collecting subsamples of the population. This would indicate that the effective trap radii were 20 feet or less.

Sizes and weights. For pest species, the sizes (length and width, in mm) and weights (in mg) are presented for life stages and ages that are likely to be discovered by scouts in the field. For the entomophagous species, sizes and weights are presented for adults of the respective species. Where more than one species may be represented (e.g., large Carabid spp.) the size presented is a mean of those species sampled.

Results and Discussion

The values presented in tables 1-5 are representative numbers for cotton production in the southeastern United States in untreated cotton. This region is likely the best for evaluating arthropod diversity and biomass in cotton -- reductions in pesticide use following boll weevil eradication have led to a very diverse and robust arthropod community. For comparison, I have presented some data from California in Table 6. These data were obtained from Gonzalez et al. (1977) and Garcia et al. (1982). The California data also provide some idea of the wide range of numbers that can be encountered for a single species in different studies. I was unable to find adequate data on pink bollworm populations, but typical threshold levels would likely be a good starting point for periods when such numbers occur.

For the purposes of this report I felt that untreated systems would be more representative of the typical fauna that cotton is capable of supporting. The variability around the tabulated numbers is quite high (2-3 times as large as the projected means), and is heavily influenced by the conditions described above. Thus, it is not presented in the tables. In addition, there is the danger of generating a false "worst case scenario" using the variability. For example, intuitively one could simply sum the maximum possible population sizes and biomasses for each species to obtain a value presumably representing the maximum number and biomass of arthropods that could occur per acre. This approach, however, is highly fallacious. Many of the populations in cotton are highly interdependent -- increases in the population of one species often lead to a decrease in others, and vice versa (this principle is inherent in the concept of secondary pest outbreaks). For example, a large number of the predators *Geocoris* spp. (big-eyed bugs) would lead to a decrease in larval populations of heliothines, armyworms, and others. As a result of these concerns, and the high variability noted above, I have used only averages in the tables, with the intent that they would represent more typical conditions. I have presented totals (numbers and biomass) for arthropod populations on the respective phenological "dates" because the values presented on these "dates" are actual representative snapshots of the total arthropod community present in cotton at that time. That is to say, the numbers are based on real data. These values thus have biological meaning. In contrast, to sum all possible maxima for the various species loses any biological meaning, as a summation of this sort is based on unsupported supposition and extrapolation of data beyond that collected. All cropping systems are susceptible to climatic and cultural variables, as noted above, that cumulatively make it difficult to generalize data. All of these factors, in addition to biotic ones such as predation, parasitism, arthropod developmental and reproductive rates, competition, and interference, affect the population sizes and the nature and magnitude of interactions among the populations. To move beyond the data, therefore, is to disregard the complexities of the trophic webs in the crop and to ignore the vagaries of the production system.

The overall arthropod complex changes dramatically, both quantitatively and qualitatively, during the growing season (species list is presented in appendix). Early in the season, most populations are relatively low, with a few species dominating (Tables 1a, 1b, and 2). Biomass of entomophages and herbivores increases as the season progresses, peaking during the blooming period and declining thereafter (Tables 3a and 4). Much of the herbivore biomass is concentrated in a single species -- the cotton aphid, *Aphis gossypii*. Similarly, the numerical and biomass ratios of herbivorous to entomophagous species was lowest early in the season, peaking in mid-season, and declining again later in the season (Table 5). The dramatic ratio increase at mid-season is chiefly due to the large aphid populations during this period. At the end of the season, aphids and soybean loopers contribute the bulk of the pest population and biomass.

Orthopteran populations become most abundant shortly before first bloom, and remain at high levels throughout the remainder of the season (Tables 1a and 3a). It should be pointed out, however, that the numbers presented are rough estimates of the orthopteran populations, and may not accurately reflect the populations present (see table headings and footnotes). Field crickets are ground dwellers, and may be quite mobile within the field. Pitfall traps may not provide an adequate estimate of their numbers. Snowy tree crickets are often predatory, in addition to being herbivores, and can reach fairly high numbers, particularly when the canopy is well developed and closed. Katydids are less common, and tend to be more of a novelty.

