United States
Department of
Agriculture

Economic
Research
Service

Agricultural
Economic
Report
Number 599

The Economic Importance of Cotton Insects and Mites

Luis Suguiyama
Craig Osteen

ADDITIONAL COPIES OF THIS PUBLICATION...

Can be purchased from the Superintendent of Documents, U.S. Government Printing Office (GPO), Washington, DC 20402. Order by title and series number. Write to the above address for price information, or call the GPO order desk at (202) 783-3238. You may charge your purchase by telephone to your VISA, MasterCard, or GPO Deposit Account. Bulk discounts are available. Foreign customers, please add 25 percent extra for postage.

Microfiche copies ($6.95 each, plus $3 for processing) can be purchased from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. Order by title and series number. Enclose a check or money order payable to NTIS. Call NTIS at (703) 487-4650 and charge your purchase to your VISA, MasterCard, American Express, or NTIS Deposit Account. NTIS will RUSH your order within 24 hours for an extra $10; call (800) 336-4700.

The Economic Research Service has no copies for free distribution.

THE ECONOMIC IMPORTANCE OF COTTON INSECTS AND MITES. By Luis Suguiyama and Craig Osteen. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 599.

ABSTRACT

Insects and mites cost cotton producers $645 million a year in yield losses and control costs (direct damage) during 1981-84, over half of which went for chemical controls. Bollworms and tobacco budworms caused the most ($216 million) in direct damage. But the total economic cost of cotton insects and mites may approach $1.3 billion after considering changes in cotton production, prices, processing, and use of other commodities. Extensive chemical use to control insects and mites potentially adds to the cost because, if not properly applied, the treatments may harm farmworkers and the environment. This report uses expert opinions and a model that simulates the absence of direct damage to estimate cotton yield losses, control costs, and the potential hazards of chemically controlling these cotton pests.

Keywords: Economic importance, cotton insects and mites, incidence, control costs, yield losses, value of damage, impact simulation, pounds of active ingredients, potential hazards

NOTE

Simulated effects in this publication are for research purposes only and do not represent official forecasts by the U.S. Department of Agriculture. The use of chemical trade names in this publication does not imply endorsement by the U.S. Department of Agriculture.

ACKNOWLEDGMENTS

The authors are grateful to Don Bull, Agricultural Research Service; Michael Hammig, Clemson University; Fred Kuchler, Economic Research Service; Jimmy Pendergrass, National Cotton Council; and James Smith, Agricultural Research Service for their valuable comments and suggestions.

1301 New York Ave., NW.
Washington, D.C. 20005-4788

October 1988

PREFACE

This report was prepared to provide cotton pest information for a pesticide assessment study. Members of the assessment team were as follows:

Harold Alford, University of California
Charles Allen, Texas A&M University
Paul Bergman, U.S. Department of Agriculture
George Cathey, U.S. Department of Agriculture
Jerry Graves, Louisiana State University
Gary Herzog, Georgia Coastal Plain Experiment Station
Robert Jones, U.S. Department of Agriculture
Thomas Leigh, University of California
Edwin Lloyd, U.S. Department of Agriculture
Craig Osteen, U.S. Department of Agriculture
Armand Padula, U.S. Department of Agriculture
Mitchell Roof, Clemson University
Luis Suguiyama, U.S. Department of Agriculture

The following individuals contributed information to the assessment team:

Jack Bachelor, North Carolina State University
Jack Baldwin, Louisiana State University
Claude Bonner, University of Arkansas
Richard Caron, University of Tennessee
Dan Clower, Louisiana State University
Charles Cole, Texas A&M University
James Coppedge, private consultant
Mike Donohoe, University of Florida
Tom Fuchs, Texas A&M University
Phillip Glogoza, Texas A&M University
R. B. Head, Mississippi State University
D. R. Johnson, University of Arkansas
Miles Karner, Oklahoma State University
Edward Kowalski, University of Missouri
W. R. Lambert, University of Georgia
Gary Lentz, University of Tennessee
Jim Lesser, Texas A&M University
R. G. Luttrell, Mississippi State University
George Mullendore, Mississippi State University
Eric Natwick, University of California
Norman Neishiem, Oklahoma State University
John Norman, Texas A&M University
Roy Parker, Texas A&M University
J. R. Phillips, University of Arkansas
Bill Plapp, Texas A&M University
Joe Powell, Louisiana State University
Richard Roush, Mississippi State University
Ronald Smith, University of Alabama
R. K. Sprenkel, University of Florida
J. W. Stewart, Texas A&M University
Carol Sutherland, New Mexico State University
Kevin Taylor, University of Arizona
H. A. Turney, Texas A&M University
James Tynes, Louisiana State University
Gene Woodall, University of Arkansas

CONTENTS

HIGHLIGHTS

Insects and mites cost cotton producers $645 million a year in yield losses and pest control costs (direct damage) during 1981-84, over half of which was spent on chemical controls. But the total economic cost may approach $1.3 billion, almost double the direct damage estimate, when changes in crop price and production are considered. Included in this greater cost are the higher prices consumers have to pay when cotton production declines. Extensive chemical use to control insects and mites potentially adds to the cost because, if not properly applied, the treatments may harm farmworkers and the environment (although recent changes in technology appear to have reduced hazards associated with pest control).

This report examines how insects and mites affect U.S. agriculture through cotton yield losses, control costs, and potential hazards caused by these pests and pest control methods. The full economic effects of pest damage to crop markets and production are captured by a simulation of how cotton production would fare in the absence of cotton insects and mites.

Bollworms and tobacco budworms caused $216 million in direct damage to U.S. cotton production, and boll weevils caused $146 million. Plant bugs ($76 million), pink bollworms ($71 million), spider mites ($64 million), and thrips ($44 million) also injured cotton production. Plant bugs and thrips infest a large portion of U.S. cotton acreage, while pink bollworms cause heavy damage in infested areas of the West.

Insects and mites reduce cotton yields, which hurt growers in heavily infested areas and consumers. But, damage from these pests extends beyond the farmers' cotton yield. Damage caused by these pests also results in higher production costs and shifts in planted acreage. Growers benefit by receiving higher prices from the lowered production, but consumers bear the cost.

Cotton injury from these pests results in significant shifts in regional crop production. The Southeast (Alabama, Florida, Georgia, and South Carolina), Delta (Arkansas, Louisiana, and Mississippi), and Mountain States (Arizona and New Mexico) would plant substantially more acres of cotton if insects and mites did not cause direct damage.

The average cotton-harvested acre received approximately 1.6 pounds of chemical (insecticide and miticide) active ingredients per year during 1981-84. These treatments add to the cost of damage to the extent they become hazardous to farmworkers or the environment. Hazards to farmworkers and the environment may have decreased in recent years with advanced control technology and lower dependence on organophosphates and organochlorines, but relative hazards to fish and other aquatic organisms may have risen.

The Economic Importance of Cotton Insects and Mites

Luis Suguiyama
Craig Osteen

INTRODUCTION

The efficiency of controlling insect and mite pests influences how cotton is produced in many areas of the United States. Growers in 16 producing States rely heavily on chemical and nonchemical controls to reduce insect and mite damage to cotton, a crop valued at $4 billion at the farm gate in 1985 (15).[1] Moreover, chemical use is potentially harmful to humans and the environment, which contributes to the total costs created by pests.

Pest-specific information on control practices and costs, yield losses, and side-effects is valuable for assessing the relative importance of insect and mite species; developing research priorities; and establishing baseline conditions for evaluating new control technologies, large-area programs, and pesticide regulations (12). Such detailed information is often difficult to obtain for cotton because of the absence of survey or experimental data over large areas, the complexity and regional diversity of pest problems, and the difficulty in measuring effects on yields, the agricultural economy, and the environment.

This report provides detailed information of cotton losses from insect and mite damage, control practices, and grower costs for the 1981-84 crop years. Cotton extension and research entomologists, referred to as experts, provided pest-specific estimates when current data were unavailable. We simulated the national and regional economic effects of cotton insect damage and control costs with a national econometric model. These results approximate the economic effects of cotton insects and mites on domestic agricultural production, producers, and consumers. Measures of relative toxicities of cotton chemical controls to humans and wildlife are also presented.

---

* Luis Suguiyama, formerly with the Economic Research Service, is an agricultural economist with the Budget Accounting Division, Animal and Plant Health Inspection Service. Craig Osteen is an agricultural economist with the Resources and Technology Division, Economic Research Service.

[1] Underscored numbers in parentheses refer to sources in the References section.

THE ECONOMIC IMPORTANCE OF INSECTS AND MITES

Aggregate economic effects of individual agricultural pests are difficult to estimate because of the number and geographic diversity of the species involved. Many pests infest several commodities, and their importance can vary greatly from year to year. Economic importance is usually determined in terms of losses and control costs. The following factors help determine the overall economic importance of individual agricultural pests on a particular crop:

- Pest incidence (range and severity of injurious population levels);
- Production loss caused by the pest;
- Control measures and grower efforts to arrest excessive damage;
- Adjustments in production practices and other input uses (such as acreage shifts, cultural practices, and pest-resistant crop varieties);
- Direct and indirect effects on human health (externalities, or the social costs of production that generally are not accounted for, such as poisoning, exposure, carcinogenicity, oncogenicity) and environmental quality (residues on land and water, beneficial organisms, wildlife); and
- Implications on future production (pest resistance) and producer income stability (risk).

Not all factors can be precisely measured because quantitative measures of the economic effects of agricultural pests are usually based on incomplete information.