One must be cautious in how pest:natural enemy ratios are interpreted in cotton agroecosystems. Most of the entomophagous species are broad generalists, attacking not only herbivores, but also other entomophages. The food web in cotton is highly complex and poorly understood -- indeed, the same can be said for the trophic relationships of any single entomophage species in cotton -- and will require considerably more study before we can attribute any meaningful interpretation to such ratios.

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Table 1a. ***[illegible]bers of various pestiferous arthropod species in cotton (in [illegible] Southeastern United States) relative to phenology of cotto[illegible] ants. Occassional species are excluded from this table (e.g., cutworms, salt marsh caterpillar, white fringed beetles, boll weevil, whiteflies, leaf-footed bugs, and grasshoppers).***

Pest species	No. arthropods per acre				
	Pinhead square	First bloom	Peak bloom	Boll maturation	Ca. 5 NAWF
Thrips (2-3)[wp]	169	4,570	60,581	26,662	4,219
Cabbage looper[wp]	506	169	0	0	0
Yellow-striped AW[wp]	506	169	0	0	0
Beet AW[wp]	169	338	169	338	0
Garden Webworm[wp]	2,025	338	338	0	0
Cotton aphid[wp]	36,906[a]	7,176,094[a]	4,102,734[a]	906,188[a]	1,489,219[a]
Tarnished plant bug[b]	9,000	18,000	14,400	3,600	0
Fleahopper (2 spp.)[dc]	242	362	0	0	0
Heliothine eggs[wp]	984	2,250	4,500	18,600	13,500
Heliothine larvae[wp]	140	281	421	703	140
Fall AW[wp]	0	0	0	169	0
Stink bugs (4 spp.)[dc]	0	0	0	201	563
Soybean looper[wp]	0	422	140	422	9,141
Total numbers	50,647	7,202,993	4,183,283	956,883	1,516,782

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[a]Cotton aphid populations were estimated by multiplying the total number of aphids per sampled plant (aphids were counted on 2 leaves on each plant) by the approximate number of leaves for a given plant stage, then dividing by 2 (because counts were taken on 2 leaves per plant). This number was then multiplied by 36,000 (the approximate number of plants per acre in a typical cotton field). The number of leaves estimated for each growth stage

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were: (1) p ead square -- 8 leaves, (2) first bloom -- 20 leaves, (3) peak b. n -- 30 leaves, (4) boll maturation -- 36 leaves, and 5 NAWF 0 leaves. The population peak typically occurs between first bloom and peak bloom.
[b]Data in this row are pooled from Snodgrass (1993) and my observations.

[dc]Data in this row were obtained primarily using drop cloths.

[wp]Values in this row were derived primarily from whole plant observations.

Table 1b. Estimated numbers of incidental Orthopterans present in cotton (in the Southeastern United States) relative to phenology of cotton plants. Katydids and snowy tree crickets are located in the cotton canopy, whereas field crickets are ground-dwelling species. The numbers presented are estimates based on field observations, but there are no studies on the efficiency of various sampling methods for any of these species.

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Orthopteran species[1]	**No. arthropods per acre**				
	Pinhead square	**First bloom**	**Peak bloom**	**Boll maturation**	**Ca. 5 NAWF**
Katydids[2]	8	15	30	30	10
Snowy tree cricket[2]	100	725	800	800	400
Field cricket[pt]	32.3	45.6	49.6	71.4	54.2

[1]Scientific names: Katydids belong to the family Tettigoniidae, and it appears that several species can be found in cotton; the snowy tree cricket, *Oecanthus fultoni*, belongs to the family Gryllidae; field crickets (*Gryllus* spp.) also belong to the family Gryllidae.

[2]Estimates in this row are rather subjective, as there are few hard data for these species. The values are based on observations using drop cloth sampling and incidental to other studies.

[pt]Pitfall traps were used to obtain estimates for these species.

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Table 2. N[illegible]ers of various entomophagous arthropod species in cotton ([illegible] the Southeastern United States) relative to phenology of co[illegible] plants. Some species are not included because of either poor data, or due to minute size (e.g., **Cotesia marginiventris, Trichogramma** *spp.,* **Lysiphlebus testaceipes***).*

Natural enemy species (full names in Table 4)	No. arthropods per acre				
	Pinhead square	First bloom	Peak bloom	Boll maturation	Ca. 5 NAWF
Geocoris spp.[wp],[dc]	844	1,969	1,547	6,891	15,328
Orius insidiosus[wp]	703	984	8,156	7,313	6,047
Solenopsis invicta[wp]	13,500	17,550	10,969	26,494	14,681
Coccinella sept.[dc]	161	3,496	603	1,406	522
Hippodamia conv.[dc]	141	3,857	3,455	482	1,768
Harmonia axyridis[dc]	40	723	563	161	121
Coleomegilla macul.[a]	840	1,300	1,670	520	0
Scymnus spp.[wp]	121	1,205	2,943	2,210	2,371
Nabis spp.[dc]	40	121	121	683	121
Chrysopid spp.[wp]	0	141	423	141	423
Hemerobiid spp.[wp]	0	0	0	141	948
Zelus spp.[dc]	0	0	0	0	141
Sinea spp.[dc]	0	0	0	0	281
Labidura riparia[pt]	60	381	744	1,326	281
Notoxus sp.[wp]	1,688	563	141	563	2,813
Podisus maculiventris[dc]	0	0	80	281	0

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Syrphid sp[illegible]	0	1,688	282	0	0
Winter spider[wp]	3,797	1,406	141	703	2,250
Green lynx spider[wp]	141	2,953	2,109	2,250	3,094
Striped lynx spider[wp]	141	1,406	1,688	1,125	2,531
Celer crab spider[wp]	141	141	1,125	423	281
Long-jawed orb weav.[wp]	0	281	0	0	0
Large Carabid spp.[pt]	1.8	5.1	6.6	3.8	12.1
Small Carabid spp.[pt]	36.8	106.4	51.8	21.6	16.4
Small spider[pt]	19.4	28.4	19.2	8.2	9.7
Large spider[pt]	2.6	7.9	8.0	5.1	4.4
Staphylinid spp.[pt]	6.0	6.6	3.3	0.7	0.3
Cicindela spp.[pt]	2.8	13.8	6.4	1.4	1.4
Megacephala spp.[pt]	1.8	40	2.6	0	0
Cardiochiles nigriceps[b]	0	4,500	5,063	2,813	2,531
Tachinid spp.[c]	1.23	1.03	1.20	1.63	0.58
Chelonus sp.[c]	0.40	0.10	0.05	0.15	0.05
Total numbers	22,430.8	44,874.3	41,922.2	55,968.6	56,577.9

[a] The data in this row were pooled from Smith & Stadelbacher (1978).

[b]These data are based on direct observations of foraging parasitoids in 128 1-meter sections of row in each of two fields.

[b]These data were obtained from Butler et al. (1982). Numbers were used only for untreated and pheromone-treated fields, and were averaged for the two sampling locations. The arthropods were collected using a suction, insect-flight trap, and do necessarily represent the total population present.

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[dc] Data in th[illegible]ow were obtained primarily using drop cloths.

[pt] Pitfall traps were used to obtain data for these taxa.

[wp] Values in this row were derived primarily from whole plant observations.

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Table 3a. I nass of various pestiferous arthropod species in cotton (in I Southeastern United States) relative to phenology of cotton nts. Occassional species are excluded from this table (e.g., cutworms, salt marsh caterpillar, white fringed beetles, boll weevil, whiteflies, leaf-footed bugs, and grasshoppers).