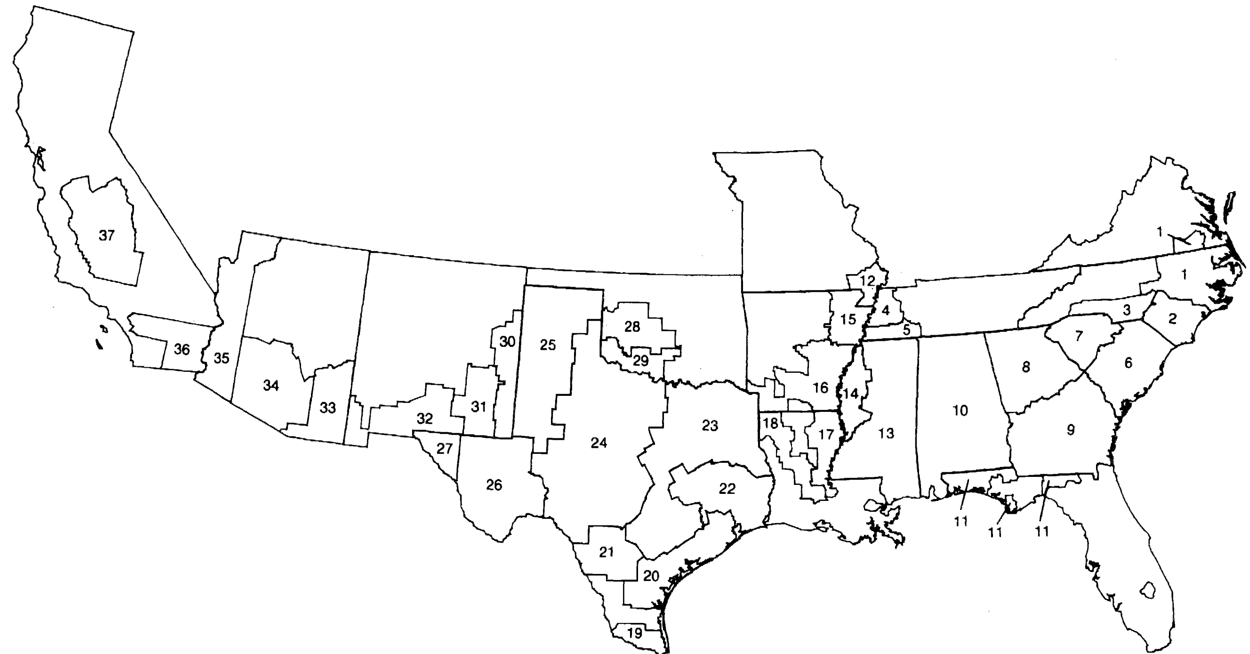
This study estimates incidence, grower control expenditures, and yield loss for important cotton insect or mite pests in each producing State. Target pests include individual species and two major complexes. Species include the aphids, fall and beet armyworms, boll weevils, cabbage loopers, cotton leaf perforators, cutworms, grasshoppers, Heliothis, pink bollworms, spider mites, stinkbugs, thrips, whiteflies, and wireworms. The Heliothis species include bollworms and tobacco budworms. The two pest complexes are the Heliothis/boll weevils and pink bollworms/other pests. The other pests category includes bollworms, boll weevils, lygus bugs, stink bugs, and other species. We also estimated aggregate market effects, adjustments in crop production, and health and environmental hazards of chemical controls resulting from the presence of insect and mite species infesting cotton.

Pest Information: Expert Estimates

We obtained information on current cotton insect and mite management practices from experts who participated in a recent cotton insecticide assessment study (10). Experts identified insect and mite pests in chronological order of occurrence from cotton planting to harvesting in 37 production subregions (see figure). Experts estimated the share of harvested acreage treated and listed the current control practices, pesticide materials, or nonchemical methods for each reported target pest. Those estimates also contain the percentage use, dosage per acre, number of treatments or applications per acre, and share of aerial applications for each chemical control practice. The assessment study also provided regional pesticide prices, application costs, and the extent and per-acre cost of pest scouting practices. Pest scouting is a widely recognized pest management technique in which cotton fields are inspected to gain information on the rates of plant growth and pest development.

The expert opinions represented typical insect and mite presence and control practices with available technology during 1981-84 and what controls experts

Cotton production subregions



Regions and subregions	Code
Appalachia:	
Virginia and North Carolina--North	1
North Carolina--South	2
Piedmont	3
Tennessee--North Brown Loam	4
South Brown Loam	5
Southeast:	
South Carolina--Coastal Plains	6
Piedmont	7
Georgia--Piedmont	8
East and Southwest	9
Alabama--Limestone Valley and South	10
Florida	11
Corn Belt:	
Missouri--Bootheel	12
Delta States:	
Mississippi--Non-Delta	13
Delta	14
Arkansas--Northeast	15
Southeast	16
Louisiana--Northeast	17
Red River Valley	18
Southern Plains:	
Texas--Lower Rio Grande	19
Upper and Lower Coast	20
Winter Garden	21
Central River Bottom	22
Blacklands	23
Rolling Plains and Upper Concho	24
High Plains	25
Trans Pecos	26
El Paso and Hudspeth Counties	27
Oklahoma--North	28
South	29
Mountain States:	
New Mexico--Southern Plains	
Pecos Valley	
Upper Rio Grande	
Arizona--Southeast	
Central	
Yuma and Mohave Counties	
West:	
California--Lower Desert Valleys	
San Joaquin Valley	

thought growers used. Experts reviewed their estimates and, in most cases, reconsidered initial estimates after comparing them with available area or State data. We grouped the final subregional estimates into State and regional estimates.

Although there have been numerous attempts at estimating yield losses from cotton insects and mites, the data have been often inadequate for statistically estimating losses over large areas. This study uses estimates of yield losses in cotton production from conference reports on cotton pest research and control (23-26), which provide annual estimates of the number of cotton bales lost to pests. These estimates are widely accepted and used by entomologists, extension personnel, pesticide vendors, and cotton producers.

Pest Incidence

The share of harvested acreage treated for a pest species or complex is one indicator of pest incidence. Table 1 shows aggregate and State estimates of acreage treated with chemicals by target pest (see subregional estimates of acreage treated by target pest in app. table 1). Experts estimated that 78 percent of the cotton harvested acreage was treated with insect and mite chemicals. Thirteen States treated over 98 percent of the harvested acreage. Three States had considerably less acreage treated with chemicals: New Mexico (81 percent), Oklahoma (63 percent), and Texas (57 percent).

Chemical controls are mainly directed at Heliothis (53 percent of harvested acreage), thrips (42 percent), boll weevils (40 percent), plant bugs (37 percent), and spider mites (17 percent). Infestation is heaviest in Southeastern and Delta States, with the exception of spider mites which prevail in Arizona and California. Some pests reach high incidence in certain regions, such as pink bollworms in Western States; seed corn maggots, wireworms, and whiteflies in California; and grasshoppers in the Southwest.

The number of chemical applications indicates the severity of pest infestation levels throughout a growing season. Heliothis and boll weevils received the most applications per harvested acre, on average, of all target insects and mites (table 2). Treated as single targets or as a complex, these two species accounted for over half of all chemical applications on cotton (2.4 out of 4.6 applications per harvested acre). Thrips and plant bugs also accounted for many applications because of the heavy incidence of these pests in many States.

The number of applications for each target pest varied by State (subregional estimates of the number of applications per harvested acre are reported in app. table 2). Oklahoma and Texas cotton averaged the lowest number of applications per harvested acre, 1.3 and 1.9, respectively. These States also had the smallest share of harvested acreage treated (table 1). In contrast, the Southeastern States averaged the highest number of applications per harvested acre, ranging from 9.7 in Alabama to 18.4 in Florida. North Carolina cotton averaged fewer insecticide applications than other Southeastern States, 5.9 applications, due to the absence of boll weevils from the eradication effort.

Control Expenditures

Insect and mite control for U.S. cotton cost about $381 million per year during 1981-84. U.S. cotton producers spent, on average, about $37 per harvested acre for insect and mite control (table 3). This average control expenditure

Table 1--Share of cotton harvested acreage treated against target pests 1/

Target pests	Acreage treated																
	AL	AZ	AR	CA	FL	GA	LA	MS	MO	NM	NC	OK	SC	TN	TX	VA	U.S. cotton
	Percent																
Heliothis	--	73.6	75.0	8.3	100.0	50.0	90.0	52.8	30.0	64.4	98.0	25.0	96.7	50.0	22.8	98.0	34.5
Boll weevils/*Heliothis*	100.0	--	55.0	--	100.0	98.8	100.0	37.0	--	--	--	--	--	.5	6.5	--	19.1
Boll weevils	30.0	32.2	43.9	.6	100.0	77.1	72.4	49.1	--	--	20.2	7.7	39.0	.5	11.7	--	20.8
Pink bollworms	--	99.5	--	5.8	--	--	--	--	--	11.3	--	--	--	--	.6	--	5.8
Pink bollworms/other pests 2/	--	94.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4.5
Spider mites	15.0	46.2	--	75.9	2.0	19.4	31.7	21.3	5.0	--	--	--	9.6	2.0	.9	--	17.0
Thrips	95.0	18.8	98.0	9.4	100.0	87.7	97.6	95.0	100.0	21.3	92.3	2.5	98.3	100.0	24.0	85.0	42.3
Plant bugs 3/	15.0	68.1	34.5	44.4	2.0	29.1	51.2	93.3	50.0	24.5	--	18.7	5.8	75.0	21.8	--	37.1
Fall and beet armyworms	--	--	--	12.3	65.0	19.1	8.8	23.5	1.0	15.5	2.7	1.0	9.6	--	4.3	2.0	7.0
Seed corn maggots/wireworms	--	--	--	84.8	--	--	--	--	--	--	--	--	--	--	--	--	10.8
Aphids	10.0	--	--	4.7	5.0	29.4	24.4	21.3	5.0	10.7	--	1.7	5.0	2.0	12.4	--	11.0
Whiteflies	--	1.0	--	10.2	2.0	--	--	4.0	--	--	--	--	1.8	--	--	--	1.7
Cotton leaf perforators	--	27.1	--	1.2	--	--	--	--	--	--	--	--	--	--	--	--	1.4
Cabbage loopers	--	--	--	4.7	2.0	.9	--	--	1.0	--	--	--	--	--	--	--	.6
Cutworms	--	2.7	--	4.7	--	--	--	--	--	--	--	--	--	--	.2	--	.8
Stinkbugs	--	--	--	2.3	--	--	--	--	--	--	--	--	--	--	--	--	.3
Grasshoppers	--	--	--	--	--	--	--	--	--	15.7	--	3.3	--	--	.3	--	.4
All insects and mites 4/	100.0	99.5	100.0	100.0	100.0	99.7	100.0	100.0	100.0	80.7	98.0	63.0	98.3	100.0	56.8	98.0	77.5

-- = Unreported or insignificant estimate.
1/ Acreage treated one or more times for specific target.
2/ Other pests include *Heliothis*, boll weevils, lygus bugs, and stinkbugs.
3/ Include lygus bugs and cotton fleahoppers.
4/ Columns may not total 100 due to multiple treatments.