Pest species	Length x width (mm)/ weight (mg)	Total biomass of arthropods per acre (mg)				
		Pinhead square	First bloom	Peak bloom	Boll maturation	Ca. 5 NAWF
Thrips (2-3)[wp]	1.4 x 0.2/ 0.05	8.5	228.5	3029.1	1333.1	211.0
Cabbage looper[wp]	3.9 x 0.7/ 0.6	303.6	101.4	0	0	0
Yellow-striped AW[wp]	4.0 x 0.9/ 0.9	455.4	152.1	0	0	0
Beet AW[wp]	3.0 x 0.8/ 0.7	118.3	236.6	118.3	236.6	0
Garden Webworm[wp]	13.0 x 2.0/ 3.06	6196.5	1034.3	1034.3	0	0
Cotton aphid[wp]	1.20 x 1.0/ 0.6	22,143.6	4,305,656.4	2,461,640.0	543,712.8	893,531.4
Tarnished plant bug[b]	6.0 x 2.5/ 4.0	36,000.0	72,000	57,600	14,400.0	0
Fleahopper (2 spp.)[dc]	3.0 x 1.2/ 0.3	72.6	108.6	0	0	0
Heliothine eggs[wp]	/ 0.1	98.4	225.0	450.0	1860.0	1350.0
Heliothine larvae[wp]	3.0 x 0.8/ 0.6	233.3	168.6	252.6	423.6	84.0

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Fall AW[w]	3.0 x 0.8/ 0.7	0	0	0	118.3	0
Stink bugs (4 spp.)[dc]	13.0 x 8.0/ 86.5	0	0	0	17,386.5	486,995.0
Soybean looper[wp]	3.9 x 0.7/ 0.7	0	295.4	98.0	295.4	6,398.7
Total biomass		67,898.8	4,380,206.9	2,524,222.3	579,766.3	1,388,570.1

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[a]Cotton aphid populations were estimated by multiplying the total number of aphids per sampled plant (aphids were counted on 2 leaves on each plant) by the approximate number of leaves for a given plant stage, then dividing by 2 (because counts were taken on 2 leaves per plant). This number was then multiplied by 36,000 (the approximate number of plants per acre in a typical cotton field). The number of leaves estimated for each growth stage were: (1) pinhead square -- 8 leaves, (2) first bloom -- 20 leaves, (3) peak bloom -- 30 leaves, (4) boll maturation -- 36 leaves, and 5 NAWF -- 40 leaves.

[b]Data in this row are pooled from Snodgrass (1993) and my observations.

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[dc] Data in this row were obtained primarily using drop cloths.

[wp]Values in this row were derived primarily from whole plant observations.

Table 3b. Estimated biomass of incidental Orthopterans present in cotton (in the Southeastern United States) relative to phenology of cotton plants. Katydids and snowy tree crickets are located in the cotton canopy, whereas field crickets are ground-dwelling species. The numbers presented are estimates based on field observations, but there are no studies on the efficiency of various sampling methods for any of these species.

Orthopteran species[1]	**Biomass of arthropods per acre (mg)**				
	Pinhead square	**First bloom**	**Peak bloom**	**Boll maturation**	**Ca. 5 NAWF**
Katydids[2]					10
Snowy tree cricket[2]					400
Field cricket[Pt]					54.2

217 [1]Scientific names: Katydids belong to the family Tettigoniidae, and it appears that several species can be found in cotton; the snowy tree cricket, *Oecanthus fultoni*, belongs to the family Gryllidae; field crickets (*Gryllus* spp.) also belong to the family Gryllidae.

[2]Estimates in this row are rather subjective, as there are few hard data for these species. The values are based on observations using drop cloth sampling and incidental to other studies.

[Pt]Pitfall traps were used to obtain estimates for these species.