Table 2--Applications per harvested acre, by target pests

Target pests	Applications per harvested acre																
	AL	AZ	AR	CA	FL	GA	LA	MS	MO	NM	NC	OK	SC	TN	TX	VA	U.S. cotton
	Number																
Heliothis	--	0.62	1.50	0.22	7.00	1.43	2.59	1.90	0.85	1.42	3.84	0.72	5.75	1.00	0.45	2.74	0.86
Boll weevils/Heliothis	7.94	--	1.10	--	7.00	6.29	4.88	1.13	--	--	--	--	--	.02	.18	--	.85
Boll weevils	.42	.32	.88	.01	3.00	3.50	1.67	1.57	--	--	.81	.31	2.19	.02	.54	--	.67
Pink bollworms	--	5.02	--	.29	--	--	--	--	--	.13	--	--	--	--	.02	--	.28
Pink bollworms/other pests 1/	--	3.12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.15
Spider mites	.20	.47	--	.99	.04	.32	.48	.39	.10	--	--	--	.15	.02	.02	--	.24
Thrips	1.19	.19	1.42	.19	1.30	1.77	1.19	1.79	1.50	.21	1.20	.04	1.56	2.45	.25	1.15	.62
Plant bugs 2/	.15	.63	.34	.53	.02	.43	.55	1.84	1.00	.35	--	.19	.09	.75	.28	--	.51
Fall and beet armyworms	--	--	--	.22	1.30	.23	.09	.47	.02	.21	.02	.01	.19	--	.04	.02	.11
Seed corn maggots/wireworms	--	--	--	.85	--	--	--	--	--	--	--	--	--	--	--	--	.11
Aphids	.10	--	--	.08	.05	.58	.24	.43	.05	.13	--	.02	.05	.02	.14	--	.15
Whiteflies	--	.02	--	.28	.02	--	--	.04	--	--	--	--	.04	--	--	--	.04
Cotton leaf perforators	--	.27	--	.02	--	--	--	--	--	--	--	--	--	--	--	--	.02
Cabbage loopers	--	--	--	.09	.02	.01	--	--	.01	--	--	--	--	--	--	--	.01
Cutworms	--	.03	--	.05	--	--	--	--	--	--	--	--	--	--	.01	--	.01
Stinkbugs	--	--	--	.02	--	--	--	--	--	--	--	--	--	--	--	--	.00
Grasshoppers	--	--	--	--	--	--	--	--	--	.35	--	.03	--	--	.01	--	.01
All insects and mites 3/	9.70	10.69	5.24	3.84	18.36	13.05	11.69	9.56	3.53	2.80	5.87	1.32	10.02	4.29	1.94	3.91	4.58

-- = Unreported or insignificant estimate.
1/ Other pests include Heliothis, boll weevils, lygus bugs, and stinkbugs.
2/ Include lygus bugs and cotton fleahoppers.
3/ Columns may not total due to tank-mixed applications for several targets.

Table 3--Expenditures per harvested acre for insect and mite control and scouting, by target pests

Target pests and scouting	Expenditures per harvested acre																
	AL	AZ	AR	CA	FL	GA	LA	MS	MO	NM	NC	OK	SC	TN	TX	VA	U.S. cotton
	Dollars																
Heliothis	--	12.90	9.20	2.62	52.14	10.36	16.70	13.27	4.96	10.27	23.36	6.23	40.26	5.65	3.47	16.56	6.53
Boll weevils/Heliothis	54.48	--	8.79	--	54.78	49.84	32.04	8.47	--	--	--	--	--	.13	1.31	--	6.01
Boll weevils	1.41	3.47	3.61	.08	11.70	12.25	5.02	6.68	--	--	4.96	1.30	11.11	.08	2.75	--	3.00
Pink bollworms	--	48.42	--	6.29	--	--	--	--	--	.67	--	--	--	--	.10	--	3.13
Pink bollworms/other pests 1/	--	47.86	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.25
Spider mites	1.11	4.53	--	20.78	.35	2.11	3.09	3.70	.42	--	--	--	1.20	.06	.15	--	3.54
Thrips	7.65	1.35	7.13	2.53	7.52	8.36	4.78	5.17	7.08	.88	8.04	.32	8.35	6.60	1.86	7.86	3.12
Plant bugs 2/	.43	7.00	1.10	8.65	.06	.27	1.37	7.24	3.23	1.46	--	.81	.28	1.64	1.04	--	2.89
Fall and beet armyworms	--	--	--	3.03	14.33	1.95	1.18	5.30	.29	1.70	.17	.10	1.53	--	.50	.17	1.28
Seed corn maggots/wireworms	--	--	--	6.74	--	--	--	--	--	--	--	--	--	--	--	--	.86
Aphids	.24	--	--	.61	.16	.51	.91	1.78	.18	.50	--	.09	.15	.06	.52	--	.58
Whiteflies	--	.34	--	3.02	.18	--	--	.23	--	--	--	--	.20	--	--	--	.42
Cotton leaf perforators	--	3.84	--	.49	--	--	--	--	--	--	--	--	--	--	--	--	.24
Cabbage loopers	--	--	--	1.31	.16	.05	--	--	.14	--	--	--	--	--	--	--	.17
Cutworms	--	.16	--	.56	--	--	--	--	--	--	--	--	--	--	.01	--	.08
Stinkbugs	--	--	--	.3	--	--	--	--	--	--	--	--	--	--	--	--	.04
Grasshoppers	--	--	--	--	--	--	--	--	--	1.88	--	.14	--	--	.02	--	.03
All insects and mites	65.32	129.86	29.84	57.02	141.38	85.70	65.10	51.84	16.30	17.37	36.53	8.98	63.08	14.22	11.73	24.59	34.17
Pest scouting	2.75	2.91	3.65	4.92	3.67	3.37	4.93	4.01	2.33	2.69	5.30	1.59	4.22	.72	1.83	5.30	2.81
Total expenditures	68.07	132.77	33.49	61.94	145.05	89.07	70.03	55.85	18.63	20.06	41.83	10.57	67.30	14.94	13.56	29.89	36.98

-- = Unreported or insignificant estimate.
1/ Other pests include Heliothis, boll weevils, lygus bugs, and stinkbugs.
2/ Include lygus bugs and cotton fleahoppers.

represents approximately 17 percent of total variable costs per acre of cotton grown in the United States, and includes $34.17 for chemical materials and application costs and $2.81 for scouting. Subregional estimates of control expenditures per harvested acre are reported in appendix table 3. Heliothis and boll weevils accounted for over 42 percent of the average control expenditure, about $16 out of $37. Cotton grown in the Southeast required the highest per-acre expenditures to control these pests: Florida ($119 per harvested acre), Georgia ($72), and Alabama ($56). The lowest per-acre expenditures for these two pests were in California ($3), Missouri ($5), and Tennessee ($6). Expenditures for pink bollworms were significant in the infested areas of the West. For example, Arizona growers spent about $96 per harvested acre to control that pest alone.

Per-acre control expenditures for all insects and mites vary according to the species occurrence, severity of infestation, and expected crop value in each State. The Southeast and Delta States reported the highest per-acre expenditures for pest control. Florida farmers spent the most, $145 per harvested acre, while Oklahoma farmers spent the least, about $11 per harvested acre.

Cotton Yield Losses

Table 4 summarizes average production-weighted loss estimates for major insect and mite targets for 1981-84. Despite control measures, about 7.4 percent of the annual cotton crop is estimated to be lost to insect and mite damage. Heliothis (2.5 percent loss of total crop), boll weevils (1.5 percent), plant bugs (1.3 percent), and spider mites (0.8 percent) were responsible for 82 percent of the total losses. The only other species causing significant yield losses, on aggregate, was the pink bollworm in the infested areas of the West. There were high yield loss estimates for cotton grown in New Mexico (18.6 percent) and North Carolina (17.1 percent) and low estimates for California (4.9 percent), Missouri (5.1 percent), and Arkansas (5.5 percent).

Value of Insect and Mite Damage

The composite values of damage (yield loss plus control costs) caused by individual pests are seldom reported for cotton. The aggregate damage attributed to cotton insects and mites has been reported as a 7- to 14-percent yield reduction and a $200-million control expenditure per year (28). Table 5 presents estimates of economic damage, which are reported as the sum value of yield losses (from table 4) and control expenditures (from table 3). The calculation of the value of yield loss assumes the average market price of cotton to be $0.5844 per pound of lint (1981-84 average). These estimates of economic damage exclude effects to the cotton market and production effects without pest damage, which are included later in the economic simulation.

The annual economic damage caused by all insects and mites on cotton producers was estimated at $645 million (table 5). Over half of the damage was attributed to Heliothis ($216 million) and boll weevils ($146 million). Plant bugs also caused significant damage, $76 million. The damage caused by pink bollworms, $71 million, is particularly significant because all damage is concentrated on only 6 percent of the total U.S. cotton harvested area (see table 1).

Table 4--Cotton yield losses caused by target insects and mites

Target pests	Cotton yield losses																
	AL	AZ	AR	CA	FL	GA	LA	MS	MO	NM	NC	OK	SC	TN	TX	VA	U.S. cotton
	Percent																
Heliothis	3.81	1.32	2.18	0.38	6.08	3.32	3.80	1.87	2.27	6.06	9.68	8.05	4.90	3.14	3.82	4.96	2.52
Boll weevils	5.13	.67	1.94	--	6.62	3.74	3.65	2.39	--	--	1.83	1.51	4.30	.82	1.78	--	1.50
Pink bollworms	--	3.27	--	.39	--	--	--	--	--	2.17	--	--	--	--	.10	--	.44
Spider mites	.51	.19	.14	2.56	.11	.13	.39	.09	.21	.57	.14	.30	.27	.89	.28	.82	.78
Thrips	.59	--	.45	.38	.70	.09	.31	.21	.56	2.26	.24	.34	.78	.35	.41	.54	.34
Plant bugs 1/	.90	1.29	.77	1.16	.15	1.57	.63	1.84	1.24	7.42	.21	.86	.48	3.02	1.50	--	1.32
Cotton leaf perforators	--	.29	--	.01	--	--	--	--	--	.12	--	--	--	--	--	--	.03
Others 2/	.70	.57	--	--	.88	.50	.71	.23	.79	.03	4.98	.38	1.11	.07	.68	--	.04
All insects and mites	11.64	7.60	5.48	4.88	14.54	9.35	9.49	6.63	5.07	18.63	17.08	11.44	11.84	8.29	8.57	6.32	7.37

-- = Unreported or insignificant estimate.
1/ Include lygus bugs and cotton fleahoppers.
2/ Include fall armyworms, beet armyworms, stink bugs, European corn borers, yellowstriped armyworms, seed corn maggots, wireworms, cabbage loopers, grasshoppers, aphids, cutworms, whiteflies, and western flower thrips.

Table 5--Value of economic damage caused by target insects and mites

Target pests	AL	AZ	AR	CA	FL	GA	LA	MS	MO	NM	NC	OK	SC	TN	TX	VA	U.S. cotton
	Economic damage																
	Million dollars																
Heliothis	20.1	10.6	10.8	6.5	2.0	11.2	37.1	28.9	1.7	2.3	4.2	8.4	5.7	4.1	62.3	*	216.1
Boll weevils	21.9	3.9	8.1	.1	1.4	11.7	29.9	24.6	--	--	.8	1.6	2.7	.7	38.1	--	145.7
Pink bollworms	--	57.5	--	11.4	--	--	--	--	--	.6	--	--	--	--	1.5	--	71.0
Spider mites	.9	2.8	.2	47.9	*	.4	2.7	4.0	.2	.2	*	.2	.2	.7	3.6	*	63.9
Thrips	2.9	.7	3.7	6.4	.2	1.4	3.5	5.9	1.3	.7	.7	.4	1.1	2.1	13.4	*	44.1
Plant bugs 1/	1.1	7.7	1.6	20.7	*	.9	2.2	14.6	1.0	2.0	.1	1.0	.2	2.9	20.3	--	76.3
Cotton leaf perforators	--	2.8	--	.7	--	--	--	--	--	*	--	--	--	--	--	--	3.6
Others 2/	1.2	2.1	2.5	20.4	.3	1.3	4.1	9.5	.6	.3	1.6	.3	.8	.4	12.6	*	57.9
All insects and mites 3/	32.8	89.5	24.8	120.5	3.1	19.6	63.6	83.1	5.2	6.3	7.8	12.5	11.1	11.0	154.4	*	645.4

-- = Unreported or insignificant estimate.
* = Damage values less than $0.5 million.
1/ Include lygus bugs and cotton fleahoppers.
2/ Include fall and beet armyworms, wireworms, seed corn maggots, aphids, whiteflies, cabbage loopers, cutworms, stink bugs, and grasshoppers.
3/ Columns may not total because expenditures for the boll weevils/Heliothis complex were allocated to each target species. The total estimated expenditures for scouting have also been included.

AGGREGATE EFFECTS OF COTTON INSECT AND MITE DAMAGE

Estimates of direct crop damage (value of yield loss plus pest control expenditures) do not fully capture how these pests affect agricultural production. These estimates exclude economic effects such as higher market prices resulting from lower crop production (assuming that agricultural markets are competitive and all other factors remain constant), and distinctions between effects on crop producers and consumers.

To approximate the annual effects of cotton insects and mites on U.S. crop production, we constructed a scenario in which cotton and other pertinent field crops suffer no damage from these pests. We, therefore, eliminated the estimates of yield losses and control expenditures as factors reducing output (yield increases and production cost decreases for affected crops). We restricted the scenario to cotton production without insect and mite damage and corn, soybean, and sorghum production without bollworm and fall armyworm damage (table 6).

We used AGSIM, a regional econometric-simulation model, to project changes in crop production in the absence of pest-related damage (2, 19). This model simulates how agroeconomic events affect the agricultural sector. Crop markets and individual production regions are not isolated from one another in this

Table 6--Simulated changes in per-acre yield and production costs when field crops suffer no damage from cotton insects and mites

Production regions	Changes in: Cotton		Corn		Soybean		Sorghum	
	Yield	Variable costs	Yield	Variable costs	Yield	Variable costs	Yield	Variable costs
	Percent	Dollars	Percent	Dollars	Percent	Dollars	Percent	Dollars
Corn Belt	5.07	-18.63	2.00	**	0.30	**	--	--
Lake States	**	**	.30	**	**	**	--	--
Northern Plains	**	**	**	**	**	**	--	--
Southern Plains	8.81	-13.31	4.00	-0.40	.50	**	4.00	-1.60
Delta States	7.23	-55.24	.50	-1.47	.50	-3.90	--	--
Mountain States	9.04	-118.09	4.00	-.40	**	**	4.00	-1.60
Pacific States	4.88	-61.94	**	**	**	**	--	--
Northeast	**	**	1.50	-1.38	1.00	-1.38	--	--
Appalachia	10.20	-20.82	.70	-1.47	6.30	-6.36	--	--
Southeast	11.12	-75.84	.70	-1.47	6.30	-6.36	--	--

** = No effect.

model.[2] Scenario results are reported as averages for the 10-year simulation period and used as a proxy of the annual economic effect.

We can use this model to estimate the economic gains to society if, in fact, these pests did not exist. Yet, since the pests do exist, the reverse implications of these economic gains are economic losses. These are the losses which we cite as aggregate effects of the cotton pest damage.

Regional effects include changes in acreage and producers' income. Aggregate effects include the simulated changes in yield per acre, price of cotton lint and cottonseed, crop acreage, domestic producers' income, domestic consumer surplus, and the net of domestic producers' income and consumer surplus. Change in consumer surplus is a monetary value resulting from a change in consumption or a change in prices for a particular crop. For example, if consumption falls and prices rise, consumers lose; that is, consumer surplus falls.

There were significant changes in cotton-planted acreage among production regions simulated without pest-related damage (table 7). Without pest damage, cotton acreage would increase 2.1 million acres, although total crop acreage in the United States would increase only 0.6 percent (table 8). Therefore, much of the increased cotton acreage would result from decreases in soybean, sorghum, and corn acreage. The Southeast and Delta States, where insects and mites cause the most direct damage to producers, would significantly increase their cotton plantings by a total 1.25 million acres. This result is consistent with the historical decline in acreage caused by insects and mites in these regions.

The amount by which cotton producers' income would change in the absence of pest damage also varies by production region. Producers in the Southeast, Delta, and Mountain States would benefit, with projected gains of $54, $44, and $40 million (net income over variable costs). All other cotton production regions would lose a combined $205 million, ranging from $9 million in the Corn Belt (Missouri) to $133 million in the Southern Plains (Texas and Oklahoma).

Aggregate cotton production would increase by about 9 percent in the absence of insects and mites (table 8). The difference between the 9-percent gain in production resulting from this scenario and the 7-percent gain (reported earlier as the aggregate yield loss caused by insects and mites in table 4) arises from increases in cotton planted acreage. Because cotton supplies would increase, the market prices of cotton lint, cottonseed, cottonseed oil, and cottonseed meal would decline by $0.15 per pound, $13.19 per ton, $0.07 per pound, and $7.10 per ton, respectively (these values are simulated for research purposes and are not official forecasts by the U.S. Department of Agriculture).

Cotton producers, on aggregate, would lose $66 million in net income over variable costs, as the reduction in crop price has a greater effect on net returns than does the decline in control costs. Crop producers can suffer net income losses from expanded agricultural output (under lack of pest damage) because demand for most crops is price-inelastic: as output expands, prices fall, and the total revenue declines. Cotton consumers would gain about $966 million from higher crop output and lower cotton prices. The net effect,

---

[2] Several economic studies have used AGSIM as an analytical policy tool. For a comparison of AGSIM results with other estimation models, see (38) and (18).

Table 7--Simulated regional changes in acreage and net income in the absence of cotton insect and mite damage

Production regions	Change in: Acreage		Producers' net income	
	Cotton	All crops	Cotton	All crops
	-----1,000 acres-----		---Million dollars---	
Corn Belt	4.48	12.45	-8.80	-126.44
Lake States	**	-2.37	**	-82.38
Northern Plains	**	1.02	**	-59.21
Southern Plains	488.86	1.58	-133.48	-111.53
Delta States	489.83	73.16	44.36	47.49
Mountain States	132.33	129.90	40.30	51.28
Pacific States	23.74	60.44	-48.91	-66.30
Northeast	**	10.87	**	5.09
Appalachia	161.68	20.38	-13.56	38.74
Southeast	754.92	256.51	54.28	83.04
U.S. total	2,055.84	563.94	-65.81	-220.22

** = No effect.

including the effects on producers and consumers of cotton and other crops, would be a gain of about $1.3 billion, about $900 million of which would accrue to the cotton sector (difference between the consumer gain of $966 million and the producer loss of $66 million).

The scenario results create an interesting comparison to direct damages. The model estimated a net gain, given that insects and mites did not damage cotton. We can reverse the model's findings and interpret the gain in the absence of pest damage as an annual net loss to the agricultural economy due to insect and mite damage. This net loss of approximately $1.3 billion doubles the $654 million in direct damage estimated earlier to cotton producers. Cotton insects and mites may have caused producers to gain $220 million as pest damage forced regional shifts in planted acreage and as price increases more than offset higher control costs (excluding the external costs of production that cannot be precisely measured, such as hazards to farmworkers and the environment and adjustments in production practices). But, domestic consumers lose $1.5 billion from the lower output and higher prices, which more than offset the gain to producers.

NONTARGET HAZARD CONSIDERATIONS

According to the expert estimates in table 9, the average U.S. cotton harvested acre receives 1.6 pounds of chemical active ingredients (a.i.) for insect and

Table 8--Simulated aggregate economic effects in the absence of cotton insect and mite damage 1/

Item change	Unit	Effect
Cotton yield per acre	Percent	-8.81
Price of--		
Cotton lint	Dollars per pound	.15
Cottonseed	Dollars per ton	13.19
Cottonseed oil	Dollars per pound	.07
Cottonseed meal	Dollars per ton	7.10
Planted acreage--		
Cotton	Million acres	2.06
Soybeans	do.	-.95
Sorghum	do.	-.75
Corn	do.	-.11
All field crops	do.	.56
Domestic producers' income above variable costs--		
Cotton	Million dollars	-65.81
All field crops	do.	-220.22
Domestic consumer surplus--		
Cotton	do.	966.43
All field crops	do.	1,475.76
Net of domestic consumer surplus and producers' income above variable costs--		
Cotton	do.	900.62
All field crops	do.	1,255.54

1/ Estimates of price and acreage changes and economic effects have been simulated for research purposes and are not official forecasts by the U.S. Department of Agriculture.

mite control (uses of microbials, sex attractants, and sulfur were not included in the tabulation). The amount of chemicals applied varies considerably among States, ranging from a high of 7.43 pounds per harvested acre in Florida to a low of 0.34 in Oklahoma. Methyl parathion (0.34 pounds per harvested acre), azinphosmethyl (0.21), pyrethroids (0.13), chlordimeform (0.12), propargite (0.11), and aldicarb (0.11) accounted for 63 percent of all a.i.'s.