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Table 4. B ass of various entomophagous arthropod species in cotton the Southeastern United States) relative to phenology of co . plants. Some species are not included because of either poor data, or due to minute size (e.g., **Cotesia marginiventris, Trichogramma** *spp.,* **Lysiphlebus testaceipes***).*

Natural enemy species	Length x width (mm) adult weight (mg)	Total biomass of arthropods per acre (mg)				
		Pinhead square	First bloom	Peak bloom	Boll maturation	Ca. 5 NAWF
Geocoris spp.[wp],[dc]	3.5 x 1.5/ 1.1	928.4	2,165.9	1,701.7	7,580.1	16,860.8
Orius insidiosus[wp]	1.6 x 1.1/ 0.15	105.5	147.6	1,223.4	1,097.0	907.1
Solenopsis invicta[wp]	3.0 x 0.4/ 0.35	4,725.0	6,142.5	3,839.2	9,272.9	5,138.4
Coccinella septempunctata[dc]	7.5 x 5.0/ 31.8	5,119.8	111,172.8	19,175.4	44,710.8	16,599.6
Hippodamia convergens[dc]	6.5 x 3.6/ 12.3	1,734.3	47,441.1	42,496.6	5,928.6	21,746.4
Harmonia axyridis[dc]	7.5 x 6.0/ 30.0	1,200.0	21,690.0	16,890.0	4,830.0	3,630.0
Coleomegilla maculata[a]	6.8 x 3.6/ 12.5	10,500.0	16,250.0	20,875.0	6,500.0	0
Scymnus spp.[wp]	2.0 x 1.7/ 0.6	72.6	723.0	1,765.8	1,326.0	1,422.6
Nabis spp.[dc]	8.0 x 2.2/ 2.4	96.0	290.4	290.4	1,639.2	290.4
Chrysopid spp.[wp]	15.0 x 1.8/	0	310.2	930.6	10.2	930.6

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	2.2					
Hemerobiid spp.[wp]	9.0 x 1.5/ 1.7	0	0	0	239.7	1,611.6
Zelus spp.[dc]	13.0 x 3.0/ 15.2	0	0	0	0	2,143.2
Sinea spp.[dc]	13.0 x 4.5/ 26.0	0	0	0	0	7,306.0
Labidura riparia[pt]	24.0 x 4.5/ 169.0	10,140.0	64,389.0	125,736.0	224,094.0	47,489.0
Notoxus sp.[wp]	3.0 x 1.0/ 0.6	1,012.8	337.8	84.6	337.8	1,687.8
Podisus maculiventris[dc]	12.8 x 7.0/ 58.0	0	0	4,640.0	16,298.0	0
Syrphid spp.[wp]	7.5 x 3.0/ 4.0	0	6,752.0	1,128.0	0	0
Chiracanthium inclusum[wp]	6.0 x 2.7/ 14.3	54,297.1	20,105.8	2,016.3	10,052.9	32,175.0
Peucetia viridans[wp]	15.0 x 5.0/ 200.0	28,200.0	590,600.0	421,800.0	450,000.0	618,800.0
Oxyopes salticus[wp]	6.2 x 2.1/ 112.0	15,792.0	157,472.0	189,056.0	126,000.0	283,472.0
Misumenops celer[wp]	5.2 x 3.1/ 19.4	2,735.4	2,735.4	21,825.0	8,206.2	5,451.4
Tetragnatha laboriosa[wp]	6.0 x 2.0/ 18.0	0	5,058.0	0	0	0
Large Carabid spp.[pt]	25.0 x 9.5/ 310.5	558.9	1,583.6	2,049.3	1,179.9	3,788.1

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Small Cara...d spp.[pt]	8.0 x 3.5/ 22.0	404.8	1,170.4	1,139.6	477.4	360.8
Small spider[pt]	7.0 x 3.5/ 14.5	281.3	411.8	278.4	118.9	140.7
Large spider[pt]	13.5 x 6.8/ 257.0	668.2	2,030.3	2,056.0	1,310.7	1,130.8
Staphylinid spp.[pt]	5.0 x 1.1/ 0.8	4.9	5.3	2.6	0.6	0.2
Cicindela spp.[pt]	13.0 x 6.1/ 85.0	238.0	1,173.0	544.0	127.5	93.5
Megacephala spp.[pt]	18.0 x 6.0/ 190.0	342.0	760.0	494.0	0	0
Cardiochiles nigriceps[b]	8.0 x 2.2/ 1.6	0	7,200.0	8,100.8	4,219.5	4,049.6
Tachinid spp.[c]	8.0 x 4.5/ 14.0	17.2	14.4	16.8	22.8	8.1
Chelonus sp.[c]	3.2 x 1.3/ 0.8	0.3	0.12	0.04	0.12	0.04
Total biomass (mg)		139,174.5	1,048,228.2	890,155.5	925,580.8	1,077,233.7

[a] The data in this row were pooled from Smith & Stadelbacher (1978).