U.S. cotton production has included heavy use of chemicals to control insect and mite damage. Chemicals affect target pests through contact, stomach poisoning, and/or inhalation when applied to the soil or as foliar treatments; are potentially toxic to other nontarget organisms and species, such as honey bees and parasites or predators of cotton pests, that benefit people; and, if not

Table 9--Pounds of active ingredients of pest control chemicals per harvested acre 1/

Active ingredients	Pest controls applied per harvested acre																
	AL	AZ	AR	CA	FL	GA	LA	MS	MO	NM	NC	OK	SC	TN	TX	VA	U.S. total
	Pounds																
Acephate	0.028	0.286	--	0.191	0.025	0.183	--	0.122	0.005	--	0.025	--	0.032	0.049	0.018	0.023	0.063
Aldicarb	.257	.268	0.245	.187	.026	.132	0.146	.094	.188	0.001	.323	--	.259	.150	.057	.320	.112
Azinphosmethyl	.263	2.432	.356	.029	.850	.598	.078	.143	--	--	--	0.002	.007	.003	.082	--	.208
Carbaryl	--	.027	--	.054	--	--	--	--	--	.061	--	.003	--	--	.002	--	.010
Carbofuran	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.004	--	.002
Chlordimeform	.406	.732	.164	.048	.613	.356	.181	.221	.088	.016	.050	.080	.330	.025	.028	.036	.119
Chlorpyrifos	.064	--	.017	.263	.030	.069	.033	.246	.001	.005	--	.001	.001	.029	.010	--	.068
Demeton	--	--	--	.015	--	--	--	--	--	--	--	--	--	--	--	--	.002
Dicofol	--	.233	--	.556	--	.010	.097	.029	.010	--	--	--	.058	--	.002	--	.092
Dicrotophos	.067	.003	.126	.021	.128	.068	.164	.096	.266	.064	.008	.013	.049	.089	.025	.008	.049
Dimethoate	--	--	.104	.017	.002	.104	.094	.096	.244	.027	.008	.004	.032	.082	.015	.008	.036
Disulfoton	.124	--	--	--	.375	.132	--	--	--	--	.027	--	.059	--	.003	.027	.008
Endosulfan	--	--	--	.023	--	--	--	--	--	--	--	--	--	--	--	--	.003
EPN	--	--	--	--	--	--	--	--	--	--	--	.077	.126	--	.052	--	.029
Lindane	--	--	--	.005	--	--	--	--	--	--	--	--	--	--	--	--	.001
Malathion	.009	.074	--	.017	--	.087	.073	--	--	.210	1.010	.022	1.319	--	.056	--	.060
Methamidophos	--	--	--	.120	--	--	--	.037	--	--	--	--	--	--	--	--	.019
Methidathion	--	.182	--	.015	--	--	--	--	--	--	--	--	--	--	--	--	.010
Methomyl	--	.077	--	.009	--	--	--	.023	.002	.184	.009	--	.054	--	.017	.009	.017
Methyl parathion	2.124	.838	.275	--	3.000	2.176	.593	.641	--	.080	--	.039	.458	.018	.193	--	.343
Monocrotophos	.068	.766	--	.037	.034	.188	.173	.050	--	--	--	.017	.218	--	.010	--	.068
Oxamyl	--	--	--	.023	--	--	--	--	--	--	--	--	--	--	.001	--	.003
Phorate	--	--	--	.024	.075	.033	--	--	--	--	.014	--	.027	--	.005	.014	.006
Phosmet	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.000
Phosphamidon	--	--	--	--	--	--	--	--	--	--	.008	--	--	--	--	.008	.000
Profenofos	.032	.017	--	.111	--	.017	--	.112	--	--	--	.004	.014	--	--	--	.027
Propargite	--	.097	--	.819	--	--	--	.031	--	--	--	--	--	--	.002	--	.113
Pyrethroids 2/	.393	.043	--	--	.030	.559	--	--	.084	--	--	--	.087	--	--	--	.024
Cypermethrin	--	.283	.096	.026	.546	--	.184	.208	--	.009	.127	.017	.124	--	.021	.091	.064
Fenvalerate	--	.059	.030	.022	.490	--	.381	--	--	.097	.116	.014	.173	.101	.013	.082	.042
Flucythrinate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.001	--	.000
Permethrin	--	--	--	.001	.001	.001	--	--	--	--	.038	.027	.035	--	--	.027	.002
Tralomethrin	--	.013	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.001
Sulprofos	--	--	--	.008	.390	.024	.039	--	--	--	--	--	.146	--	--	--	.006
Thiodicarb	.043	--	--	--	.819	.079	.043	.251	.015	--	--	.021	--	--	.004	--	.033
Trichlorfon	--	--	--	.015	--	--	--	--	--	--	--	--	--	--	--	--	.002
Total	3.878	6.430	1.413	2.656	7.434	4.816	2.279	2.400	.903	.754	1.763	.341	3.608	.546	.621	.653	1.642

-- = Unreported or insignificant estimate.

1/ Excludes use of microbials, sex attractants, and sulfur. Also excludes materials with less than 0.001 pounds of active ingredients per harvested acre.

2/ In some chemical control entries, only an aggregated use estimate for all pyrethroids was provided.

properly applied, may spill over into the environment. The intensive use of chemicals on cotton also creates occupational hazards to farmworkers (farmers, applicators, mixers, loaders, cleanup workers, and flaggers). Such potential side-effects are important factors in the overall effects that agricultural pests have on society.

This report uses four average indices of the relative toxicities of cotton chemicals to nontarget organisms to quantify the potential health and environmental hazards of chemical use on cotton. We adopted these toxicity indices from Metcalf's study, which rated pesticides in regard to their safety and effects on human health and environmental quality (9). These indices are based on extensive testing of the chemical properties of pesticides, which is required for use registration. Indices of toxicity to mammals from oral and skin exposure are proxies for occupational hazards to cotton workers. Indices of acute toxicity to fish and honey bees are proxies for hazards to nontarget organisms.

In classical toxicology, the LD50 (lethal dose 50) value of a chemical is defined as that dose of the chemical [in milligrams (mg) per kilogram (kg) of body weight] which kills 50 percent of the test animals. A large value for the LD50 indicates a substance of low toxicity, while small value indicates a very potent poison. Indices for toxicity to mammals range from 1 to 5 for increasing hazard:

Oral, LD50 (rats)

1 = Greater than 1,000 mg
2 = From 200 through 1,000 mg
3 = From 50 through 200 mg
4 = From 10 through 50 mg
5 = Less than 10 mg

Dermal, LD50 (rabbits)

1 = Greater than 20,000 mg
2 = From 2,000 through 20,000 mg
3 = From 200 through 2,000 mg
4 = From 20 through 200 mg
5 = Less than 20 mg

The relative toxicity of pesticides to fish and honey bees is reported as a lethal concentration (LC50) in the environment [parts per million (p/m) or parts per billion (p/b)] which kills 50 percent of exposed organisms. LC50 values are not frequently reported on pesticide labels for many cotton chemicals; therefore, indices for toxicity to fish and honey bees range from 1 to 5:

Fish and Honey Bees, LC50

1 = Relatively nontoxic
2 = Somewhat toxic
3 = Toxic
4 = Highly toxic
5 = Extremely toxic

The average toxicity index (ATI) is a measure of the relative hazard for an average cotton chemical application per harvested acre. ATI's for each hazard category were computed as the weighted sum of the index for each chemical times its share of total a.i.'s:

$$ATI_{ij} = \sum_{i,j}^{n} \text{toxicity index}_{ij} \cdot (q_j / Q),$$

where: subscript i is the hazard category, j is the chemical, q is the quantity of a.i. for chemical j per harvested acre, and Q is the quantity of all a.i. per harvested acre (last column of table 9).

We calculated the ATI's for the average U.S. cotton harvested acre during 1981-84 using indices for the relative toxicity of each cotton chemical reported in table 9 (see app. table 4 for these indices). We also compared the ATI's for the average harvested acre treated with chemicals in 1981-84 with those for 1976 and 1979 (table 10). Appendix table 5 shows estimates of the amount of a.i. by material applied in 1976 and 1979 per harvested acre.

The potential occupational and environmental hazards raise the costs of pest damage. However, recent changes in technology appear to have reduced hazards associated with cotton pest control. The mix of chemicals applied to cotton for insect and mite control in 1981-84 was, on average, less hazardous than in 1976 and 1979 (table 10). Increased use of newer and safer compounds, decreased use of organochlorines and organophosphates, and wider adoption of pest management techniques contributed to the apparent decline. Only the potential hazard for aquatic organisms seems to have increased in recent years.

A more comprehensive analysis of hazards posed by the use of cotton chemicals was beyond the scope of this study. Toxicity indices reported in this study are not accurate enough to assess risks for regulatory decisions. Measurements of the many factors affecting risk are difficult to discern. For example, data on the length of exposure, use of protective clothing, size of fields, and number of loads per application are needed to quantify farmworkers' risk of skin exposure to chemicals (6, 11, 16). Estimates of cancer risks over a lifetime must also be extrapolated from low levels of chemical exposure in laboratory animal studies. Limitations and uncertainties with available analytical methods have led scientists to question the usefulness of such assessments (1). We also omitted a numerical rating for soil persistence (rate that a chemical degrades in the soil) for each chemical control due to insufficient data.

Table 10--Average toxicity indices (ATI's) for cotton insect and mite control materials

Hazard categories (nontarget organisms)	USDA estimates, 1976	USDA estimates, 1979	Expert estimates, 1981-84
		Index	
Toxicity to mammals--			
Rats (oral)	3.579	3.492	3.148
Rabbits (dermal)	3.424	3.339	3.095
Toxicity to other organisms--			
Fish	2.721	2.236	2.413
Honey bees	3.954	3.550	2.998

ACCURACY AND CREDIBILITY OF EXPERT ESTIMATES

Expert estimates are often used when current survey or experimental data cannot be obtained with available resources, as occurred with this study. However, there are always concerns and limitations expressed about the accuracy and objectivity of expert opinions. The level of accuracy is difficult to assess because comparable statistics generally do not exist. Expert opinions are susceptible to bad or erroneous assumptions, may disagree with other expert estimates, and lack statistical reliability. Bias is also a potential problem for subjective estimates, so enumerators must try to guide experts into considering all relevant information and making impartial judgments.

Cotton extension and research entomologists have considerable experience in estimating average pest infestations, yield losses, and control practices. For example, all cotton pesticide assessment studies have relied on expert opinions to determine how yield and control practices would change in the event of pesticide regulatory actions. Expert estimates of yield losses caused by insects have been published since 1979 (24). Biological data, needed to evaluate boll weevil management strategies, were published in 1981 (29).

But it is difficult to obtain pest-specific estimates for large areas using survey and experimental methods. For example, absolute production losses are difficult to estimate because many physical and environmental factors also determine yield in complex and dynamic crop ecosystems (13). Published loss assessments generally result from experimental studies where replicated tests of pest control methods are conducted in adjacent treated and untreated plots. But, such information cannot be easily extrapolated over large areas or for average farm conditions.

Grower surveys also present estimation problems, because growers relate their pesticide use to specific target pests (17). Differences in the ability of growers to identify or recall pest species when reporting target pests may lead to systematic errors in assessing the economic importance of a given pest. Factors such as the level of detail in responses relating to target pests, differences in the ability of survey enumerators, and timing of surveys also affect the quality of information. Such factors become crucial in cotton-producing areas where multiple pest infestations and applications occur throughout a growing season.

Study estimates can be compared with estimates from other surveys and experiments to assess this study's accuracy. Suguiyama and Carlson reported comparable estimates of acreage treated for 10 important cotton insects and mites from a farm pesticide survey for the 1979 crop year (17). Although the estimates of acreage treated by target pest deviated slightly (table 11), estimates of total harvested acreage treated with chemicals differed significantly. The 1979 estimate showed 63 percent of the harvested acreage was treated, which is similar to the composite 1984-85 estimate of 64 percent reported by the Economic Research Service (27, 30) (table 12). Both estimates are significantly lower than the 78 percent estimated by experts in this study.

Comparisons of State estimates show no significant differences in the acreage treated for Alabama, Arizona, Georgia, Louisiana, Mississippi, and South Carolina where chemical controls are used on most of the area planted to cotton. However, expert estimates of acreage treated for Arkansas, California, Missouri, New Mexico, Oklahoma, Tennessee, and Texas were considerably higher than farm survey estimates. One reason for this discrepancy could be the annual changes in pest

Table 11--Share of acreage treated and number of applications per harvested acre against target insects and mites

Target pests	Expert estimates, 1981-84		1979 estimates 2/	
	Share of acreage treated	Applications per acre treated 1/	Share of acreage treated	Applications per acre treated
	Percent	Number	Percent	Number
Heliothis	33.6	2.56	47.8	5.70
(tobacco budworms only)	--	--	9.2	4.77
Boll weevils/*Heliothis*	19.1	4.45	--	--
Boll weevils	20.8	3.22	22.1	3.94
Plant bugs 3/	37.1	1.37	--	--
Cotton fleahoppers	--	--	16.8	2.41
Lygus bugs	--	--	12.6	1.56
Pink bollworms	5.8	4.83	3.7	4.83
Spider mites	17.0	1.41	28.3	1.96
Aphids	11.0	1.36	13.7	1.61
Armyworms	7.0	1.57	2.8	1.74
All insects and mites	77.5	5.91	63.4	5.10

-- = Unreported or insignificant estimate.
1/ Adjusted by dividing estimates reported in table 2 by the corresponding share of acreage treated in table 1.
2/ Estimates reported by Suguiyama and Carlson (17) on a planted acre basis were adjusted by a factor of 91.8 percent (share of harvested to planted acreage in 1979 crop).
3/ Include lygus bugs and cotton fleahoppers.

populations captured by annual farm surveys (12). Nonetheless, it appears that the experts either overestimated the amount of acreage treated with insecticides, or perceived increased pest incidence over the study period.

We compared our per-acre expenditures for 1981-84 with estimates reported in the Cotton Insect Research and Control Conference proceedings (table 13). Their per-acre average cost (excluding scouting costs) was $32, which is very similar to our study estimate of $37. However, the estimated per-acre expenditures differed significantly for each producing State. The 1981-84 cost of production survey estimates for cotton chemicals (including insecticides, miticides, herbicides, fungicides, and nematicides) ranged between $42-49 per acre, which are higher than our study estimates for insecticides and miticides (15).

Our estimates of yield loss differ across time from those by Schwartz (13), Schwartz and Klassen (14), and USDA's Agricultural Research Service (21) (table

Table 12--Share of harvested cotton acreage treated with insecticides

States	Expert estimates, 1981-84	USDA estimates 1984	USDA estimates 1985
		Percent	
Alabama	100	90	98
Arizona	96	93	99
Arkansas	100	83	85
California	100	80	78
Florida	100	--	--
Georgia	100	96	100
Louisiana	100	95	100
Mississippi	100	97	96
Missouri	100	65	39
New Mexico	81	27	37
North Carolina	98	--	--
Oklahoma	63	46	21
South Carolina	98	91	98
Tennessee	100	71	76
Texas	57	37	45
Virginia	98	--	--
U.S. total 1/	78	65	63

-- = Unreported or insignificant estimate.
1/ Harvested acreage-weighted estimates.

14). Except for losses caused by spider mites, yield losses used in this study are considerably lower than those of other studies. Schwartz and Schwartz and Klassen's studies derived pest loss estimates under best control practices on infested cotton acreage from published research studies. The USDA report estimated losses caused by only the four major insect pests for 1951-60. Changes in pest control technology and cotton production practices have occurred since those studies.

CONCLUDING REMARKS

Commonly used methods to estimate pest damages on a particular crop rely on the value of yield losses and control expenditures. This report assesses the value of insect and mite damage on cotton for 1981-84 and simulates the aggregate effects on U.S. agriculture in the absence of these pests. Estimates in this report constitute benchmarks in the absence of comparable statistical data. Cotton experts provided estimates of pest incidence, control measures, and cotton yield losses. The reliability of the results depends heavily on the ability and experience of experts to document the extent of pest infestations and control practices.

There are also limitations with the methods used in this study. The analysis of market and production effects depends heavily on assumptions concerning the absence of pest damage and the analytical model. This analysis does not consider important questions about the allocation of resources to control pests; implications on future control technologies, cotton subsidy programs, and producer income stability; and investment decisions to research new pest control options. Risk-assessment approaches for measuring chemical exposure also require comprehensive analyses of factors that are difficult to discern, uncertainties, assumptions, and data extrapolations. Incorporating all of these relevant variables would improve the assessment of economic importance.

Table 13--Cotton insect and mite control expenditures per harvested acre, 1981-84

States	Expert estimates 1/	Conference estimates 2/
	Dollars	
Alabama	68.07	53.92
Arizona	132.77	83.28
Arkansas	33.49	34.72
California	61.94	21.40
Florida	145.05	136.83
Georgia	89.06	77.37
Louisiana	70.03	59.65
Mississippi	55.85	42.53
Missouri	18.63	7.73
New Mexico	20.05	17.68
North Carolina	41.83	34.40
Oklahoma	10.57	39.33
South Carolina	67.30	89.06
Tennessee	14.94	7.24
Texas	13.56	22.61
Virginia	29.89	34.93
U.S. average	36.98	32.43

1/ Include cost of pest scouting per harvested acre.
2/ Adjusted to 1986 dollars with index of prices paid for agricultural chemicals.

Table 14--Cotton yield losses caused by insects and mites, selected estimates for 1951-84

Target pests	Loss per harvested acre		Loss per treated acre		
	USDA estimates, 1951-60 1/	Conference estimates, 1981-84 2/	Schwartz estimates, 1945-80 3/	Schwartz and Klassen estimates, 1965-78 4/	Conference estimates, 1981-84 2/
			Percent		
Heliothis	4.00	2.52	14.70	12.07	6.30
Boll weevils	8.00	1.50	20.60	19.00	5.00
Plant bugs 5/	3.40	1.32	12.40	12.50	3.50
Pink bollworms	--	.44	9.20	10.00	7.50
Spider mites	--	.78	.05	0	4.50
Thrips	--	.34	--	18.01	.80
Aphids	--	--	7.90	--	--
Cabbage loopers	--	--	29.60	--	--
All insects and mites	--	7.37	--	--	9.51

-- = Unreported or insignificant estimate.
1/ Source: (21).
2/ Sources: (23-26).
3/ Source: (13).
4/ Source: (14).
5/ Include lygus bugs and cotton fleahoppers.

REFERENCES

(1) Anderson, Elizabeth L., and the Carcinogen Assessment Group of the U.S. Environmental Protection Agency. "Quantitative Approaches in Use to Assess Cancer Risk," Risk Analysis, Vol. 3, No. 4 (1983), pp. 277-95.

(2) Collins, Glen S., and C. Robert Taylor. "TECHSIM - A Regional Field Crop and National Livestock Econometric Simulation Model," Agricultural Economics Research, Vol. 35, No. 2 (Apr. 1983), pp. 1-8.

(3) Crop Protection Chemicals Reference. New York, NY: Chemical and Pharmaceutical Press. 1986.

(4) Eichers, Theodore R., Paul A. Andrilenas, and Thelma W. Anderson. Farmers' Use of Pesticides in 1976, AER-418. U.S. Dept. Agr., Econ. Stat. Coop. Serv., Dec. 1978.

(5) Farm Chemicals. Farm Chemicals Handbook '86. Willoughby, OH: Meister Publishing Co. 1986.

(6) Honeycutt, Richard C. "Field Worker Exposure: The Usefulness of Estimates Based on Generic Data," Dermal Exposure Related to Pesticide Use: Discussion of Risk Assessment, American Chemical Society Symposium Series No. 273 (1985), pp. 369-75.

(7) Maddy, K.T., R.G. Wang, James B. Knaak, C.L. Liao, S.C. Edmiston, C.K. Winston. "Risk Assessment of Excess Pesticide Exposure to Workers in California," Dermal Exposure Related to Pesticide Use: Discussion of Risk Assessment, American Chemical Society Symposium Series No. 273 (1985), pp. 446-65.

(8) McDowell, Robert, Marsh Cleveland, and Craig Osteen. Insecticide Use on Cotton in the United States, 1979, ERS Staff Report AGES820519. U.S. Dept. Agr., Econ. Res. Serv., May 1982.

(9) Metcalf, Robert L. "Selective Use of Insecticides in Pest Management," Twenty-Fifth Illinois Custom Spray Operators Training School. Coop. Ext. Serv., Univ. of Illinois at Urbana-Champaign. 1973.

(10) Osteen, Craig, and Luis Suguiyama. Losing Chlordimeform Use in Cotton Production, AER-587. U.S. Dept. Agr., Econ. Res. Serv., May 1988.

(11) Reinert, Joseph C., and David J. Severn. "Dermal Exposure to Pesticides: The Environmental Protection Agency's Viewpoint," Dermal Exposure Related to Pesticide Use: Discussion of Risk Assessment, American Chemical Society Symposium Series No. 273 (1985), pp. 357-68.

(12) Ridgway, Richard L. "Assessing Agricultural Crop Losses Caused by Insects," Proceedings of the E.C. Stakman Commemorative Symposium on Crop Loss Assessment, Minneapolis, MN. 1980.

(13) Schwartz, P.H. "Losses in Yield of Cotton Due to Insects," Cotton Insect Management with Special Reference to the Boll Weevil, AH-589, R.L. Ridgway, E.P. Lloyd, and W.H. Cross, eds. U.S. Dept. Agr., Agr. Res. Serv., Nov. 1983.

(14) Schwartz, P.H., and W. Klassen. "Estimates of Losses Caused by Insects and Mites to Agricultural Crops," CRC Handbook of Pest Management in Agriculture, David Pimentel, ed. Boca Raton, FL: CRC Press, Inc. 1981.

(15) Starbird, Irving, Edward H. Glade, Jr., W.C. McArthur, Fred T. Cooke, Jr., and Terry Townsend. The U.S. Cotton Industry, AER-567. U.S. Dept. Agr., Econ. Res. Serv., June 1987.

(16) Stevens, James T., and Darrell D. Sumner. "The Use of Exposure Studies in Risk Assessment," Dermal Exposure Related to Pesticide Use: Discussion of Risk Assessment, American Chemical Society Symposium Series No. 273 (1985), pp. 467-78.