[b]These data are based on direct observations of foraging parasitoids in 128 1-meter sections of row in each of two fields.

[b]These data were obtained from Butler et al. (1982). Numbers were used only for untreated and pheromone-treated fields, and were averaged for the two sampling locations. The arthropods were collected using a suction, insect-flighty trap

[dc] Data in this row were obtained primarily using drop cloths.

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[pt]Pitfall tra[illegible] ere used to obtain data for these taxa.

[wp]Values in this row were derived primarily from whole plant observations.

Table 5. Ratios of numbers and biomass of pests to entomophagous arthropod species in cotton (in the Southeastern United States) relative to phenology of cotton plants.

Ratios	Ratio of pests to entomophages at:					Season average
	Pinhead square	**First bloom**	**Peak bloom**	**Boll maturation**	**Ca. 5 NAWF**	
No. pests/No. entomophages	2.26	161.10	99.91	17.12	27.04	61.49 ± 67.20
Biomass pests/ biomass entomophages	0.49	4.18	2.84	0.63	1.29	1.89 ± 1.59

Table 6. R ive abundance of selected arthropods in California cotton. omasses can be approximated by using the unit masses pre ed in Tables 3a and 4 above for the respective taxon, and multiplying it by the number presented in the table.

Species	Mean numbers of arthropods per acre on approximate dates						
	18 June	**30 June**	**15 July**	**28 July**	**14 August**	**28 August**	**8 September**
Tetranychus spp.	0[1]	0[1]	270,000[1]	2,970,000[1]	5,805,000[1]	4,950,000[1]	
Trichoplusia ni	0[1]	0[1]	10,800[1]	75,600[1]	54,000[1]	59,400[1]	
Orius tristicolor nymphs	0[1] 0[2]	0[1] 7,409[2]	135,000[1] 2,227[2] 7,955[2]	486,000[1] 1,909[2] 1,591[2]	432,000[1] 1,364[2] 0[2]	2,268,000[1] 0[2] 0[2]	682[2] 318[2]
Orius tristicolor adults	0[1] 59,045[2]	0[1] 42,000[2]	8,100[1] 19,636[2] 27,273[2]	62,100[1] 18,955[2] 19,318[2]	140,400[1] 24,136[2] 17,409[2]	264,600[1] 25,500[2] 26,500[2]	26,727[2] 31,864[2]
Geocoris pallens adults	10,800[1] 34,455[2]	45,900[1] 12,909[2]	48,600[2] 32,318[2] 17,500[2]	86,400[1] 28,727[2] 21,227[2]	38,400[1] 30,636[2] 32,682[2]	38,400[1] 8,409[2] 16,727[2]	2,227[2] 9,091[2]
Geocoris pallens nymphs	1,364[2]	5,500[2]	27,727[2] 26,955[2]	12,591[2] 15,818[2]	14,727[2] 12,909[2]	5,818[2] 3,818[2]	3,273[2] 4,955[2]
Nabis spp. nymphs	1,909[2]	0[2]	909[2] 0[2]	682[2] 773[2]	1,364[2] 9,091[2]	5,500[2] 12,455[2]	7,409[2] 41,773[2]
Nabis spp. adults	7,409[2]	6,727[2]	3,273[2] 318[2]	9,091[2] 2,227[2]	12,591[2] 6,409[2]	10,682[2] 11,000[2]	11,000[2] 14,045[2]
Chrysopid ssp. larvae	2,591[2]	1,909[2]	318[2] 1,136[2]	0[2] 2,591[2]	1,909[2] 11,682[2]	9,636[2] 32,909[2]	10,682[2] 84,409[2]
Notoxus sp.	38,727[2]	18,727[2]	11,682[2] 5,636[2]	24,818[2] 12,818[2]	40,318[2] 16,727[2]	11,682[2] 9,091[2]	3,273[2] 773[2]