(17) Suguiyama, Luis F., and Gerald A. Carlson. Field Crop Pests: Farmers Report the Severity and Intensity, AIB-487. U.S. Dept. Agr., Econ. Res. Serv., Feb. 1985.

(18) Swanson, Earl R., and Arthur H. Grube. "Economic Impact of the Cancellation of the Use of Trifluralin in Soybeans: A Comparison of Selected Estimation Models," North Central Journal of Agricultural Economics, Vol. 8, No. 1 (Jan. 1986), pp. 143-53.

(19) Taylor, C. Robert, James Eales, and Michael D. Franks. "AGSIM--An Econometric Based Simulation Model of U.S. Crop and Livestock Production," unpublished manuscripts, Univ. of Illinois at Urbana-Champaign, Jan. 1987.

(20) Thomson, W.T. Agricultural Chemicals, Book 1: Insecticides, Acaricides and Ovicides. Fresno, CA: Thomson Publications. 1982.

(21) U.S. Department of Agriculture, Agricultural Research Service. Losses in Agriculture, AH-291, Aug. 1965.

(22) ____________, Agricultural Research Service. 33d Annual Conference Report on Cotton-Insect Research and Control, Feb. 1980.

(23) ____________, Agricultural Research Service. 35th Annual Conference Report on Cotton-Insect Research and Control, Feb. 1982.

(24) ____________, Agricultural Research Service. 36th Annual Conference Report on Cotton-Insect Research and Control, Feb. 1983.

(25) ____________, Agricultural Research Service. 37th Annual Conference Report on Cotton-Insect Research and Control, Feb. 1984.

(26) ____________, Agricultural Research Service. 38th Annual Conference Report on Cotton-Insect Research and Control, Feb. 1985.

(27) ____________, Economic Research Service. Agricultural Resources: Inputs Outlook and Situation Report, AR-1, Feb. 1986.

(28) ____________, Economic Research Service. Overall Evaluation: Beltwide Boll Weevil/Cotton Insect Management Programs, ERS Staff Report AGES810721, May 1981.

(29) ____________, Economic Research Service. The Delphi: Insecticide Use and Lint Yields, ERS Staff Report AGES810507, May 1981.

(30) ____________, Economic Research Service. "1984 Objective Yield Survey," unpublished data.

(31) ____________, National Agricultural Pesticide Impact Assessment Program. Pesticide Assessment of Field Corn and Soybeans: Corn Belt States, ERS Staff Report AGES850524A, Dec. 1985.

(32) ____________, National Agricultural Pesticide Impact Assessment Program. Pesticide Assessment of Field Corn and Soybeans: Delta States, ERS Staff Report AGES850524B, Dec. 1985.

(33) ____________, National Agricultural Pesticide Impact Assessment Program. Pesticide Assessment of Field Corn and Soybeans: Lake States, ERS Staff Report AGES850524C, Dec. 1985.

(34) _____________, National Agricultural Pesticide Impact Assessment Program. Pesticide Assessment of Field Corn and Soybeans: Northeastern States, ERS Staff Report AGES850524D, Dec. 1985.

(35) _____________, National Agricultural Pesticide Impact Assessment Program. Pesticide Assessment of Field Corn and Soybeans: Northern Plains States, ERS Staff Report AGES850524E, Dec. 1985.

(36) _____________, National Agricultural Pesticide Impact Assessment Program. Pesticide Assessment of Field Corn and Soybeans: Southeastern States, ERS Staff Report AGES850524F, Dec. 1985.

(37) Ware, George W. Pesticides, Theory and Application. San Francisco, CA: W.H. Freeman and Company. 1983.

(38) Webb, Shwu-Eng H., and Fred Kuchler. Models for Evaluating Economic Impacts of Policy Changes: A Comparison, ERS Staff Report AGES831212, U.S. Dept. Agr., Econ. Res. Serv., Jan. 1984.

Appendix table 1--Share of cotton harvested acreage treated against target pests 1/

Target pests	NC subregions			TN subregions		SC subregions		GA subregions		MS subregions		AR subregions		LA subregions		TX subregions	
	1	2	3	4	5	6	7	8	9	13	14	15	16	17	18	19	20
	Percent																
Heliothis	98.0	100.0	85.0	50.0	50.0	99.0	70.0	50.0	50.0	30.0	65.0	50.0	95.0	90.0	90.0	59.0	18.0
Boll weevils/Heliothis	--	--	--	--	2.0	--	--	80.0	100.0	50.0	30.0	5.0	95.0	100.0	100.0	100.0	49.0
Boll weevils	5.0	45.0	40.0	--	2.0	40.0	27.0	30.0	80.0	85.0	30.0	5.0	75.0	70.0	90.0	98.0	54.0
Spider mites	--	--	--	2.0	2.0	10.0	5.0	10.0	20.0	5.0	30.0	--	--	25.0	80.0	--	--
Thrips	90.0	100.0	70.0	100.0	100.0	99.0	90.0	50.0	90.0	95.0	95.0	98.0	98.0	100.0	80.0	--	20.0
Plant bugs 2/	--	--	--	75.0	75.0	5.0	15.0	15.0	30.0	90.0	95.0	40.0	30.0	50.0	60.0	85.0	90.0
Fall and beet armyworms	2.0	4.0	2.0	--	--	10.0	5.0	5.0	20.0	30.0	20.0	--	--	10.0	--	--	--
Aphids	--	--	--	2.0	2.0	5.0	5.0	20.0	30.0	5.0	30.0	--	--	25.0	20.0	--	10.0
Whiteflies	--	--	--	--	--	2.0	--	--	--	2.0	5.0	--	--	--	--	--	--
Cabbage loopers	--	--	--	--	--	--	--	--	1.0	--	--	--	--	--	--	--	--
Cutworms	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4.0
All insects and mites	98.0	100.0	85.0	100.0	100.0	99.0	90.0	95.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.0

See footnotes at end of table.

Continued--

Appendix table 1--Share of cotton harvested acreage treated against target pests 1/--continued

	TX subregions							OK subregions		NM subregions			AZ subregions			CA subregions	
Target pests	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
	Percent																
Heliothis	100.0	98.0	15.0	10.0	23.0	88.0	75.0	15.0	30.0	30.0	90.0	70.0	45.0	70.0	100.0	95.0	3.0
Boll weevils	100.0	35.0	40.0	10.0	--	--	--	1.0	10.0	--	--	--	--	--	90.0	10.0	--
Pink bollworms	--	--	--	--	--	15.0	75.0	--	--	--	10.0	20.0	95.0	100.0	100.0	100.0	--
Pink bollworms/other pests 3/	--	--	--	--	--	--	--	--	--	--	--	--	45.0	100.0	100.0	--	--
Spider mites	100.0	15.0	5.0	--	--	--	--	--	--	--	--	--	20.0	40.0	80.0	90.0	75.0
Thrips	75.0	15.0	70.0	2.0	33.0	2.0	5.0	1.0	3.0	20.0	10.0	30.0	7.0	20.0	20.0	--	10.0
Plant bugs 2/	100.0	85.0	65.0	5.0	15.0	20.0	15.0	15.0	20.0	15.0	40.0	20.0	60.0	60.0	100.0	100.0	41.0
Fall and beet armyworms	5.0	--	--	--	7.0	5.0	20.0	--	1.0	--	10.0	30.0	--	--	--	50.0	10.0
Seed corn maggots/wireworms	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	90.0
Aphids	5.0	--	20.0	2.0	18.0	20.0	5.0	1.0	2.0	--	15.0	15.0	--	--	--	--	5.0
Whiteflies	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.0	95.0	5.0
Cotton leaf perforators	--	--	--	--	--	--	--	--	--	--	--	--	--	30.0	30.0	20.0	--
Cabbage loopers	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.0
Cutworms	--	--	--	--	--	--	--	--	--	--	--	--	--	3.0	3.0	--	5.0
Stinkbugs	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	40.0	--
Grasshoppers	--	--	--	1.0	--	3.0	--	4.0	3.0	15.0	20.0	20.0	--	--	--	--	--
All insects and mites	100.0	98.0	92.0	15.0	65.0	92.0	85.0	45.0	80.0	60.0	92.0	87.0	95.0	100.0	100.0	100.0	100.0

-- = Unreported or insignificant estimate.
1/ Acreage treated one or more times for specific target pest. Estimates for Alabama, Florida, and Virginia are shown in text table 1.
2/ Include lygus bugs and cotton fleahoppers.
3/ Other pests include Heliothis, boll weevils, lygus bugs, and stinkbugs.

Appendix table 2--Applications per harvested acre, by target pests

	NC subregions			TN subregions		SC subregions		GA subregions		MS subregions		AR subregions		LA subregions		TX subregions	
Target pests	1	2	3	4	5	6	7	8	9	13	14	15	16	17	18	19	20
									Number								
Heliothis	2.74	6.20	1.62	1.00	1.00	6.08	1.91	0.99	1.46	0.60	2.60	1.00	1.90	2.70	1.80	0.76	0.18
Boll weevils/*Heliothis*	--	--	--	--	.10	--	--	3.58	6.46	1.00	1.20	.10	1.90	5.00	4.00	3.00	1.15
Boll weevils	.20	1.80	1.60	--	.10	2.29	1.12	.66	3.68	3.40	.60	.10	1.50	1.40	3.60	7.84	1.97
Spider mites	--	--	--	.02	.02	.16	.09	.18	.33	.10	.54	--	--	.38	1.20	--	--
Thrips	1.15	1.32	.94	2.45	2.45	1.58	1.40	.68	1.84	1.70	1.84	1.47	1.37	1.15	1.50	--	.20
Plant bugs 1/	--	--	--	.75	.75	.08	.30	.15	.45	1.28	2.14	.40	.30	.50	.90	.85	1.80
Fall and beet armyworms	.02	.02	.02	--	--	.20	.05	.08	.24	.60	.40	--	--	.10	--	--	--
Aphids	--	--	--	.02	.02	.05	.05	.20	.60	.10	.60	--	--	.25	.20	--	.10
Whiteflies	--	--	--	--	--	.04	--	--	--	.02	.05	--	--	--	--	--	--
Cabbage loopers	--	--	--	--	--	--	--	--	.01	--	--	--	--	--	--	--	--
Cutworms	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.04
Total applications 2/	4.76	10.91	4.48	4.61	4.81	10.99	5.26	5.91	13.49	9.11	10.59	4.30	9.07	12.16	13.71	12.61	5.72

See footnotes at end of table.