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Spiders ([illegible] identified)	4,818[2]	3,909[2]	2,909[2] 773[2]	2,591[2] 1,591[2]	3,273[2] 3,045[2]	4,500[2] 3,818[2]	,273[2] 2,227[2]
Lygus hesperus nymphs	0[1]	0[1]	0[1]	29,700[1]	51,300[1]	45,900[1]	

[1]These data were obtained from Garcia et al. (1982). The planting density in their study was approximately 27,000 plants per acre. The work apparently consists of data from a single year and a single location (a plot 30 rows wide by 200 m long). The year of the study was not presented in the paper, but was likely within a few years prior to 1982. No mention was made of insecticide applications; presumably the fields were untreated.

[2]These values were obtained from Gonzalez et al. (1977) in studies of 2 untreated cotton fields in 1970. The area around the fields was treated for pink bollworm, and these treatments likely influenced the arthropod numbers within the study fields. The original values were reported as per hectare, but have been converted to per acre here.

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Appendix. Scientific and common names of taxa listed above.

Entomophagous species		Pest species	
Scientific name	**Common name**	**Scientific name**	**Common name**
Geocoris punctipes	Big-eyed bug	Thripidae (3 spp.)	Thrips
Geocoris uliginosus	Big-eyed bug	*Trichoplusia ni*	Cabbage looper
Geocoris pallens	Big-eyed bug	*Spodoptera eridania*	Yellow-striped armyworm
Orius insidiosus	Insidious flower bug	*Spodoptera exigua*	Beet armyworm
Orius tristicolor	Minute pirate bug	*Platynota stultana*	Garden webworm
Solenopsis invicta	Red imported fire ant	*Aphis gossypii*	Cotton aphid
Coccinella septempunctata	7-spotted lady beetle	*Lygus lineolaris*	Tarnished plant bug
Hippodamia convergens	Convergent lady beetle	*Pseudatomoscelis seriatus*	Cotton fleahopper
Harmonia axyridis	Asian lady beetle	*Helicoverpa zea*	Cotton bollworm
Coleomegilla maculata	Pink spotted lady beetle	*Heliothis virescens*	Tobacco budworm
Scymnus spp. (≥ 3 spp.)	Scymnus lady beetle	*Spodoptera frugiperda*	Fall armyworm
Nabis spp. (≥ 3 spp.)	Damsel bugs	*Nezara viridula*	Southern green stink bug
Chrysopid spp. (≥ 2 spp.)	Green lacewing	*Euschistus* spp. (≥ 3 spp.)	Brown stink bug
Hemerobiid spp. (≥ 2 spp.)	Brown lacewing	*Pseudoplusia includens*	Soybean looper
Zelus spp. (≥ 2 spp.)	Leafhopper assassin bug	*Tetranychus* spp.	Spider mites
Sinea spp. (≥ 2 spp.)	Spined assassin bug		
Lygus hesperus	Western plant bug		
Labidura riparia	Striped earwig		
Notoxus monodon	Hooded beetle		
Podisus maculiventris	Spined soldier bug		
Syrphid spp. (≥ 2 spp.)	Hover fly		
Chiracanthium inclusum	Winter spider		
Peucetia viridans	Green lynx spider		
Oxyopes salticus	Striped lynx spider		

Misumenops celer	Celer crab spider
Tetragnatha laboriosa	Long-jawed orb weaver
Carabidae (≥ 6 spp.)	Ground beetle
Lycosidae (≥ 3 spp.)	Wolf spider
Salticidae (≥ 3 spp.)	Jumping spider
Staphylinidae (≥ 3 spp.)	Rove beetle
Cicindela spp. (≥ 3 spp.)	Tiger beetle
Megacephala (2 spp.)	Tiger beetle
Cardiochiles nigriceps	Red-tailed wasp
Tachinidae (≥ 3 spp.)	Tachinid flies
Chelonus sp.	N/A