Continued--

Appendix table 2--Applications per harvested acre--continued

Target pests	TX subregions							OK subregions		NM subregions			AZ subregions			CA subregions	
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
								Number									
Heliothis	9.00	5.29	0.31	0.12	0.39	2.29	1.50	0.20	0.90	0.68	2.27	1.33	0.61	0.60	1.00	2.85	0.06
Boll weevils	3.00	.99	.70	.20	--	--	--	.04	.40	--	--	--	--	--	.90	.20	--
Pink bollworms	--	--	--	--	--	.30	2.25	--	--	--	.15	.20	2.85	5.70	3.70	5.00	--
Pink bollworms/other pests 3/	--	--	--	--	--	--	--	--	--	--	--	--	.61	2.34	7.40	--	--
Spider mites	2.00	.37	.05	--	--	--	--	--	--	--	--	--	.20	.40	.82	1.53	1.12
Thrips	.75	.13	1.05	.02	.33	.02	.05	.01	.05	.20	.10	.30	.07	.20	.20	--	.10
Plant bugs 1/	2.00	1.25	.81	.05	.17	.30	.15	.15	.20	.20	.70	.20	.60	.60	.74	1.70	.40
Fall and beet armyworms	.05	--	--	--	.07	.05	.20	--	.01	--	.19	.38	--	--	--	.50	.20
Seed corn maggots/wireworms	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.90
Aphids	.05	--	.20	.02	.22	.26	.05	.01	.02	--	.23	.15	--	--	--	--	.08
Whiteflies	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.10	2.47	.15
Cotton leaf perforators	--	--	--	--	--	--	--	--	--	--	--	--	--	.30	.30	.34	--
Cabbage loopers	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.10
Cutworms	--	--	--	--	--	--	--	--	--	--	--	--	--	.03	.03	--	.05
Stinkbugs	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.40	--
Grasshoppers	--	--	--	.01	--	.06	--	.04	.03	.07	.40	.50	--	--	--	--	--
Total applications 2/	16.85	8.03	3.12	.42	1.17	3.50	4.34	.44	1.61	1.15	4.03	3.06	4.33	10.27	15.18	14.99	3.16

-- = Unreported or insignificant estimate.

1/ Include lygus bugs and cotton fleahoppers.

2/ Columns may not total due to tank-mixed applications for several target pests and due to treatments of chlordimeform for yield enhancement, which are not reported separately.

3/ Other pests include Heliothis, boll weevils, lygus bugs, and stinkbugs.

Appendix table 3--Control expenditures per harvested acre, by target pests

Target pests and scouting	NC subregions			TN subregions		SC subregions		GA subregions		MS subregions		AK subregions		LA subregions		TX subregions	
	1	2	3	4	5	6	7	8	9	13	14	15	16	17	18	19	20
									Dollars								
Heliothis	6.56	38.03	9.00	5.65	5.65	42.65	12.83	6.80	10.58	3.69	18.39	5.88	11.87	17.46	11.27	5.99	1.22
Boll weevils/Heliothis	--	--	--	--	.51	--	--	27.73	51.20	6.96	9.27	.80	15.20	32.98	25.31	21.60	8.10
Boll weevils	1.23	11.03	9.81	--	.34	11.51	6.48	2.32	12.86	14.20	2.66	.41	6.17	4.28	10.33	41.16	8.10
Spider mites	--	--	--	.06	.06	1.24	.71	1.05	2.18	.81	5.24	--	--	2.53	7.12	--	--
Thrips	7.86	8.63	6.41	6.60	6.60	8.43	7.37	4.06	8.62	4.49	5.53	6.96	7.26	4.73	5.14	--	.67
Plant bugs 1/	--	--	--	1.64	1.64	.23	.85	.09	.28	4.44	8.74	1.28	.96	1.29	1.98	3.35	6.34
Fall and beet armyworms	.17	.16	.17	--	--	1.63	.41	.59	2.03	6.21	4.81	--	--	1.34	--	--	--
Aphids	--	--	--	.06	.06	.15	.14	.20	.53	.31	2.57	--	--	.93	.73	--	.34
Whiteflies	--	--	--	--	--	.22	--	--	--	.21	.24	--	--	--	--	--	--
Cabbage loopers	--	--	--	--	--	--	--	--	.05	--	--	--	--	--	--	--	--
Cutworms	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.34
All insects and mites	25.82	57.85	25.39	14.01	14.86	66.06	28.79	42.84	88.33	41.32	57.45	15.33	41.46	65.54	61.88	72.10	25.11
Pest scouting	5.30	5.30	5.30	.72	.72	4.22	4.22	2.18	3.44	2.97	4.57	3.65	3.65	4.93	4.93	2.05	2.85
Total expenditures	31.12	63.15	30.69	14.73	15.58	70.28	33.01	45.02	91.77	44.29	62.02	18.98	45.11	70.47	66.81	74.15	27.96

See footnotes at end of table.

Continued--

Appendix table 3--Control expenditures per harvested acre, by target pests--continued

Target pests and scouting	TX subregions							OK subregions		NM subregions			AZ subregions			CA subregions	
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
	Dollars																
<u>Heliothis</u>	79.23	45.14	2.66	0.98	2.80	19.88	13.04	1.59	7.78	5.48	13.13	11.54	--	14.60	13.12	32.32	0.79
Boll weevils	15.54	5.27	3.09	1.10	--	--	--	.17	1.68	--	--	--	--	1.30	12.66	1.42	--
Pink bollworms	--	--	--	--	--	1.86	13.81	--	--	--	.95	.93	33.33	41.55	79.45	108.42	--
Pink bollworms/other pests 2/	--	--	--	--	--	--	--	--	--	--	--	--	8.97	30.32	127.29	--	--
Spider mites	17.55	3.08	.63	--	--	--	--	--	--	--	--	--	3.73	2.10	13.35	24.74	23.78
Thrips	5.91	.68	3.55	.14	2.76	.11	.49	.02	.42	.77	.41	1.29	1.85	.97	2.43	--	1.00
Plant bugs 1/	11.47	4.69	3.00	.18	.59	1.07	.52	.65	.86	.77	3.16	.74	6.34	5.57	12.29	32.52	5.63
Fall and beet armyworms	.63	--	--	--	.82	.63	1.85	--	.13	--	1.39	3.08	--	--	--	7.21	2.77
Seed corn maggots/wireworms	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.16
Aphids	.18	--	.77	.07	.78	.37	.18	.05	.11	--	.88	.57	--	--	--	--	.65
Whiteflies	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.67	31.62	1.26
Cotton leaf perforators	--	--	--	--	--	--	--	--	--	--	--	--	--	3.91	5.40	8.51	--
Cabbage loopers	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.39
Cutworms	--	--	--	--	--	--	--	--	--	--	--	--	--	.14	.31	--	.59
Stinkbugs	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.20	--
Grasshoppers	--	--	--	.06	--	.30	--	.15	.13	.40	2.16	2.69	--	--	--	--	--
All insects and mites	130.51	58.86	13.70	2.53	7.75	24.22	29.89	2.63	11.11	7.42	22.08	20.84	54.22	100.46	267.97	251.96	45.02
Pest scouting	6.80	6.20	3.25	1.26	1.76	2.94	1.84	1.31	1.69	2.69	2.78	2.62	3.18	2.95	2.64	25.00	3.68
Total expenditures	137.31	65.06	16.95	3.79	9.51	27.16	31.73	3.94	12.80	10.11	24.86	23.46	57.40	103.41	270.61	276.96	48.70

-- = Unreported or insignificant estimate.

1/ Include lygus bugs and cotton fleahoppers.

2/ Other pests include Heliothis, boll weevils, lygus bugs, and stinkbugs.

Appendix table 4--Cotton chemicals: toxicity indices 1/

Active ingredients	Mammals: Rats (oral)	Mammals: Rabbits (dermal)	Nontarget organisms: Fish	Nontarget organisms: Honey bees
	Index			
Acephate	2	3	1	3
Aldicarb	5	5	2	5
Azinphosmethyl	4	3	4	2
Carbaryl	2	2	1	4
Carbofuran	5	2	2	5
Carbophenothion	4	4	3	4
Chlordimeform	3	3	3	1
Chlorpyrifos	3	2	3	3
Cypermethrin	1	2	3	3
Demeton	5	5	3	5
Diazinon	3	3	2	4
Dicofol	2	2	2	2
Dicrotophos	4	3	3	2
Diflubenzuron	1	1	1	1
Dimethoate	2	4	1	4
Disulfoton	5	5	3	5
Endosulfan	4	4	3	1
Endrin	5	5	5	2
EPN	4	3	2	3
Ethion	3	3	2	3
Fenamiphos	5	4	3	3
Fenvalerate	2	2	4	3
Flucythrinate	3	3	4	3
Lindane	3	3	3	2
Malathion	1	2	2	1
Methamidophos	4	4	3	3
Methidathion	4	4	3	4
Methomyl	4	3	3	3
Methyl parathion	4	4	1	5
Monocrotophos	5	3	5	3
Naled	2	3	2	3
Oxamyl	5	3	3	3
Oxydemeton-methyl	3	3	2	4
Parathion	5	5	2	4
Permethrin	1	2	4	3
Phorate	5	5	4	5
Phosmet	3	2	3	3
Phosphamidon	4	4	1	5
Profenofos	2	3	3	3
Propargite	1	2	2	1
Sulprofos	3	3	3	3
Thiodicarb	1	2	1	1
Toxaphene	3	3	4	4
Tralomethrin	1	2	3	3
Trichlorfon	3	2	1	2

1/ See text for index equivalents.

Sources: (3, 5, 20, 37)

*U.S. GOVERNMENT PRINTING OFFICE:1988-241-852:80288/ERS

Appendix table 5--Quantity of chemicals applied for insect and mite control per harvested acre, 1976 and 1979

Active ingredients	1976	1979
	Pounds	
Acephate	--	0.030
Aldicarb	0.043	.038
Azinphosmethyl	.021	.029
Carbaryl	.035	.001
Carbophenothion	--	.002
Chlordimeform	.407	.074
Chlorpyrifos	--	.005
Demeton	--	.001
Diazinon	.003	.002
Dicofol	--	.038
Dicrotophos	.023	.021
Dimethoate	.008	.018
Disulfoton	.167	.018
Endosulfan	.062	.001
Endrin	.028	--
EPN	.563	.207
Fenvalerate	--	.033
Malathion	.004	.003
Methamidophos	--	.010
Methidathion	--	.012
Methomyl	.054	.031
Methyl parathion	1.823	.371
Monocrotophos	.136	.033
Naled	--	.002
Parathion	.062	.030
Permethrin	--	.052
Phorate	.015	.009
Propargite	--	.052
Sulprofos	--	.015
Toxaphene	2.409	.090
Trichlorfon	--	.004
Other 1/	.015	.507
Total average per harvested acre	5.878	1.739

-- = Unreported or insignificant estimate.
1/ Includes many materials that were applied in mixtures.

Sources: (4, 8).